# Evaluation of gestational weight management interventions for women with obesity

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for the degree of Doctor of Philosophy

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# Candidate Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.

2. None of the material contained in the thesis has been used in any other submission for an academic award.

3. I am aware of and understand the University's policy on plagiarism and certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.

4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy.

5. The word count of the thesis is approximately 44,000 words with an additional 30,000 words within the published / submitted articles.

| | |
|---|---|
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| Date of Submission | *February 2024* |
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# Abstract

**Background:**
The prevalence of extreme obesity (body mass index (BMI) ≥40kg/m²) is increasingly common during pregnancy. Women with obesity and their infants are at increased risk of adverse outcomes including excessive gestational weight gain (GWG) and increased risk of childhood obesity.

**Aim:**
The primary aim of this thesis was to explore GWG management among women with a BMI ≥40kg/m².

**Methods:**
An overview of systematic reviews on the effectiveness of lifestyle interventions to reduce GWG in women with overweight or obesity was undertaken followed by a sequential explanatory mixed methods study. This included:

1. A dominant quantitative component collecting retrospective data to explore the impact of an antenatal healthy lifestyle service for women with a BMI≥40kg/m² on GWG, pregnancy and birth outcomes and childhood obesity up to age 5.
2. A supplementary qualitative component undertaking semi-structured interviews with thirteen women with a BMI≥40kg/m² to explore their experiences of gestational weight management.

**Key findings:**
Findings across the research programme were integrated narratively. The findings indicated a lack of impact of most antenatal healthy lifestyle services. Within the overview of systematic reviews current lifestyle interventions among women with overweight or obesity reduced average GWG by 0.3 to 2.4kg but had minimal impact on clinical outcomes. Similarly, the antenatal healthy lifestyle service made no difference to mean GWG. There were no beneficial clinical effects from the antenatal healthy lifestyle service (3 visits) except for a higher rate of breastfeeding at discharge compared to women in the comparison cohort. Nor was there any association between lifestyle service attendance and childhood overweight or obesity up to 5 years.

Socio-demographic context and parity were noted to be important. Those from more deprived backgrounds were less likely to attend the service and more likely to have a child with overweight or obesity by school age. The antenatal healthy lifestyle service appeared to be effective among multiparous women, as those offered three visits had a lower rate of weight gain and fewer small for gestational age infants.

Within the qualitative interviews women highlighted the stigma they experienced, especially when healthcare providers placed excessive focus on the risks of obesity during pregnancy without providing practical advice and support.

The final integrated finding suggested the need to refine interventions in terms of their content, timing and format.

**Conclusion:**
Lifestyle based interventions may cause a small reduction in GWG, however their impact on clinical outcomes was minimal. More holistic approaches to weight management during pregnancy are required for women with obesity, with future interventions focussing on environmental and social factors, not just changing individual behaviour.

**Original contribution:**
This work makes an original contribution by evaluating experiences and outcomes of antenatal weight management in women with a BMI≥40kg/m², a subgroup frequently lacking in previous research. Additionally, it explored the long-term association between antenatal weight management service attendance and childhood obesity, which has seldomly been undertaken previously.

# Acknowledgements

*"Research is formalized curiosity. It is poking and prying with a purpose."*
Zora Neale Hurston(1, p.174)

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## Abbreviations used within the thesis

ADHD – attention deficit hyperactivity disorder

AHLS – antenatal healthy lifestyle service

aOR – adjusted odds ratio

aRR – adjusted relative risk

ASD – autism spectrum disorder

BCT – behaviour change technique

BMI – body mass index

CI – confidence interval

cm – centimetre

COM-B model – Capability, Opportunity, Motivation, Behaviour model

DSM – Diagnostic and Statistical Manual

AMI – index of Multiple Deprivation

IOM – Institute of Medicine

g – gram

GCP – Good Clinical Practice

GDPR – General Data Protection Regulation

GWG – gestational weight gain

GDM – gestational diabetes mellitus

HRA – Health Research Authority

kg – kilogram

LGA – large for gestational age

m – metre

mm – millimetre

NHS – national health service

NICE – National Institute of Health and Care Excellence

OHID – Office for Health Improvements and Disparities

OR – odds ratio

PHE – Public Health England

PR – Prevalence ratio

RCOG – Royal College of Obstetricians and Gynaecologists

RCT – Randomised Controlled Trial

RR – relative risk

SGA – small for gestational age

UK – United Kingdom

USA – United States of America

WHO – World Health Organization

# Preliminaries

## Article-based thesis

This thesis is presented in an article-based format. Sheffield Hallam guidance for an article-based thesis states that it will usually include three to five publications, but this numerical range is a guide, rather than a regulation. Normally, the outputs should all either be published/accepted for publication or submitted to publishing outlets for peer review. At the point of submission, an article-based thesis must include at least one article that has been through full peer-review and has been accepted for publication. An article-based thesis will usually contain an explanation of the research question, a background section of the relevant literature within the research topic, and the methodology used within the research programme. After presenting the articles on which the thesis is based, the findings from the individual research elements are integrated and discussed, including a discussion around the original contribution to the knowledge of the research undertaken.

This article-based thesis includes four articles that are published within peer reviewed journals at the time of submission and one article that is currently under review. These articles report distinct, but linked aspects of the research programme. These articles are reproduced within this thesis, accompanied by a narrative. The candidate's contribution to each article is outlined in Appendix A.

## Research outputs

### Articles:

**Fair F**, Soltani H (2021). A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity, *Obesity Reviews*, 22(5):e13199.

**Fair FJ**, Soltani H (under review) Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study.

**Fair FJ**, Soltani H (2024) A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index. *Women and Birth*, 37(1):197-205.

**Fair FJ**, Soltani H (2024) Association of child weight with attendance at a healthy lifestyle service and sociodemographic characteristics among women with obesity during pregnancy. *Maternal and Child Nutrition*, 20(2):e13629. doi: 10.1111/mcn.13629.

**Fair FJ**, Watson H, Marvin-Dowle K, Spencer R, Soltani H (2022). "Everything is revolved around me being heavy … it's always, always spoken about." Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above. *PLoS ONE*, 17(6):e0270470.

## Published abstracts:

**F Fair**, H Soltani (2020) Evaluating the long-term impact of an antenatal healthy lifestyle service: retrospective cohort study. *European Journal of Public Health,* 30(Supplement_5):v267. Accepted as oral presentation at the 16th World Congress on Public Health – Rome (rearranged to virtual) 12th-17th October 2020.

**F Fair**, H Soltani (2020) Experiences of maternal weight management services among women with a raised body mass index. *European Journal of Public Health,* 30(Supplement_5):v851. Accepted as poster presentation at the 16th World Congress on Public Health – Rome (rearranged to virtual) 12th-17th October 2020.

## Oral presentations:

**FJ Fair**, H Soltani (2020) Experiences of maternal weight management services among women with a raised body mass index. Presented at the International and European Congress on Obesity – Dublin (rearranged to virtual) 17th-20th May 2020

**FJ Fair**, H Soltani (2022) Lifestyle interventions for reducing gestational weight gain in women with overweight or obesity: an overview of systematic reviews.

Presented at Zoom Forward 2022 European Congress on Obesity – Maastricht 4th-7th May 2022.

## Poster presentations:

**FJ Fair**, H Soltani (2020) An evaluation of the long-term impact of an antenatal maternal healthy lifestyle service: a retrospective cohort study. Presented at the International and European Congress on Obesity – Dublin (rearranged to virtual) 17th-20th May 2020.

# Chapter 1: Introduction

This chapter sets the scene for the programme of research. It provides a brief rationale for the study. It then outlines the aims of the programme of research and explains the thesis structure.

## 1.1 Brief rationale

While seldomly seen a few decades ago, people with a body mass index (BMI) ≥40kg/m² now make up almost 10% of the population in some countries such as the United States of America (USA)(2). There has been a corresponding increase in women* with a BMI ≥40kg/m² when booking for pregnancy care including in the United Kingdom (UK)(3). These women with the highest class of obesity are at increased risk of multiple complications during pregnancy and the postnatal period for both them and their infant(4). They are also at increased risk of excessive gestational weight gain (GWG), with 45.8% of women with a BMI ≥40kg/m² found to gain excessive gestational weight(5). Excessive GWG itself is associated with multiple adverse perinatal outcomes(6).

To manage GWG interventions have been developed which mainly include healthy eating or physical activity or a combination of the two. However, systematic reviews have given inconsistent results when evaluating the effectiveness of interventions designed to manage GWG(7,8). Some evidence particularly suggests such interventions may be less effective among women with obesity(9).

Given the additional risks for women with obesity during pregnancy guidance has been developed to ensure appropriate care pathways(10,11). However, uncertainty remains among professionals over the most effective form of weight management during pregnancy for women with obesity, with providers and commissioners desiring more clarity within guidelines on which to base their practice(12). This has currently resulted in wide geographical variations in

* The terms ‘woman’ and ‘mother’ have been used within this thesis. However, it is acknowledged that not all people who give birth will identify themselves as a ‘woman’ or as a ‘mother’. Additionally, it is recognised that not all people who identify themselves as a mother have gestated their children.

maternal weight management service availability across England[12]. A deeper understanding of effective weight management during pregnancy for women with the most extreme forms of obesity is therefore essential.

## 1.2 Research programme

This thesis explored gestational weight management for women with obesity. This was borne out of a research project that evaluated an innovative midwife-led service known locally as ‘Monday clinic’ which supported women with obesity regarding healthy eating, physical activity and weight management during pregnancy. This antenatal healthy lifestyle service was established in 2009. From 2009 to 2012 the service offered one routine visit with an additional optional visit. From 2012-2017 the service offered three routine visits. In 2015, Sheffield Hallam University was approached to externally evaluate this service. This led to a research funding bid being submitted to the Burdett Trust for Nursing. This funding bid comprised of three elements. Firstly, to compare pregnancy and birth outcomes across the two different levels of service provision, as well as comparing pregnancy and birth outcomes to a separate Trust where no antenatal healthy lifestyle service was available. Secondly, the funding bid planned to evaluate the long-term effects of attendance at the antenatal healthy lifestyle service and gestational weight gain on childhood weight up to reception age from data collected as part of the routine National Child Measurement Programme. Finally, a qualitative component was planned to explore the experiences of women attending the antenatal healthy lifestyle service.

## 1.3 Research programme aims

The overall research question for this research was:

*What interventions are effective at managing GWG in women with obesity?*

To answer this question and provide a better understanding of gestational weight management interventions for women with obesity the programme of research focussed on four specific aims. These were:

- To establish from the current research literature the effectiveness of lifestyle interventions for women with overweight or obesity for reducing GWG and other adverse outcomes for the mother and the infant.
- To explore the impact of a service supporting women with the highest class of obesity to achieve adequate GWG and improve maternal and infant outcomes.
- To investigate the association between providing a weight management service to women with a high BMI during pregnancy and long-term child weight outcomes.
- To explore the experiences of weight management during pregnancy among women with the highest class of obesity.

## 1.4 Overview of the programme or research

To achieve the research aims, a programme of research was planned which included five linked studies. Where each article fits into the scheme of the research programme is presented graphically in Figure 1.1. It comprised of an overview of systematic reviews, followed by a sequential explanatory mixed methods study.

## 1.5 Research Programme timeline

July 2009 – Monday clinic service established.

July 2012 – The number of routine visits during pregnancy at the Monday clinic service increased the from one to three.

June 2015 – Burdett Trust for Nursing funding bid submitted to undertake quantitative and qualitative evaluation of Monday clinic (Articles B-E).

November 2015 – Burdett Trust for Nursing funding bid successful.

July 2016 – Ethical approval for the quantitative component received and data collection commenced.

January 2017 – Quantitative data collection begins at neighbouring NHS Trust.

March 2017 – Analysis of partial Monday Clinic data set to inform qualitative component.

September 2017 - Quantitative data collection for Monday Clinic completed.

**Figure 1.1. Overview of the research programme**

| | |
|---|---|
| Chapter 1. Introduction | |
| Chapter 2. Background | |
| Chapter 3. Systematic review → | Article A: A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity |
| Chapter 4 Methodology | |
| Chapter 5 Evaluation of differing intensities of an antenatal healthy lifestyle service → | Article B: Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study |
| Chapter 6 Evaluation of an antenatal healthy lifestyle service versus a comparison cohort → | Article C: A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index |
| Chapter 7 Association between antenatal healthy lifestyle service attendance and long-term child weight outcomes → | Article D: Association of child weight with attendance at a healthy lifestyle service and sociodemographic characteristics among women with obesity during pregnancy. |
| Chapter 8 Experiences of weight management during pregnancy → | Article E: “Everything is revolved around me being heavy … it’s always, always spoken about.” Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above. |
| Chapter 9 Integration of the findings | |
| Chapter 10 Discussion | |
| Chapter 11 Conclusions | |

2017 – Mondy clinic service discontinued.

October 2017 - Quantitative data collection completed for childhood weight measurements.

October 2017 – Ethical approval for qualitative component received.

November 2017 – Recruitment to qualitative component begins.

January 2018 – Ethical amendment for qualitative component to include telephone interviews as an option as well as focus group.

September 2018 – Quantitative data collection completed from neighbouring NHS Trust (comparison site).

September 2018 – Further ethical amendment for qualitative component to include women who had not attended the original Monday Clinic.

December 2018 - February 2019 – qualitative data interviews undertaken.

September 2019 – Protocol for overview of systematic reviews developed.

October 2020 – Overview of systematic reviews completed and submitted.

February 2019 – July 2023 – Analysis for Articles B-E completed and articles submitted.

## 1.6 Thesis structure

**Chapter 1** provides an introduction to the thesis. A brief rationale is provided and the overall aims of the programme of research stated. An overview of the chapters within the thesis is provided.

**Chapter 2** contains a summary of the background literature pertinent to the topic area. This includes the adverse outcomes related to obesity during pregnancy, as well as the adverse outcomes related to excessive gestational weight gain. The interventions frequently used to manage gestational weight gain are also briefly discussed. The chapter identifies the gaps within the current literature and research.

**Chapter 3** contains Article A “A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity.” This was accepted for publication in Obesity Reviews in January 2021, being published online in early view before being published in the May 2021 edition of Obesity Reviews. It provides a detailed summary of interventions to reduce gestational weight gain among women with overweight or obesity.

**Chapter 4** details the methodological approaches underpinning the programme of research, including the theoretical perspectives and the philosophical assumptions and justification for a mixed methods approach to the research programme.

**Chapter 5** contains Article B “Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study.” This article is currently under review in Midwifery. It compares maternal and infant outcomes among women with a BMI ≥40kg/m² offered one antenatal healthy lifestyle service appointment to those offered three appointments.

**Chapter 6** contains Article C “A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index.” This was accepted for publication in Women and Birth and published online as an “Article in Press” on 9th September 2023, before being published in the February 2024 edition of Women and Birth. It analyses the maternal and infant outcomes among women with a BMI ≥40kg/m² attending an antenatal healthy lifestyle service appointment compared to women in the neighbouring Trust who were not offered this service.

**Chapter 7** contains Article D “Association of attendance at a healthy lifestyle service and sociodemographic characteristics among women with obesity during pregnancy on long-term child weight.” This article was accepted for publication in Maternal and Child Nutrition, being published online in “Early view” on 4th February 2024. This manuscript explored the association between antenatal healthy lifestyle service attendance and other maternal and newborn characteristics on long-term child weight outcomes up to 5 years of age.

**Chapter 8** contains Article E ““Everything is revolved around me being heavy … it’s always, always spoken about.” Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above.” This was published by PLoS One in June 2022. It explores the experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above.

**Chapter 9** reviews how the original aims were addressed within the research programme. It then provides an integration of the findings across the different aspects of the research programme, including the meta-review, quantitative and qualitative aspects. Results from the different components were compared and contrasted and integrated across the different constituent parts of the research with a more general answer to the research question presented.

**Chapter 10** discusses the key findings of the research programme in light of other literature. The limitations and strengths of the research programme are then discussed.

**Chapter 11** concludes the research programme. Implications for practice, policy and research are identified and the contribution to knowledge from this research programme is outlined.

# Chapter 2: Background

## 2.1 Introduction

Body mass index (BMI) is defined by a person's weight in kilograms divided by the square of their height in meters. It is used as a measure of nutritional status in adults(13). Table 2.1 shows the World Health Organization classifications for adult BMI(13).

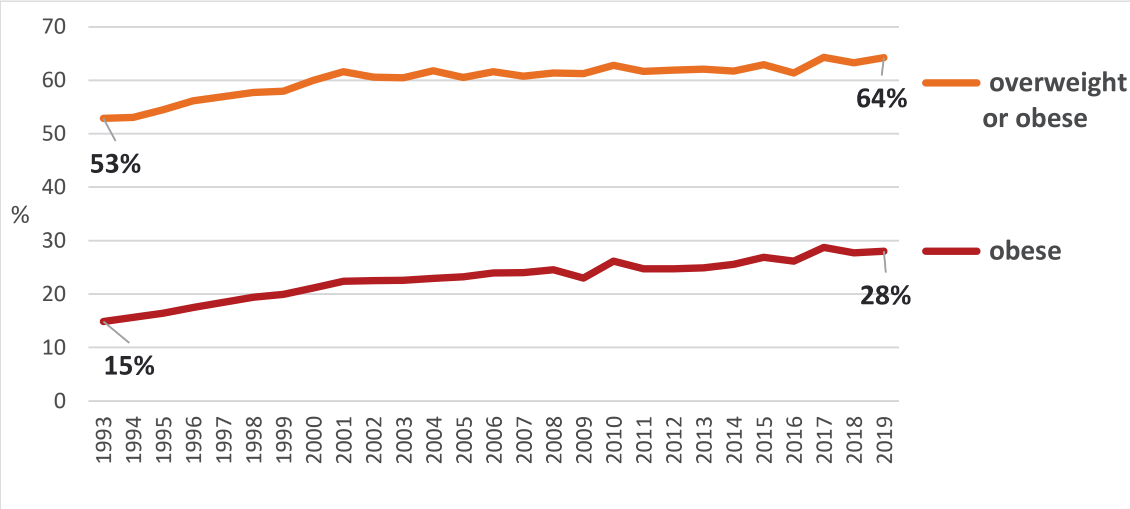
**Table 2.1. Classification of adult BMI**(13)

| **Classification** | **BMI** (in kg/m²) |
|---|---|
| Underweight | <18.50 |
| Recommended range | 18.50-24.99 |
| Overweight | 25.00-29.99 |
| Obese | ≥30.00 |
| Obese class I | 30.00-34.99 |
| Obese class II | 35.00-39.99 |
| Obese class III | ≥ 40.00 |

Across the globe the prevalence of overweight and obesity have increased over recent decades(14). Within England over 60% of the adult population are now classified as having overweight or obesity, with obesity raising from 15% in 1993 to 28% by 2019 and overweight and obesity raising from 53% to 64% within the same time period (See Figure 2.1)(15).

In parallel with rising obesity figures globally, the number of women with obesity during pregnancy has been rising over recent decades. Maternal obesity across Europe varies from 7% to 25%, with the figure in USA cohorts being even higher at approximately 40% of women entering pregnancy with obesity(16). Within Europe, the United Kingdom (UK) is estimated to have one of the highest rates of maternal obesity(16); with rates almost trebling over recent decades from 7.6% in 1989(17) to 22.2% in 2018-2019(18). There has also been a profound increase in the proportion of people with a BMI of 40kg/m² or more in the USA, raising from 2% in the 1980's to almost 10% by 2019[2]. UK figures are less consistently documented, but current data suggests 3.3% of women booking for pregnancy care had a BMI ≥40kg/m² [3].

**Figure 2.1. Prevalence of adult overweight and obesity in England over time** (Data source: NHS Digital, 2022[15])




Each woman with a raised BMI is an individual and will have their own reasons for their current obesity. The environment in which we live has become increasingly obesogenic over recent decades[19]. Food has become increasingly available and affordable, with the food industry marketing foods that are highly processed, high in sugar, energy-dense and micro-nutrient poor[19]. Fast food outlets have also increased[19]. At the same time energy expenditure within occupations has typically decreased. Physical activity within the home has also become restricted with increasing use of technology such as televisions and games consoles for entertainment[19]. Increased use of screens is also linked to delayed sleep onset and shorter sleep duration which are additionally linked to higher risks of obesity[19]. The obesogenic environment exploits people's psychosocial, social and economic vulnerabilities[19]. For example the psychosocial factors associated with obesity include emotional eating, food addiction and poor self-esteem[19]. Furthermore, body weight is reported to be the most common reason for bullying during childhood[19].

The prevalence of obesity is strongly associated with social inequalities[16], with women with obesity having lower educational levels than women with a BMI in the recommended range or underweight[16,20]. Women in the most deprived quintile are also more likely to have a BMI in the obese range than those in the least deprived quintile after adjusting for other confounding factors such as age, ethnicity, smoking status and parity (adjusted odds ratio (aOR) 1.60, 95% Confidence Interval (CI) 1.13-2.26)[21]. As deprivation quintile increases the odds of all classes of obesity increase, but the largest increases are seen for class III obesity[22]. Food insecurity is also increasing, particularly recently after the covid-19 pandemic and global increases in fuel and food costs[22]. Within Britain 40% of consumer survey respondents indicated that they were worried about affording food for the next month[23]. When faced with food insecurity, women often sacrifice their own food intake to provide for their children[22]. Food insecurity is associated with poor diet quality as healthy foods increase in price, leading to eating energy dense foods[22,23]. Those from deprived areas are also more likely to live in smaller houses with limited storage and areas to prepare fresh ingredients, further inhibiting their food choices. Additionally, the incidence of obesity increases with advancing age among women of reproductive age[15,24]. This may partly be due to the process of childbearing itself, which is acknowledged to contribute to the rise of overweight and obesity in women[25].

### 2.1.1 BMI as a measure of obesity

BMI has been used to define obesity within this thesis as it is internationally recognised and the most commonly used measure. However, it is recognised that the use of BMI is not without its limitations and critique. It is known that those from an Asian background have increased risk of conditions such as type 2 diabetes and cardiovascular disease at substantially lower BMIs[26]. This partly may be because BMI cannot differentiate between the weight of different components, for example fat, muscle, bone or fluid[27]. This lack of differentiation of lean body mass and fat mass[28,29] means that a healthy muscular individual can be given the same BMI categorisation as someone with extensive body fat and associated medical comorbidities[27]. Additionally, it is increasingly recognised that visceral fat rather than total fat mass most accurately predicts mortality risk and that body fat distribution is associated with risk of cardiometabolic disease[29]. As BMI categorisation cannot distinguish fat distribution, waist measurement and waist-to-hip ratio are seen as increasingly important[27] and more highly associated with cardiovascular disease risk[30]. While BMI is the most commonly used method to assess body composition in pregnancy, other anthropometric measures such as abdominal or arm circumference and waist-to-hip ratio are sometimes used as is bioelectrical impedance analysis[31]. A review however found that modern methods of measurement such as magnetic resonance imaging, bioimpedance spectroscopy and hydrodensitometry were used in less than 2% of research studies[31].

It is suggested that being 'fit and fat' is possible, with fitness being more important than fatness for long-term prognosis[32], with research finding that almost one third of people with obesity are metabolically healthy[33]. Some therefore argue that unnecessary anxiety is caused to at least one third of people labelled as obese who are told that they need to lose weight to become healthy[27]. However, others have questioned whether the 10-30% of individuals with obesity who are metabolically healthy are really healthy or whether metabolically healthy obesity is a transitory rather than permanent state with the onset of obesity related metabolic diseases merely delayed[34]. Additionally, even metabolically healthy individuals may not experience full physical, mental and social wellbeing[34]. Therefore, when considering whether a person has obesity the impact of excess weight on physical, mental and social health should be assessed not just using the simple classification of BMI[35]. Indeed, healthcare providers themselves report finding BMI categorisation too rigid, instead wanting a more individualised approach to assessing women's needs during pregnancy including around fat distribution and overall health[36].

## 2.2 Complications associated with obesity during pregnancy

There is a well-established link between raised pre-pregnancy BMI and multiple complications for the mother and infant; with a progressive escalation of adverse outcomes as BMI increases[37]. Individual participant meta-analysis has shown that the proportion of women with at least one adverse outcome during pregnancy [for example pre-eclampsia, gestational hypertension, gestational diabetes (GDM), Caesarean birth, preterm birth, small for gestational age (SGA) or large for gestational age (LGA)] was 34.1% of women with a BMI in the recommended range, 42.0% of women with overweight, 50.2% of women with class I obesity, 56.8% of women with class II obesity and 61.1% of women with class III obesity(20). Similarly, a separate individual participant meta-analysis of 39 cohort studies undertaken in Europe, Australia and North America including 265,270 births estimated that of all pregnancy complications, 23.9% were attributable to maternal overweight or obesity prior to pregnancy; with the highest risk of pregnancy complications being for mothers with a BMI ≥40kg/m² (Odds Ratio (OR) 2.99, 95% CI 2.68-3.34)(38).

The impact of maternal BMI on maternal and infant complications, both during pregnancy, the immediate postpartum period and longer-term are discussed below.

### 2.2.1 Maternal complications in the perinatal period

#### 2.2.1.1 Gestational diabetes

GDM is the most common medical complication during pregnancy(39). It is of concern given the long-term association between GDM and increased risk of type 2 diabetes and cardiovascular disease for the mother and additional metabolic risks for the infant including obesity, hypertension and hyperinsulinaemia(39).

A significant body of evidence, including multiple meta-analyses have highlighted the increased incidence of GDM with increasing maternal BMI. It has been calculated that 42.8% of GDM is attributable to maternal overweight and obesity(38) and estimated that each 10% increase in maternal pre-pregnancy BMI increases the relative risk of GDM by approximately 10%(40). One meta-analysis including 962,966 women in 33 observational studies, found that compared to women with a BMI in the recommended range the risk of GDM was increased in women with overweight (adjusted relative risk (aRR) 1.52, 95% CI 1.15-1.89) and women with obesity (aRR 2.24, 95% CI 1.97-2.51)(41). This was regardless of whether BMI was self-reported or measured at antenatal clinic(41). A further individual participant meta-analysis of 39 cohort studies and a meta-analysis of 36 studies both showed GDM decreased in women with underweight compared to women with a BMI in the recommended range but increased in women with overweight or obesity[38,42]. Several meta-analyses have shown GDM to be highest in women with a pre-pregnancy BMI ≥40kg/m² (OR 7.59, 95% CI 6.14-9.38)[38] and (RR 4.62, 95% CI 3.61-5.93)[43]. The risk of GDM among women with a BMI ≥40kg/m² was higher even when they were compared to women with class I obesity (RR 1.84, 95% CI 1.44-2.34) or women with class I or class II obesity combined (RR 1.68, 95% CI 1.52-1.86)[4]. The link between maternal overweight or obesity and increased risk of GDM occurs regardless of adequacy of gestational weight gain (GWG)[44]. The risk of GDM is known to vary according to ethnicity, with women from a Black and minority ethnic background with a BMI ≥35kg/m² 1.6 times more likely to develop GDM than white women with an equivalent BMI[45]. However, even when adjusting for factors such as ethnicity, parity, and hypertension the odds of GDM have been shown to progressively increase with increasing BMI[37]. When looking at the potential impact of multiple different independent factors on the odds of GDM, after previous history of GDM and history of preterm birth, maternal obesity was associated with the next largest increase in odds of GDM[46]. This is due to the adipose tissue in those with obesity becoming larger and dysfunctional, resulting in inflammation[47]. Long term systemic inflammation prevents the proper action of insulin and develops into insulin resistance[47]. Insulin sensitivity is believed to decrease by 40-50% during pregnancy[48]. When these natural changes to blood glucose and insulin resistance that occur during pregnancy under the influence of human placental lactogen, progesterone and cortisol are combined with the underlying insulin resistance due to obesity, it makes a diagnosis of GDM more likely[49].

Given the limitations in classification of risk by BMI, other maternal adiposity measures such as abdominal subcutaneous fat thickness, waist circumference, waist-to-hip ratio and body fat distribution have been considered. Within a meta-analysis of 11 cohort studies the odds of GDM were increased in women with the highest level of central adiposity compared to those with the lowest levels of central adiposity (aOR 2.76, 95% CI 2.35-3.26)[50]. The odds of GDM were also higher among those with higher waist circumference (OR 1.40, 95% CI 1.04-1.88) and waist-to-hip ratio (OR 2.73, 95% CI 1.67-4.45)[51]. Several reviews have similarly shown multiple anthropometric measures to be increased in women with GDM compared to women without GDM including waist, neck, and upper arm circumference(51,52), hip circumference(52), waist-to-hip ratio, fat mass percentage(51,52) and visceral adipose tissue depth, as well as showing maternal height was decreased in women with GDM(52).

#### 2.2.1.2 Gestational hypertension and pre-eclampsia

Women with overweight or obesity prior to pregnancy are more likely to have hypertensive disorders in pregnancy(53). It has been calculated that 35.6% of gestational hypertension is attributed to maternal overweight and obesity(38). This link between obesity and hypertensive disorders in pregnancy has been identified regardless of GWG(44). An individual participant meta-analysis, of 39 cohort studies undertaken in Europe, Australia and North America including 265,270 births, showed that while women with underweight had a reduced odds of gestational hypertension compared to women with a BMI in the recommended range (OR 0.63, 95% CI 0.55-0.73), women with overweight or obesity were at increased odds of gestational hypertension, with women with a BMI ≥40kg/m² having the highest odds (OR 5.40 (95% CI 4.47-6.51)(38). Other meta-analyses have shown similar increased risks of gestational hypertension for women with a BMI ≥40kg/m² when compared both to women with a BMI in the recommended range(43), as well as when compared to women with class I obesity (BMI 30-34.9kg/m²) (Relative Risk (RR) 1.64, 95% CI 1.49-1.81) or class I and class II obesity combined (BMI 30-39.9kg/m²) (RR 1.44, 95% CI 1.34-1.54)(4).

Increasing BMI is also associated with increased risk of pre-eclampsia, with each 10% increase in maternal pre-pregnancy BMI increasing the relative risk of pre-eclampsia by approximately 10%(40). Meta-analyses consistently show raised maternal pre-pregnancy BMI increases the risk of pre-eclampsia. Compared to women with a BMI in the recommended range, one meta-analysis of 22 studies found increased odds of pre-eclampsia in women with overweight (OR 1.73, 95% CI 1.59-1.87) or obesity (OR 3.15, 95% CI 2.96-3.35)(54); and a further meta-analysis of over 30 studies found increased odds of pre-eclampsia in women with pre-pregnancy overweight (OR 1.89, 95% CI 1.74-2.05) or obesity (OR 3.57, 95% CI 3.29-3.87)(42). Within the first of these meta-analyses the effect estimates were similar within studies that adjusted for confounders and those that did not, as well as in studies at low risk of bias and those at high risk of bias[54]. A further individual participant meta-analysis of 39 cohort studies showed the highest odds of pre-eclampsia among women with a pre-pregnancy BMI ≥40kg/m² (OR 6.50, 95% CI 5.48-7.73)[38]. Even when comparing women with a BMI ≥40kg/m² to other women with obesity, either class I obesity alone or class I and class II obesity combined, the risk of pre-eclampsia remains higher[4]. Overall, it has been estimated that 34.6% of pre-eclampsia is attributable to maternal overweight and obesity[38].

The effect of central maternal adiposity has also been considered with one review showing hypertensive disorders were higher in women with higher waist circumference and waist-to-hip ratio[51].

The potential mechanisms by which obesity causes pre-eclampsia are being increasingly understood. These include the link between obesity and insulin resistance which lead to an increased risk of gestational diabetes and type II diabetes, both of which are associated with pre-eclampsia[54]. Obesity is also characterised by hypertriglyceridemia which is associated with endothelial dysfunction[54]. Adipose tissue is known to release adipokines such as leptin which is pro-inflammatory[55]. Leptin levels are also higher among women with pre-eclampsia, so leptin may be one of the factors connecting obesity and pre-eclampsia[55]. Additionally, women with obesity have been shown to have impaired vasodilation and vasoconstriction in myometrial arteries compared to women with a BMI in the recommended range[56]. While no women with pre-eclampsia were included within that study, the differences in vascular function with obesity were noted to be similar to those seem with pre-eclampsia[56].

#### 2.2.1.3 Preterm birth

Preterm birth is a birth that occurs before 37 completed weeks of gestation[57]. It is estimated that approximately 15 million preterm births occur each year globally[57]. While the majority occur in low and middle income countries, within Europe estimates of preterm birth are around 5%[58]. Long-term consequences of preterm birth are believed to include poorer cognitive outcomes including academic performance and working memory, as well as lower levels of motor skills and more behavioural problems such as attention deficit[59]. Poorer cognitive outcomes are seen across all children born under 37 weeks gestation, but the most pronounced effects are for those born under 34 weeks gestation[59].

Some studies suggest an increased risk of preterm birth for women with a BMI outside of the recommended range. For example, an individual participant meta-analysis of 39 cohort studies undertaken in Europe, Australia and North America showed that compared to women with a BMI in the recommended range the risk of preterm birth was increased with pre-pregnancy underweight as well as overweight and obesity, with the highest rate in women with a pre-pregnancy BMI ≥40kg/m² (OR 1.52, 95% CI 1.24-1.87)[38]. Even when compared to other women with obesity, women with a BMI ≥40kg/m² have been shown to have increased risk of preterm birth less than 37 weeks; RR 1.31 (95% CI 1.19-1.43) compared to women with class I obesity and RR 1.20 (95% CI 1.13-1.27) compared to women with class I and class II obesity combined[4]. One study however suggested that increased risk of preterm birth among women with overweight and obesity was limited to those with inadequate GWG[44].

While the risk of preterm birth (<37 weeks) was increased in women with underweight, overweight or obesity compared to women with a BMI in the recommended range in the most recent review, very preterm birth (<32 weeks) was only increased in women with underweight or obesity[42]. Other studies have looked at the impact of maternal BMI on different types of preterm birth. One of these found women with obesity were at higher risk of preterm birth, especially spontaneous preterm birth[60]. In contrast, a recent case control study from across 20 centres in Brazil noted the risk of spontaneous pre-term birth decreased in women with overweight or obesity[61]. However, being overweight or obese increased the risk of provider-initiated preterm birth, where induction was carried out due to maternal or fetal compromise from medical complications such as GDM, pregnancy induced hypertension or polyhydramnios[61].

A reason behind the inconsistencies seen in previous studies may be due to a significant interaction between specific maternal genes and maternal pre-pregnancy BMI on the risk of preterm birth[62]. There is a potential that for women who carry specific genes modifying their BMI prior to pregnancy could impact their risk of preterm birth[62].

#### 2.2.1.4 Mode of birth and associated complications

Caesarean Section rates are increasing globally and while they can be a life-saving procedure for the mother or the infant, they are associated with many adverse consequences[63]. For the mother these include increased recovery time, maternal haemorrhage, postpartum infection, and the need for hysterectomy, as well as longer term outcomes that impact subsequent pregnancies such as increased risk of abnormal placentation, uterine rupture and preterm birth[63]. For the infant potential adverse outcomes include altered gut microbiome diversity, altered immune development, allergy and asthma[63].

Meta-analysis evidence shows that compared to women with a BMI in the recommended range, women with a BMI ≥40kg/m² are less likely to have a vaginal birth (RR 0.72, 95% CI 0.62-0.84)[43]. The rate of instrumental birth however appears not to be linked to maternal BMI, with no difference in operative vaginal birth noted with increasing BMI in a cohort study of over 112,000 women[64] and no increased risk of instrumental birth in women with a BMI ≥40kg/m² compared to women with either class I obesity (RR 1.06, 95% CI 0.84-1.33) or class I and class II obesity combined (RR 0.99, 95% CI 0.88-1.11)[4].

The evidence however unanimously supports an increased risk of Caesarean birth in women with overweight or obesity compared to women with a BMI in the recommended range. Within a meta-analysis of 33 studies[65], a meta-analysis of 19 studies[43] and a recent meta-analysis of 86 studies[42] the odds of Caesarean birth increased with increased BMI. The highest risk of Caesarean birth was among women with a BMI ≥40kg/m² [43]. Even when compared to women with class I obesity or with class I and class II obesity combined, a systematic review has shown women with a BMI ≥40kg/m² were at increased risk of Caesarean birth[4]. Furthermore, when measures of central adiposity have been used rather than BMI, the odds of Caesarean birth increase by 71% with a waist circumference of 80cm or more, increase by 5-32% for every 5mm increase in abdominal subcutaneous fat thickness[66] and increase with increased hip-to-waist ratio[51]. Caesarean birth can be either an elective or emergency procedure. Both forms of Caesarean birth are increased for women with overweight or obesity[42] and in women with a BMI ≥40kg/m² [43] compared to women with a BMI in the recommended range. Furthermore, for intrapartum Caesarean births, the risk increases with increasing BMI regardless of whether the labour was spontaneous or induced[64].

As discussed previously, women with obesity have higher levels of leptin, as well as other adipokines, visfatin and apelin which are all known to decrease myometrial contractility[67]. Women with obesity also frequently have higher levels of cholesterol, which has been linked to inhibited oxytocin receptor function in the myometrial cells with a resultant reduced contraction force and frequency[67]. These changes can lead to dysfunctional labour and therefore may partially explain the increased Caesarean birth rate among women with obesity[67].

As well as being more likely to experience Caesarean birth, women with obesity are at higher risk of complications associated with Caesarean birth. One example is anaesthetic complications. A systematic review of eight studies found that women with a BMI ≥30kg/m² were more likely than women with a BMI <30kg/m² to experience multiple attempts to site an epidural and more likely to experience epidural failure, defined either as failure to cite an epidural or unsatisfactory analgesia[68]. Women with a BMI ≥40kg/m² had the highest odds of epidural failure[68]. Given this increased risk of epidural failure it is not surprising that the rate of general anaesthesia increases with increasing BMI[45]. The highest rate of general anaesthesia has been shown among women requiring a Caesarean birth after a spontaneous onset of labour, rather than for those who had a planned Caesarean prior to the onset of labour[45].

An increased incidence of surgical site infection is another adverse outcome noted for women with obesity. Increased infection in women with obesity was found in 14 of the 19 studies incorporated into an overview of systematic reviews[60]. A more recent study has reinforced this link, with higher risk of surgical wound complications noted among women with a BMI ≥40kg/m² compared to women with a BMI in the recommended range (RR 2.17, 95% CI 1.34-3.51)[64]. Even when compared to women with class I obesity or class I and class II obesity combined, a systematic review has shown that women with a

BMI ≥40kg/m² were at greater risk of wound complications after Caesarean birth[4]. However, once stratifying analyses according to planned mode of birth, a further systematic review of ten observational studies in women with a BMI ≥40kg/m², showed that women with an anticipated vaginal birth compared to women with a planned Caesarean birth had a higher risk of postpartum haemorrhage, but lower risk of wound infection[69].

Regarding placentation issues, the literature is less clear. For instance, a systematic review incorporating eight studies showed the odds of placental abruption reduced in women with overweight or obesity compared to women with a BMI in the recommended range[70], but a cohort of over 112,000 women that were not included in the above systematic review found no difference in abruption in women with a BMI ≥40kg/m² compared to women with a BMI in the recommended range[64]. Other evidence suggests women with obesity are at increased risk of abnormally invasive placenta but given the increased odds of abnormally invasive placenta after a previous Caesarean birth the increased risk could just be related to the increased risk of Caesarean birth rather than to obesity per se[71].

The high risk of Caesarean birth among women with obesity is of additional concern given that a meta-analysis of 94 observational studies has shown maternal obesity reduces the odds of a successful vaginal birth after a Caesarean[72]. The other factors within the meta-analysis associated with reduced odds of successful vaginal birth after Caesarean were diabetes, hypertensive disorders in pregnancy and induction of labour[72], which are all increased in women with obesity. Furthermore, among women with a BMI ≥40kg/m² with a previous Caesarean birth, those who planned a trial of labour compared to those who planned a further Caesarean birth were more likely to experience uterine dehiscence, a hospital stay longer than 4 days and to give birth to an infant with an Apgar score less than 7 at 5 minutes[69].

#### 2.2.1.5 Induction

A meta-analysis demonstrated higher odds of induction of labour in women with overweight (OR 1.23, 95% CI 1.17-1.30) and obesity (OR 1.55, 95% CI 1.36-1.77) compared to women with a BMI in the recommended range[42]. Even when compared to women with class I obesity (RR 1.36, 95% CI 1.21-1.54) or class I and class II obesity combined (RR 1.21, 95% CI 1.14-1.29), women with a BMI ≥40kg/m² are at increased risk of induction[(4)]. However, one systematic review has noted induction outcomes are poorer among women with maternal obesity compared to women with a BMI in the recommended range, with increased rates of Caesarean birth, higher doses of prostaglandins, higher doses of synthetic oxytocin, longer time to birth after commencing oxytocin and less successful cervical ripening and/or achieving active labour[(73)]. When considering maternal adiposity rather than BMI, higher waist circumference and hip-to-waist ratio have both been associated with increased induction of labour[(51)].

Despite increased rates of induction with a raised BMI, the odds of postdates birth (≥42 weeks gestation) is higher among both women with overweight and women with obesity[(42)] and for each five unit increase in maternal BMI there are increased odds of post-term birth (≥41 weeks gestation) (OR 1.13, 95% CI 1.05-1.21, 11 studies) and birth ≥42 weeks gestation (OR 1.19, 95% CI 1.12-1.26, 19 studies)[(74)]. It has been suggested that that the increased inflammation levels, higher leptin levels in the blood, insulin resistance and the imbalance of lipids such of cholesterol, lipoprotein and triglycerides all associated with maternal obesity may influence the onset of labour and therefore increase the need for induction; however the exact causal pathway is unclear[(74)]. However the increased risk of postdates birth is of concern given that a meta-analysis, covering 15 million pregnancies, looking at stillbirth and neonatal death found that the risk of stillbirth increased from 0.11 per 1000 pregnancies at 37 weeks gestation to 3.18 per 1000 pregnancies at 42 weeks gestation[(75)]. There was one additional stillbirth for every 1449 pregnancies that advanced from 40 to 41 weeks. Neonatal death also increased significantly from 41 to 42 weeks RR 1.87 (95% CI 1.07-2.86)[(75)].

#### 2.2.1.6 Breastfeeding

The World Health Organization recommends breastfeeding is initiated within one hour of birth[(76)] and that infants are exclusively breastfed until six months of age[(77)]. Evidence suggests that infants fed with breastmilk substitutes are at increased risk of gastrointestinal infections, respiratory infections, asthma, as well as increased risk of obesity and diabetes in later life and that mothers who do not breastfeed their infants are at increased risk of ovarian cancer, breast cancer, type 2 diabetes and postnatal depression[78].

Numerous systematic reviews and overviews of reviews have found that women with overweight or obesity were less likely to initiate breastfeeding than women with a BMI in the recommended range[60,79-82], with non-initiation of breastfeeding being highest in women with obesity[80,81]. Most of these reviews and meta-analyses combined adjusted effect estimates, although the exact confounders adjusted within each included study varied but included factors such as maternal age, education, employment, socio-economic status, smoking and mode of birth. A further retrospective study of 7,491 women from routinely collected hospital data in Australia, published after the most recent systematic reviews found that compared to women with a BMI in the recommended range, the odds of not breastfeeding was increased in women with overall obesity (OR 1.66, 95% CI 1.40-1.96) and with class III obesity (OR 2.61, 95% CI 2.07-3.29)[83]. These lower rates of breastfeeding with higher maternal BMI were noted regardless of mode of birth and after adjusting for confounding factors of maternal age, socioeconomic status, comorbidities and infant birthweight[83].

Additionally, most systematic reviews have noted increased cessation of both exclusive breastfeeding and any breastfeeding in women with overweight or obesity compared to women with a BMI in the recommended range[80-82], with the highest risk noted in women with obesity[80,81]. A dose response relationship between BMI and breastfeeding outcomes has also been noted, with the risk of cessation of breastfeeding increasing with each increasing category of BMI[79], as well as for every unit increase in BMI[84].

Numerous reasons have been hypothesised to impact on breastfeeding initiation, duration and exclusivity including the increased risk of delayed onset of lactogenesis in women with obesity compared to women with a BMI in the recommended range noted within several systematic reviews[79,85,86]. It is suggested that this may be due to the leptin secreted by adipose tissue in women with obesity inhibiting the oxytocin that is required for the milk ejection reflex[85]. Additionally, women with obesity have been found to have lower baseline levels of prolactin and release less prolactin in response to the infant suckling which may reduce the quantity of breastmilk produced(85). This may explain why women with overweight or obesity are more likely to self-report having insufficient milk(86).

Qualitative research has also found women with obesity to report mechanical barriers to breastfeeding such as their larger breasts making it more difficult to position and attach the infant, as well as difficulties in finding nursing bras to fit(87). The size of their breasts also led some women to worry that their infant would suffocate while trying to feed(88,89). Women with obesity's difficulties with successfully latching their infant also led them to report more breast problems such as cracked nipples(87). Birth complications such as Caesarean section(87) and medical interventions(90) are also more prevalent among women with obesity. After an operative birth women have reported feeling 'out of it' and to have delayed skin-to-skin contact with their infants, both of which created barriers to breastfeeding initiation(88). Medical complications sometimes also meant women were separated from their infants which left the woman feeling out of control which in turn amplified their doubts in their ability to breastfeed(89).

Psychosocial factors have also been reported to influence breastfeeding outcomes among women with overweight and obesity. Compared to women without obesity, women with obesity are less likely to believe in the nutritional adequacy of breastmilk, less likely to believe that significant others prefer them to breastfeed and less likely to have been exposed to family or friends who had breastfed(91). Women with obesity have also been shown to have poorer body image(87,91), leading to a lower confidence in their ability to breastfeed(87). Women with obesity also report feeling uncomfortable about feeding in public(88,92,93). Within the hospital in the days after the birth, especially if by Caesarean section, women reported finding it difficult to shut the curtains around their bed, or even if they did then staff would often come in and leave them open again(88). This meant women felt exposed in front of other women and their visitors, especially if they were experiencing difficulties with latching or needed to manually express breastmilk for their infant(88,92). Even once home women felt uncomfortable feeding in front of visitors within their home and anxious about feeding in public as they were self-conscious about exposing their body to others(88,93). The lack of pictures of women with a raised BMI within breastfeeding literature only served to reinforce women's perception that breastfeeding for women with obesity was unacceptable to society[89].

Various systematic reviews have also found the composition of breastmilk is changed in women with obesity. A positive correlation between maternal BMI and both leptin and adiponectin concentrations in breastmilk has been noted, with both of these hormones having a role to play in regulating appetite and metabolism[94]. The concentration of fatty acids within breastmilk was shown within a systematic review of 6 studies to vary, with women with overweight having an increased ratio of Omega 6 compared to Omega 3 and women with obesity having lower levels of Omega 3[95]. A balance in the ratio between Omega 6 and Omega 3 is essential for brain formation, development, and functioning[94]. Further systematic reviews incorporating 31 studies[96] and 66 studies[97] found higher fat concentration in mature breastmilk[96,97] but not colostrum[96] and higher lactose concentration in colostrum but not mature breastmilk[96], but no differences in total energy[97] or protein levels[96,97] between women with a raised BMI or adiposity compared to women with a BMI in the recommended range.

#### 2.2.1.7 Mental health outcomes

Some evidence suggests that women with obesity are at increased risk of depression during the perinatal period. Numerous systematic reviews have found higher rates of antenatal depression symptoms in women with obesity than women with a BMI in the recommended range[60,98,99]. In one review, the higher a woman's BMI the higher the risk of major depressive symptoms during pregnancy[100]. Women with pre-pregnancy obesity are also more likely to experience postpartum depression than women with a BMI in the recommended range[60,98,99]. While some reviews only noted higher levels of postpartum depression among women with a BMI ≥35kg/m² [98], others have noted increased odds of postpartum depression among women with underweight, overweight and obesity[99].

Evidence from reviews also suggests a positive association between maternal obesity and anxiety both during pregnancy[60,100,101] and in the postpartum[101]. Within one review the highest levels of anxiety were seen among women with obesity[101]. However, none of the studies within the review assessed anxiety according to the Diagnostic and Statistical Manual (DSM) of Psychiatric Disorders criteria, so it was unknown if anxiety levels reach clinical significance[101].

Additionally, women with a raised BMI have been shown to have an increased perception of stress, lower self-esteem scores[100] and to report poorer Quality of Life, lower levels of social support and higher socioeconomic deprivation during pregnancy[102] than women with a BMI in the recommended range.

It is important to note however that the causality of mental health concerns and obesity is unclear within current evidence. It is unknown whether women with poor mental health struggle with weight management leading to obesity or whether having a raised BMI leads to increased feelings of stigmatisation which impact upon the woman's mental health[60].

#### 2.2.1.8 Covid-19

The recent Covid-19 pandemic has highlighted additional challenges faced by women with obesity during the perinatal period. Several systematic reviews and an individual participant meta-analysis have found raised maternal BMI increased severe covid-19 infection during pregnancy[103], intensive or critical care admission[103,104], requirement for ventilation[103,104] and maternal death[103,105,106]. For women who had a laboratory confirmed positive covid infection, a further systematic review showed women with obesity during pregnancy were at higher risk of stillbirth and neonatal mortality[105].

#### 2.2.1.9 Other maternal outcomes

Multiple other outcomes have been associated with increased BMI. Evidence has shown an increased risk of miscarriage among women with obesity. A systematic review of 6 studies incorporating a total of 28,538 women who conceived spontaneously, found the rate of miscarriage was 13.6% in women with obesity compared to 10.7% in women with a BMI in the recommended range[107]. Similarly, a Chinese cohort that used the Asian classification of obesity (BMI ≥28kg/m²), found the risk of miscarriage doubled in women with obesity compared to those with a BMI in the recommended range (RR 2.03 95% CI 1.26-3.27)[108]. This increased risk of miscarriage remained even when adjusting for potential confounders including maternal age, education, parity, miscarriage history and hypertension status[108]. Women with obesity are also at higher risk of recurrent miscarriage[107,109], however this relationship is not seen among women with overweight[109].

A retrospective cohort study of 743,630 women has also shown that compared to women with a BMI in the recommended range, women with overweight or obesity prior to pregnancy had increased risk of thromboembolism, deep vein thrombosis, acute renal failure and intensive care unit admission[110]. A review has also shown that women with obesity are at increased risk of asthma exacerbations during pregnancy compared to women with a BMI in the recommended range[111]. When reviewing all maternal deaths occurring during pregnancy or the first year afterwards in the UK, 34% of women who died had obesity in 2013-2015 and in 2015-2017[112,113]. This reduced slightly to 27% in 2018-2020[114] but remained higher than the proportion of women entering pregnancy with obesity. A meta-analysis of 1,308,888 participants within 16 studies found increased risk of shoulder dystocia in women with obesity compared to those without; with the risk of shoulder dystocia increasing with increasing class of obesity[115].

The evidence for several other outcomes is inconsistent. While one meta-analysis found no association with obesity and postpartum haemorrhage when exclusively looking at atonic postpartum haemorrhage[116], another looking at all forms of postpartum haemorrhage found higher odds among both women with overweight (OR 1.18, 95% CI 1.11-1.26) and with obesity (OR 1.38, 95% CI 1.25-1.54)[42]. Additionally, a review looking exclusively at women with a BMI ≥40kg/m² found their risk of both antenatal and postpartum haemorrhage were higher than for women with class I obesity alone or class I or class II obesity combined[4].

For urinary incontinence, one review that only included studies that adjusted for at least one confounding factor such as age, mode of birth or infant weight found that for every 5kg/m² increase in pre-pregnancy BMI, the risk of urinary incontinence increased[117]. Another review however found no association between BMI prior to pregnancy and urinary incontinence in pregnancy[118].

However, when BMI was measured during pregnancy, rather than pre-pregnancy, low quality evidence suggested maternal overweight or obesity during pregnancy was associated with increased odds of urinary incontinence during pregnancy[118]. When considering pelvic girdle pain in pregnancy, a scoping review of 24 articles found a positive association with overweight or obesity within some studies, however this was not consistent across all included studies[119]. Compared to women with a BMI in the recommended range, women with overweight or obesity were however more likely to have persistent pelvic girdle pain at 12 weeks postpartum, and women with obesity were also more likely to still experience pelvic girdle pain at six months postpartum[120].

As well as being at increased risk of numerous adverse outcomes during pregnancy, women with severe obesity (BMI ≥40kg/m²) are more likely to enter pregnancy with pre-existing conditions such as diabetes mellitus and hypertension compared to women with a BMI in the recommended range[43]. In and of themselves these pre-existing conditions are also linked to poorer pregnancy outcomes.

### 2.2.2 Long-term maternal complications

Several long-term adverse outcomes after pregnancy have been noted among women with obesity.

Among women who had GDM there is a high incidence of them going on to develop type 2 diabetes mellitus, with women with obesity during pregnancy being at particularly high risk[121]. A meta-analysis of 17 studies has shown increased risk of metabolic syndrome after GDM among women with a higher BMI during pregnancy[122].

When considering anorectal dysfunction after birth, a meta-analysis of eight studies that reported the outcome according to maternal BMI found maternal obesity was a risk factor for anal incontinence (OR 1.48, 95% CI 1.28-1.72)[123], with maternal obesity being a risk factor for anal incontinence in both the short term (within the first year after birth) and long-term (>1 year after birth)[123].

### 2.2.3 Neonatal complications

#### 2.2.3.1 Fetal size

Fetal growth is known as an important factor for long-term child health and health in adulthood. Low birthweight or being born small for gestational age (SGA) are associated with increased risk of disease in adulthood including, type 2 diabetes, increased blood pressure and risk of cardiovascular disease(124,125). Being born macrosomic (birthweight ≥4000g) is equally disadvantageous being linked to increased risk of obesity in adulthood, type 2 diabetes, hypertension and cardiovascular disease(125). Some evidence has also suggested an association between being born large for gestational age (LGA) and obesity and cardiovascular risk later in life(126). Many reviews have explored the association between fetal size and maternal pre-pregnancy BMI, with the evidence presented below.

Reviews unanimously concur that fetal macrosomia increases with increasing maternal BMI. When compared to women with a BMI in the recommended range, increased macrosomia has been noted among women with overweight(42,127), as well as women with all classes of obesity(42,127-130), or with class III obesity (BMI ≥40kg/m²)(43). One meta-analysis demonstrated the increased risk of macrosomia among women with obesity was similar in studies that adjusted for 5 or more confounding factors to those that only adjusted for 1-4 confounding factors such as maternal age, education, parity, ethnicity or race, GWG, smoking status or sociodemographic status(130). Women with obesity also have increased odds for birthweight ≥4500g(128). When considering maternal measures of adiposity rather than BMI, macrosomia increases with increased waist and neck circumference and increasing waist-to-hip ratio, but not with increased subcutaneous fat(131). GDM, which is increased in women with overweight or obesity prior to pregnancy, is itself an independent risk factor for fetal macrosomia(132). This makes it difficult to ascertain whether overweight and obesity per se or their link with GDM are responsible for macrosomia(53). However, within a cohort of women exclusively with GDM the odds of macrosomia were still increased among women with overweight or obesity compared to women with a BMI in the recommended range, suggesting an independent impact of maternal BMI not just mediated through the link to GDM(133).

However, it has also been suggested that increased fetal macrosomia may partly be due to difficulties in estimation of fetal size[134]. Manual palpation and ultrasound are less accurate in women with obesity which may delay interventions such as induction which could limit fetal size[134]. Additionally, physical inactivity may be the underlying cause of increased macrosomia rather than maternal obesity per se, as macrosomia is associated with physical inactivity prior to pregnancy[135], especially for physical activity related to household chores such as cleaning[136], regardless of maternal weight.

When considering LGA, evidence from reviews unanimously agrees that women with a raised BMI are more likely to have an LGA infant than women with a BMI in the recommended range. This relationship has been found among women with overweight[42,127], as well as women with obesity[42,127-129]. Among women with obesity the odds of LGA in the different meta-analyses vary from 1.88[129] to 2.42[128]. Several meta-analyses have shown women with a BMI ≥40kg/m² have the greatest risk of an LGA infant compared to women with a BMI in the recommended range [RR 2.51, 95% CI 2.00-3.17[43]; OR 3.06, 95% CI 2.69-3.49[38]]. Even when women with a BMI ≥40kg/m² were compared to women with a lower class of obesity (either class I obesity or class I and class II obesity combined) their risk of LGA remained higher[4]. It has been calculated that 20.6% of LGA at birth are attributable to maternal overweight and obesity prior to pregnancy[38]. For women with obesity, the relationship between maternal BMI and LGA persisted in a cohort of 219,868 women, regardless of the adequacy of their GWG[44]. However, for women with overweight the odds of LGA were only increased among women with recommended or above recommended GWG[44]. Increased odds of LGA have also been noted in systematic reviews that used measures of central adiposity rather than BMI[66,131]. They found that the odds of LGA increased 21% for every 5mm increase in abdominal subcutaneous fat thickness[66] and increased in women with a waist circumference over 80cm[66,131]. Furthermore, for every 0.1 unit increase in waist-to-hip ratio a 120g increase in birthweight was noted, after adjusting for multiple confounding factors[66]. Finally, even in a study that exclusively looked at women diagnosed with GDM, the odds of LGA were highest among women with obesity compared to women with a BMI in the recommended range[133].

The impact of BMI on low birthweight is unclear. One systematic review, including 60 studies with 1,392,799 women, found higher odds of low birthweight infants among women with obesity (OR 1.24, 95% CI 1.09-1.41)[129], but a more recent review found no difference among women with overweight (OR 0.98, 95% CI 0.88-1.08) or obesity (OR 0.84, 95% CI 0.71-1.00) compared to women with a BMI in the recommended range[42]. In contrast maternal BMI has an inverse relationship with infants born SGA. Meta-analyses[42,127,129,137], as well as a large recent cohort of 265,270 births[38] have found a reduced risk of SGA in women with overweight and obesity compared to women with a BMI in the recommended range. Even when compared to women with lower classes of obesity (either class I alone or class I and class II combined), women with a BMI ≥40kg/m² had a lower risk of SGA[4].

Alterations in fetal growth in women with obesity may be due to placental differences. For example, compared to women with a BMI in the recommended range women with obesity have altered placental vascular function[138] and changes in placental cell turnover, with reductions in both placental cell proliferation and apoptosis especially for women with class III obesity[139]. These placental changes may affect the supply of nutrients to the fetus. In addition, women with obesity show impaired vasodilation and vasoconstriction in myometrial arteries compared to women with a BMI in the recommended range, however the impact of this on fetal size was unclear as all women with obesity within the study gave birth to an infant with a birthweight that was appropriate for gestational age and their pregnancies were uncomplicated[56].

#### 2.2.3.2 Mortality

Stillbirth is variably defined within different studies; with some studies not offering a definition[42,43] and others including death of the fetus in utero after 20 weeks gestation[42,43] or death in utero after 24 weeks gestation[43]. Neonatal death is usually classified as death within the first 28 days after birth and infant death as death prior to one year of age. Systematic reviews have shown that compared to women with a BMI in the recommended range, mothers with obesity[42,129] including those with a BMI ≥40kg/m² [43] have increased odds of a stillborn infant. Even when compared to women with a lower class of obesity (either BMI 30-34.9kg/m² or BMI 30-39.9kg/m²), women with a BMI ≥40kg/m² still have an increased risk of stillbirth[4]. One meta-analysis found the risk of stillbirth increased for each 5kg/m² increase in maternal BMI (RR 1.24, 95% CI 1.18-1.30)[140].

While one meta-analysis found no difference in neonatal death according to BMI[42], several other meta-analyses have found increased risk of neonatal death with increased BMI[140,141], especially among women with the highest class of obesity (BMI ≥40kg/m²)[4,43]. A further study estimated that 11% of all neonatal deaths within their cohort of 1,857,822 births could be attributed to maternal overweight or obesity prior to pregnancy[142]. Systematic reviews have also shown increased risks of infant death in women with overweight[141] or obesity[141,143] compared to women with a BMI in the recommended range.

#### 2.2.3.3 Neonatal morbidity

The Apgar score is commonly used to assess the condition of the newborn; through assessment of the neonates Appearance, Pulse, Grimace, Activity and Respiration and provides a score from 1 to 10. Other important measures of neonatal morbidity include cord blood pH levels which are a measure of fetal metabolic condition at birth and requirement for admission to a neonatal intensive care unit.

Maternal overweight and obesity have been associated with increased odds of infant Apgar score less than 7 at 1 minute within a meta-analysis of 11 cohort studies, with women with BMI ≥40kg/m² having the highest odds of an infant with a low Apgar score[144]. Similarly, infants born to a mother with overweight or obesity are more likely to have an Apgar score less than 7 at 5 minutes[42,43,144] compared to women with a BMI in the recommended range, with the odds again being highest for those with class III obesity[43,144]. Even when compared to women with a lower class of obesity, either class I obesity or class I and class II obesity combined, women with a BMI ≥40kg/m² were at increased risk of having an infant with a 5 minute Apgar score of ≤7[4]. While one meta-analysis found no association between maternal BMI and the cord pH of the neonate[144], a separate meta-analysis showed the risk of umbilical cord pH less than 7.1 was higher among women with a BMI ≥40kg/m² than for women with class I obesity (RR 11.96, 95% CI 5.57-25.66) or class I and class II obesity combined (RR

8.87, 95% CI 4.99-15.76), although this outcome was only reported in one included study[4]. High leptin levels in blood from the umbilical cord vein have been associated with lower Apgar scores[145]. Newborn infants of women with obesity have higher concentrations of leptin in the umbilical cord blood[48]. While this may be one explanation of the lower Apgar scores for infants of women with obesity, the longer length of labour with increasing BMI may also impact neonatal condition at birth.

Meta-analyses show the risk of an infant being admitted to neonatal intensive care increases in women with obesity compared to women with a BMI in the recommended range[42,43,129], with infants of women with a BMI ≥40kg/m² at the highest risk[43]. Even when compared to other women with class I obesity or class I and class II obesity combined, women with a BMI ≥40kg/m² continue to have an increased risk of their infant requiring neonatal unit admission[4]. The association was similar when using central adiposity as a predictor of adverse pregnancy outcome rather than BMI, with every 5mm increase in abdominal subcutaneous fat thickness linked to a 14% increase in the odds of special care or neonatal intensive care admission[66]. The increased risk of being admitted to neonatal intensive care for infants of women with obesity is likely to be mediated by the increased risk of GDM, pre-eclampsia, preterm birth and low Apgar score associated with maternal obesity.

Other aspects of neonatal morbidity have also been studied. Compared to women with a BMI in the recommended range infants of women with overweight or obesity are at increased risk of early postnatal infection[43], neonatal sepsis[64], birth trauma, hypoglycaemia, and respiratory distress[43]; with the highest risk for each morbidity noted in those with a BMI ≥40kg/m². Even when compared to women with class I obesity or class I and class II obesity combined, infants born to women with a BMI ≥40kg/m² are at increased risk of birth trauma[4].

#### 2.2.3.4 Congenital malformations

Many studies have explored the impact of maternal obesity on congenital malformations which are discussed below.

Numerous meta-analyses of observational studies have shown increased congenital heart defects in the offspring of women with overweight[146-148] or obesity during pregnancy[146-150] compared to women with a BMI in the recommended range. The odds of congenital heart defects progressively increase with increasing maternal BMI[146,148,149]. The association between congenital heart defects and maternal overweight or obesity has been noted regardless of whether studies adjusted for maternal age, education or smoking[148]. The mechanism for increased congenital heart disease is not fully understood, however, several factors have been suggested. These include that raised maternal BMI is linked to decreased folate and glutathione which may compromise fetal development[147] and that women with a raised BMI are at increased risk of pre-eclampsia, hypertension in pregnancy[53] and GDM[53,147,150] which are all themselves linked to congenital heart defects. However, one review explored this further and noted congenital heart defects remained associated with maternal obesity even after excluding women with diabetes, both pre-existing and gestational[149], suggesting that diabetes is not the sole contributor to the increased risk.

An increased risk of other congenital malformations has also been shown in multiple meta-analyses for women with a raised BMI compared to women with a BMI in the recommended range. These include increased risk of an infant with cerebral palsy[151], congenital abnormalities of the kidneys and urinary tract[152], cleft lip, cleft palate[153,154] and talipes[155]. Women with obesity are also at increased odds of having neural tube defect[156,157]. This may partly be explained by lower intake of folate within the diet, reduced periconception folic acid supplement use[158] and higher folate deficiency[159] among women with obesity, and lower serum folate levels even after controlling for dietary and supplement intake[158]. When considering the risk of any congenital anomaly, a cohort study of over 112,000 women found the risk increased with increasing maternal BMI[64]; however, it was unclear whether increased anomalies were a direct result of raised maternal BMI or due to other co-morbidities.

## 2.2.4 Long-term child complications

### 2.2.4.1 Obesity

The impact of the uterine environment on fetal programming through epigenetics on outcomes into adult life is increasingly being understood[160,161]. However, it remains difficult to separate the impact of the in-utero environment from the postnatal environment to separate the effects of shared environment and genetic factors on child weight[162]. While the literature regarding the associations between maternal BMI prior to or during pregnancy and long-term child outcomes are presented below, it is noted that correlation does not necessarily imply causation, with numerous other confounding environmental factors also potentially playing a part in long-term child outcomes.

Multiple meta-analyses have shown that maternal overweight or obesity prior to or during pregnancy are associated with increased childhood overweight and obesity[127,163-165], despite childhood overweight and obesity being measured at different time points from 1 to 18 years. In all reviews, the odds of childhood overweight or obesity were progressively higher as maternal BMI increased, with one review finding the highest risk in children born to women with a BMI ≥40kg/m² across all child age ranges examined[164]. The percentage of childhood overweight or obesity attributable to maternal pre-pregnant overweight or obesity was 21.7% in early childhood (2-5 years), 29.5% in mid childhood (5-10 years) and 41.7 % in late childhood (10-18 years)[164]. Children born to women with overweight or obesity prior to pregnancy also have increased body fat percentage, fat mass and fat free mass[166]. The role of GDM as a mediating factor has been explored in several reviews. One found increased childhood obesity with raised maternal BMI remained after adjusting for GDM and gestational hypertension[164] and two others found the increased risk of childhood overweight and obesity was largely explained by maternal pre-pregnancy BMI[167,168], with no association between GDM and childhood obesity after adjusting for maternal BMI[168]. Furthermore, a review of eight models that explored the risk factors for childhood overweight or obesity, found that maternal BMI was the most common risk factor within the models, alongside birthweight and gender (all present in 7 out of the 8 models)[169].

Some studies have focussed on parental obesity, not just maternal obesity. These showed adverse child cardio-metabolic profiles were associated with both maternal and paternal BMI[170]. The risk of parental obesity (either the mother or the father) on childhood obesity has been found to be different for different socio-economic groups, with an association among those of low socio-economic status, but not those with high socio-economic status[171]. The lack of a stronger association with maternal BMI than paternal BMI suggests that child adiposity is more related to genetics and familial environment than to intra-uterine environment[170]. DNA methylation is the mechanism by which genes can be turned on or off[172]. A systematic review exploring the impact of parental nutrition on offspring epigenetics, found methylation across the genome was significantly different in children born to mothers with overweight, obesity and also with malnutrition[173]. In particular, offspring born to either mothers or fathers with obesity had changes at methylation sites near to genes involved or suspected to be involved in growth and adiposity compared to offspring born to parents with a BMI in the recommended range[173]. Additionally, differences in DNA methylation in the placenta has been noted in women with obesity with many of these differences in methylation noted in regions close to obesity related genes[174].

Girls born to mothers with pre-pregnancy overweight or obesity have been found to have earlier onset of puberty than those born to mothers with a BMI in the recommended range, with this effect continuing when adjusting for maternal age at menarche[175]. Girls born to a mother with pre-pregnancy overweight or obesity on average reached pubertal milestones 3 months earlier[175]. It was recognised that the increased rates of childhood obesity among the offspring of women with overweight or obesity may be one of the mediating factors for earlier pubertal timing[175].

#### 2.2.4.2 Diabetes

Compared to children of mothers with a BMI in the recommended range, offspring of women with either overweight or obesity during pregnancy have an increased risk of type 2 diabetes, even after adjusting for numerous potential confounders including maternal history of diabetes or hypertension, maternal age at birth, parity and socio-economic status[176]. The exact mechanisms linking maternal obesity and offspring type 2 diabetes are only partially understood. However, infants exposed to maternal hypertension in pregnancy are at increased risk of type 2 diabetes in adulthood[177], which is of importance given that raised maternal BMI is associated with increased risk of gestational hypertension and pre-eclampsia[38]. Additionally, it is suggested that the higher circulating glucose levels, as well as the complex neuroendocrine and inflammatory changes seen during pregnancy in women with obesity may programme adverse fetal outcomes[176]. Maternal obesity is also known to influence DNA methylation which may lead to earlier onset of type 2 diabetes in the offspring[176]. However, environmental factors such as neonatal and infant overnutrition may also contribute to higher rates of diabetes in the infant[176].

Results for the risk of type 1 diabetes in the offspring of women with overweight or obesity during pregnancy are less consistent. While one study did not find an association[176], others with higher numbers of cases of type 1 diabetes, have found increased childhood type 1 diabetes in children of women who were either overweight or obesity prior to pregnancy compared to women with a BMI in the recommended range[178,179]. A separate meta-analysis of 6 studies has also shown an increased risk of type 1 diabetes in infants of high birthweight, compared to those of normal birthweight[179], with high birthweight being seen more frequently in women with obesity[38].

#### 2.2.4.3 Hypertension

For each 5kg/m² increase in maternal pre-pregnancy BMI an increase of 1.9mmHg in offspring systolic blood pressure and 0.5mmHg increase in diastolic blood pressure has been noted[180]. However, a further review that examined the impact of maternal BMI on offspring blood pressure, noted inconsistent results in the two ‘good’ quality included studies that adequately accounted for confounders[181].

#### 2.2.4.4 Neuro development

Children born to mothers with pre-pregnancy obesity have been shown to have lower neuro-cognitive development[182-184], as well as poorer cognitive and gross motor function[185]. The current evidence is however limited for attributing causality, due to the unknown impact of residual confounding effects[185]. More research is required to better understand whether physiological, epigenetic or other factors such as increased risk of GDM, pre-eclampsia, preterm birth or Caesarean birth mediate the relationship between maternal obesity and child neuro-cognitive development[182].

Numerous systematic reviews have found increased rates of attention deficit hyperactivity disorder (ADHD) in children of women with pre-pregnancy overweight or obesity compared to women with a BMI in the recommended range[183,184,186,187], with women with class III obesity having the highest risk of offspring with ADHD (RR 2.87, 95% CI 2.50-3.31)[187]. One review undertook sensitivity analyses which showed the increased risk of ADHD with maternal overweight or obesity continued whether undertaking the meta-analysis with adjusted or unadjusted odds ratios, whether the included studies had used retrospective or prospective study designs and whatever the quality of the included studies – high, medium or low[183]. However, a different review felt that the association could be due to unmeasured familial confounding rather than due to a direct causal link of maternal BMI, as the association was no longer evident once looking only at full siblings or at full cousins[187].

Autism spectrum disorders have also been extensively studied with numerous reviews finding an association between maternal overweight[188] and maternal obesity with increased odds of autism in the offspring[183,184,188,189]. The risk of autism was increased regardless of whether maternal BMI was measured prior to pregnancy or in the first trimester[188]. A further cohort study of 81,892 mother-infant pairs published after the above systematic reviews, also found an increased risk of autism for infants born to mothers with pre-pregnancy obesity compared to women with a BMI in the recommended range[190]. An additional review of 21 studies covering almost 6.5 million participants found infants born to mothers who experienced pre-eclampsia during pregnancy were at higher risk of autism as were infants of women experiencing gestational hypertension (OR 1.37, 95% CI 1.21-1.54)[191]. This is of note given the above association observed between maternal BMI, gestational hypertension and pre-eclampsia[38].

#### 2.2.4.5 Atopic diseases

Increased odds of asthma and/or wheeze in infants of women with overweight or obesity during pregnancy was observed in a systematic review of observational studies[(192)]. The odds increased with increasing maternal BMI, with each 1kg/m² increase in BMI increasing childhood asthma or wheeze (OR 1.03, 95% CI 1.02-1.03)[(192)]. In contrast atopic dermatitis is higher among children of mothers with pre-pregnancy underweight (OR 1.06, 95% CI 1.02-1.10) and lower with pre-pregnancy overweight (OR 0.91, 95% CI 0.88-0.94) and obesity (OR 0.87, 95% CI 0.85-0.90)[(193)].

#### 2.2.4.6 Cancer

A review that looked at childhood cancer found no difference in overall risk of cancer between women with overweight or obesity compared to women with a BMI in the recommended range[(194)]. When looking at specific types of cancer the review suggested increased childhood leukaemia with maternal overweight or obesity[(194)]. Another review similarly found that every 5kg/m² increase in maternal BMI, as well as maternal diabetes, were associated with increased leukaemia in the offspring, but decreased risk of central nervous system tumours[(195)].

### 2.2.5 Costs of maternal obesity to the national health service

In addition to the above health risks, these complications can lead to higher rates of hospital admission, a requirement for more interventions and a longer length of hospital stay, with significant cost implications and demands on health service resource utilisation[(196,197)]. Some studies have looked in detail at the increased cost of maternity care for women with overweight or obesity in comparison to women with a BMI in the recommended range. A Welsh cohort found each woman with overweight cost £698 more and each woman with obesity £1172 more[(196)]. A Scottish cohort, which adjusted for sociodemographic factors, calculated slightly lower increased maternity related costs associated with raised BMI, being £150 for women with overweight, £399 for women with class I and class II obesity and £755 for women with a BMI ≥40kg/m² [(198)]. From the Welsh cohort the total additional costs of maternal obesity to the National Health Service (NHS) across the UK per year were calculated to be between £105-£286 million[199]. Studies have also looked at healthcare usage among children born to women with obesity during pregnancy compared to children of women with a BMI in the recommended range. Children born to mothers with obesity during pregnancy have a greater number and duration of inpatient visits and increased general practitioner visits in the first year[200], as well as increased physician visits (10%), hospital admissions (16%) and number of days spent in hospital (10%) up to 18 years old[201]. The additional healthcare related costs for infants born to women with obesity were estimated to be £1138 within the first year of life[200] and approximately £218 higher physician visits costs and £856 hospital costs across the first 18 years of life[201].

## 2.3 Gestational weight gain during pregnancy

### 2.3.1 Guidance

In the United States of America (USA), the Institute of Medicine (IOM) have developed weight gain guidance for singleton pregnancies in accordance with pre-pregnant BMI[202]. These are shown in Table 2.2. To develop these IOM GWG guidelines, the researchers focussed on both maternal and infant health, as well as short- and long-term outcomes.

Some have however suggested lower weight gains than currently recommended by IOM guidelines or even a small weight loss may be safe for women with obesity and so have called for tighter recommendations[20,203-205]. One study assessing the risk of individual adverse outcomes according to GWG among women with different pre-pregnancy BMIs, showed that women with a BMI from 30-34.9kg/m² had lower odds of gestational hypertension with a gestational weight loss or a weight gain below 5kg compared to women with a weight gain within IOM recommendations[203]. Women with a BMI from 35-39.9kg/m² had lower odds of Caesarean birth with a gestational weight loss or a weight gain below 5kg compared to women with a weight gain within IOM recommendations[203]. All women with obesity had lower odds of macrosomia with a weight loss of 5kg or more, and women with a BMI ≥40kg/m² also had lower odds of macrosomia with a gestational weight loss of up to 5kg[203]. The same review also looked at the safety of weight loss on the risk of SGA and found that weight loss was not associated with low birthweight or SGA for women with obesity prior to pregnancy[203]. Others have looked for the optimal GWG range to minimise the risk of multiple adverse outcomes. For example, Oken et al. (2009)[204] found a weight loss of 7.6kg during pregnancy for women with obesity was associated with the lowest predicted prevalence of 5 adverse outcomes; preterm birth, LGA, SGA, weight retention and childhood obesity.

**Table 2.2. Body mass index and gestational weight gain classifications**

<table>
<tr><th></th><th>International BMI classification (in $kg/m^2$)[13]</th><th>IOM recommended GWG (in kg)[202]</th><th>Voerman et al., (2019)[20] recommendations (in kg)</th></tr>
<tr><td>Underweight</td><td><18.5</td><td>12.5-18</td><td>14-15.9</td></tr>
<tr><td>Recommended BMI</td><td>18.5–24.9</td><td>11.5-16</td><td>10-17.9</td></tr>
<tr><td>Overweight</td><td>25.0–29.9</td><td>7-11.5</td><td>2.0-15.9</td></tr>
<tr><td>Obesity grade 1</td><td>30.0-34.9</td><td rowspan="3">5-9</td><td>2-5.9</td></tr>
<tr><td>Obesity grade 2</td><td>35.0-39.9</td><td>Weight loss of 1kg or a gain of 0-3.9</td></tr>
<tr><td>Obesity grade 3</td><td>≥40</td><td>0-5.9</td></tr>
</table>

IOM = Institute of Medicine

Within a further cohort of 337,590 women the GWG associated with the lowest incidence of both LGA and SGA was 8kg for women with overweight, 0kg for women with class I obesity, -4kg for women with class II obesity and -5kg for women with class III obesity[205]. A final study by Voerman et al., (2019) used individual participant analysis from 25 European and North American cohort studies[20]. The presence of one or more adverse outcomes out of pre-eclampsia, gestational hypertension, GDM, Caesarean birth, preterm birth and SGA or LGA was used to estimate the optimal GWG for different BMI categories and are presented in Table 2.2[20]. However, they felt the magnitude of weight gain was only weakly associated with the adverse outcomes so had poor predictive value[20].

The call for tighter recommendations for women with obesity is not however unchallenged within the literature. A systematic review of 6 cohort studies of weight loss in pregnancy in women with obesity found that compared to women with GWG within IOM recommendations, weight loss during pregnancy was associated with decreased odds of LGA and Caesarean birth, but increased odds of SGA, although this relationship with SGA became less pronounced as class of maternal obesity increased(206). Across all classes of obesity, multivariate analysis showed no significant difference between those who experienced weight loss during pregnancy and those who gained within IOM recommendations for other outcomes such as shoulder dystocia, pre-eclampsia, GDM, induction of labour and neonatal intensive care admission(206). The same authors also looked at GWG below recommendations among women with obesity(207). When pooling the odds ratios across the 18 included studies, compared to women with obesity who gained weight within IOM recommendations, weight gain below IOM recommendations (<5kg) was associated with increased odds of preterm birth (aOR 1.46, 95% CI 1.07-2.00) and SGA (aOR 1.24, 95% CI 1.13-1.36), but decreased odds of LGA (aOR 0.77, 95% CI 0.73-0.81) as well as macrosomia (aOR 0.64, 95% CI 0.54-0.77), gestational hypertension (aOR 0.70, 95% CI 0.53-0.93), pre-eclampsia (aOR, 0.90, 95% CI 0.82-0.99) and Caesarean birth (aOR 0.87, 95% CI 0.82-0.92)(207). The decreased odds of LGA and increased odds of SGA were similar across all classes of obesity. No effect was noted on the odds of neonatal intensive care admission, shoulder dystocia, induction of labour, GDM or infant Apgar scores(207). They therefore suggested that weight gain below recommendations or weight loss in women with obesity should not routinely be recommended during pregnancy as SGA is a key predictor of neonatal morbidity(206,207). However, these reviews(206,207) looked at risk factors individually, rather than calculating the weight gain that would minimising the risk of multiple adverse outcomes as undertaken within many of the studies that have called for tighter restrictions.

The evidence presented highlights that the ideal weight management during pregnancy for women with obesity is still to be fully determined. The need to consider stratifying GWG recommendations according to class of obesity has also been raised(203). Given continued uncertainty over the ideal gestational weight gain for women with a BMI ≥40kg/m², within this programme of research the internationally recognised IOM guidance has been followed.

#### 2.3.1.1 Adherence to GWG recommendations

A global meta-analysis of 63 studies found that 27.8% of women across the globe gained above IOM recommendations and 39.4% gained below recommendations[(208)]. The highest rates of GWG above recommendations were noted in North America at 50.6% and the lowest in Asia at 20.2%[(208)]. Overall GWG decreases with increasing BMI, however due to the tighter GWG recommendations for women with obesity there is a higher proportion of women with obesity who gain weight above IOM recommendations compared to women with a BMI in the recommended range[(2)]. A recent individual participant analysis found that 19.1% of women with a BMI in the recommended range had a weight gain above IOM recommendations compared to 44.5% of women with obesity[(209)]. Other previous studies have also noted high proportions of women with obesity to gain weight above IOM recommendations during pregnancy including 60%[(210)] to 68%[(211)] in Canadian cohorts and 55%[(212)] to 84.6% in USA cohorts[(213)]. Most studies do not differentiate excessive GWG according to the different classes of obesity, however one cohort of women in the USA only included women with a BMI ≥40kg/m² and found 45.8% exceeded IOM recommendations[(5)]. While the applicability of the USA study to the UK context is not fully known, an individual participant data analysis of women of all BMI categories from 33 cohorts across Europe, North America and Oceania found similar patterns of GWG across the different countries /continents[(214)]. Given the rise in excessive GWG with raising BMI, it is unsurprising research has found the factor most strongly related to excessive GWG is pre-pregnancy maternal BMI[(215)].

### 2.3.2 Other maternal characteristics associated with GWG

The interaction between GWG and maternal characteristics other than obesity have been considered in numerous studies. These factors are discussed below.

One review felt the role of parity on GWG was unclear, with both positive and negative relationships noted within the 32 included studies providing data[(216)].

Fourteen studies found primiparous women had higher GWG, 9 studies reported multiparous women gained more weight and 10 studies found no association between parity and weight gain(216). In particular, a meta-analysis of the 16 studies that accounted for pre-pregnancy BMI found no significant difference according to parity(216).

A systematic review including 680,613 women, showed women with low education attainment were more likely to have a GWG outside of IOM recommendations(217). Within that review income status of the household or family, social class and socioeconomic status were not associated with adherence to IOM guidelines(217). However, a recent review has shown increased risk of both excessive GWG (OR 1.27, 95% CI 1.05-1.54) and inadequate GWG (OR 1.49, 5% CI 1.26-1.76) with food insecurity(218). When considering income level of the country in which the original study was undertaken, food insecurity remained associated with inadequate GWG in both high income and low or middle income countries, but the association with excessive GWG was only significant in low or middle income countries(218).

Other previous studies and reviews assessing predictors of GWG have also demonstrated a correlation between GWG and maternal age(219-222), maternal height(219,220) and maternal smoking status(219), although they did not always remain significant once adjusting for other factors. However, in all previous studies women with a BMI ≥40kg/m² were a small minority of the total sample.

One review, incorporating 12 studies, looked at psychosocial risk factors and found that depression, body image dissatisfaction and perceived lack of social support were associated with excessive GWG among women at low risk of mental health issues and with a normal pregnancy(223). A separate review of 35 studies however did not find that depression was related to excess GWG, except in one included study in adolescents(224). Several reviews have found no relationship between excessive GWG and anxiety(223,224), stress(223,224), self-efficacy or self-esteem(223). Other factors associated with excess GWG include concerns about weight gain, negative body image, negative attitude towards weight gain, inaccurate perceptions of their body weight, having a higher than recommended target weight gain, less knowledge about weight gain and perceived barriers to healthy eating(224). In contrast protective factors against excessive GWG included lower than recommended target weight gain, internal locus of control for weight gain and high self-efficacy for healthy eating(224).

## 2.3.3 Maternal outcomes

As well as the complications associated with obesity during pregnancy, due to their higher rates of excessive GWG women with obesity are also at risk of the multiple adverse effects associated with excessive GWG. The adverse outcomes associated with weight gain above IOM recommendations for the mother and the infant are therefore considered below. Consideration has also been given to the adverse outcomes from weight gain below IOM recommendations, to highlight the requirement for appropriate GWG.

### 2.3.3.1 Gestational hypertension and pre-eclampsia

Compared to GWG within IOM recommendations a systematic review has shown higher odds of hypertensive disorders in pregnancy, pre-eclampsia and gestational hypertension with excessive GWG(225). When looking exclusively at women with maternal overweight or obesity, excessive GWG remained associated with increased odds of any hypertensive disorder in pregnancy(225). Within the included studies weight gain associated with oedema and other factors was not separated. As oedema is more likely in pregnancies that are complicated by pre-eclampsia, it is not clear whether excessive weight gain is a cause or a consequence of pre-eclampsia(225). However, oedema is less likely in women with gestational hypertension as this is not characterised by the presence of proteinuria, therefore the link between weight gain and hypertension is more likely to be related to increased adiposity(225). In contrast, women with inadequate GWG had lower odds of pre-eclampsia, with this association noted across all classes of obesity(226).

### 2.3.3.2 Gestational diabetes

To determine the impact of GWG on GDM, weight gain after the first trimester requires adequate adjustment(227), as GDM is diagnosed prior to GWG in latter pregnancy. When looking at excessive GWG prior to GDM screening, one meta-analysis of eight studies found that risk of GDM increased in women of all BMI categories with excessive GWG compared to those without(228). This association remained significant within the four studies that adjusted for confounding factors such as previous GDM, maternal age, smoking, ethnicity, BMI and parity(228). A separate study that explored the classes of obesity separately, found that every standard deviation increase in weight gain in the first trimester was associated with increased odds of GDM for women with class I obesity and class II obesity, but no such association was shown for women with class III obesity(227). The authors hypothesised this may be due to the higher levels of insulin resistance already present in women with class III obesity at the start of pregnancy(227). When looking independently at second trimester weight gain, no association was found with GDM for women of any BMI(227).

#### 2.3.3.3 Preterm birth

A few reviews have found no differences in the odds of preterm birth with GWG below IOM recommendations compared to within recommendations, including in one review exclusively looking at women with obesity(229) and a further review that considered all three classes of obesity separately(226). However, the evidence generally supports that GWG below IOM recommendations is associated with increased risk of preterm birth; including in an individual participant meta-analysis of 265,270 births across multiple continents(38), a further individual participant data meta-analysis(209), a systematic review of over one million women(6) and a case-control study across 20 centres in Brazil(61). Within the individual participant meta-analyses confounding factors adjusted for included smoking(38,209), maternal age, education level, parity and infant gender(38) and within the systematic review all studies included for the preterm birth outcome were judged by review authors to have at least partially adjusted for confounders(6). When considering the effect across different BMI categories inconsistencies were however seen, with some noting a significant impact of low GWG on preterm birth across all BMI categories, but with the greatest effect among women with underweight(6); while others only found a significant association in women with obesity(209). However, it should be noted that when birth is preterm there has been less time in which to gain pregnancy weight, which may complicate the interpretation of the association between GWG below recommendations and preterm birth[61].

For weight gain above IOM recommendations compared to within IOM recommendations, the evidence is conflicting. One systematic review found decreased risk of preterm birth with excessive GWG[6], with the decrease being significant for women with a BMI in the recommended range, overweight or obesity. Two further studies, an individual participant data meta-analysis and a review, found no difference in the odds of preterm birth with GWG above IOM recommendations[209,229]. In contrast an individual participant meta-analysis[38] and a case-control study across 20 centres in Brazil[61] found increased risk of preterm birth with excessive GWG. Provider initiated preterm birth and prelabour preterm rupture of the membranes particularly increased with excessive GWG irrespective of initial BMI, while spontaneous preterm birth only increased with excessive GWG in women with overweight or obesity[61]. A systematic review that exclusively looked at women with obesity, also found medically indicated preterm birth was increased in women with obesity with GWG over IOM recommendations, however heterogeneity between studies was high[229].

#### 2.3.3.4 Mode of birth

Weight gain below IOM recommendations compared to GWG within recommendations was found in one systematic review, which incorporated over one million women, to make no difference in the odds of Caesarean birth (OR 0.98, 95% CI 0.96-1.02)[6]. However, three other reviews which conducted analyses separately according to class of obesity showed that the risk of Caesarean birth decreased with GWG below IOM recommendations in women from all classes of obesity[226,230,231].

Weight gain above IOM recommendations compared to GWG within IOM recommendations has been associated with increased odds of caesarean birth within systematic reviews[6,231] and an individual participant data meta-analysis[209]. When splitting women with excessive GWG into quartiles, the odds of Caesarean birth were particularly increased in women with the highest weight gains above IOM recommendations[209]. While the reviews found excessive

GWG increased the odds of Caesarean birth consistently across all BMI categories[6] and all classes of obesity[231], the individual participant data meta-analysis only showed a significant effect among women with overweight or obesity, not for women with a BMI in the recommended range[209]. A further review that conducted analysis according to class of obesity, showed that women with class I obesity had the greatest risk of Caesarean birth with increased GWG[230]. GWG above recommendations has also been associated with increased risk of instrumental birth across all classes of obesity[231]. It has been suggested that similarly to maternal obesity, excessive GWG changes placental function and causes insulin resistance resulting in hormone changes and increased risk of Caesarean birth[6]. Additionally, it is possible that excess abdominal and pelvic adipose tissue may distort the birth canal and prevent effective descent of the fetal head and prolong the first and second stage of labour necessitating a medically assisted birth[231]. Excessive GWG may also increase adipose deposits within the myometrium leading to impaired uterine function, prolonged labour and more requirement for assisted birth[232]. Finally, excessive GWG is also associated with increased birthweight, which itself is associated with increased risk of adverse birth outcomes[232].

#### 2.3.3.5 Induction

Within a Swedish cohort of 174,953 women with a singleton live birth, excessive GWG was associated with increased risk of induction of labour in women with a BMI in the recommended range, overweight or obesity[232]. This study adjusted for maternal age, height, parity, early pregnancy BMI, smoking, marital status, chronic hypertension and pre-pregnancy diabetes[232].

#### 2.3.3.6 Breastfeeding

Excessive GWG has been associated in a meta-analysis with decreased initiation of breastfeeding[80]. The risk of cessation of any breastfeeding was also increased with excessive GWG in women with pre-pregnancy overweight or obesity compared to women with a BMI in the recommended range and GWG within recommendations[80]. Inadequate GWG similarly reduced breastfeeding initiation and increased exclusive breastfeeding cessation[80].

However, most of the included studies did not adjust for confounding factors making it difficult to rule out interacting influences on GWG and breastfeeding such as socio-economic status and education. There are several possible explanations for the association between GWG and breastfeeding including that the excessive adipose tissue laid down with excessive GWG acts as a reservoir of progesterone which inhibits lactogenesis(80). Additionally, excessive GWG is associated with increased rates of Caesarean birth which itself is linked to poorer breastfeeding outcomes(80). Women with body image concerns have also been shown to be less likely to breastfeed for 6 months(233,234) and more likely to report stopping breastfeeding due to embarrassment or concerns about feeding the infant in public(233). Given that women with higher weight retention at 6 months postpartum have higher body image concerns during pregnancy, as well as shorter breastfeeding durations(233) and that women with excessive GWG are more likely to have higher weight retention in the postpartum period(215), it is likely that body image concerns at least partially explains the link between excessive GWG and shorter breastfeeding duration(233).

#### 2.3.3.7 Maternal mental health

A systematic review looking at maternal anxiety concluded that too few studies explored anxiety in early pregnancy in relation to subsequent excessive GWG or postpartum weight retention to draw conclusions about any associations(101). A more recent cohort study has shown no associated between generalised anxiety in the first trimester and subsequent GWG, although anxiety in the second trimester has been associated with lower GWG which suggests a complex association between mental health and GWG(235).

A systematic review of 16 studies found increased odds of postnatal depression among women with both inadequate GWG (OR 1.14, 95% CI 1.08-1.20) and excessive GWG (OR 1.31, 95% CI 1.06-1.61) compared to women with a GWG in the recommended range(236).

#### 2.3.3.8 Placental abruption

A systematic review examining the association between GWG and placental abruption only found two relevant studies(70). Both studies found GWG below

IOM recommendations was associated with increased likelihood of placental abruption. The risks associated with GWG above IOM recommendations were different between the two studies; with one cohort in the USA finding the odds of placental abruption decreased with excessive GWG and the other study from Taiwan finding no significant association(70). Multiple confounders were adjusted within the original studies including maternal age, smoking status, parity, BMI and pregnancy related complications(237,238). It has been hypothesised that abruption may be related to nutritional insufficiency which contributes to poor development of the placenta and hence increased likelihood of abruption(70).

### 2.3.4 Long-term maternal outcomes

The main long-term maternal outcome from excessive GWG noted within the literature was weight retention. Excessive GWG has been linked to increased risk of maternal overweight or obesity postpartum(215,239). One meta-analysis showed excessive GWG had a long-term impact, with women with excessive GWGs retaining 4.72kg more than women with a recommended GWG more than 15 years later(240). As the postpartum period from one pregnancy becomes the preconception period for any subsequent pregnancies, this postpartum weight retention causes the woman to start any subsequent pregnancies with a higher BMI than the previous one(241). The repetitive cycle throughout the childbearing course is thought to lead to increased BMI in women of childbearing age(241). GWG if not lost prior to any subsequent pregnancy, will therefore influence future pregnancy outcomes(242), due to the far-ranging impact of overweight and obesity during pregnancy as discussed above. A cohort study exploring weight retention between pregnancies demonstrated that women who gained 4 or more BMI units between pregnancies compared to women who remained within one unit of their original BMI, had an increased risk of stillbirth and infant mortality in the subsequent pregnancy(243). Systematic reviews have also shown an association between an increase in BMI between pregnancies and decreased odds of SGA(244) and increased odds of LGA(244,245), GDM(244,245), Caesarean birth(244), pre-eclampsia and pregnancy induced hypertension(245) and a trend towards increased macrosomia(244). The increased odds of LGA, GDM and pregnancy induced hypertension were particularly pronounced in women with a BMI in the recommended range during their first pregnancy, but the effect was noted across all women[244,245]. The same reviews found that a reduction in BMI by 1kg/m² between pregnancies increased the odds of SGA[244,245] and preterm birth[245] and decreased LGA[244] but had no impact on the odds of Caesarean birth[244]. The impact of a reduction of BMI between pregnancies was again more pronounced in women with a BMI in the recommended range at the start of their first pregnancy.

## 2.3.5 Neonatal outcomes

### 2.3.5.1 Fetal size

Both inadequate and excessive GWG impact upon fetal size.

Multiple meta-analyses have shown that inadequate compared to recommended GWG increases the odds of SGA[6,38,226,246,247] and decreases the odds of LGA and macrosomia[6,226]. This effect was consistent across all BMI categories[6], as well as across all classes of obesity[6,246,247] except in one review that found that after adjusting for covariates inadequate GWG was not associated with SGA for any class of obesity[226]. One review found increased odds of SGA and decreased odds of LGA with weight gain below IOM recommendations was consistent across the continents of USA, Europe and Asia, including when regional BMI categories were applied to GWG recommendations[248]. However, a more recent systematic review of GWG exclusively in women with obesity only found increased risk of SGA with inadequate GWG in USA and Europe, but not in Asia although only two studies were included within the latter subgroup[247].

Within numerous meta-analyses, GWG above recommendations has the opposite effect to inadequate GWG. Compared to recommended GWG, excessive GWG lowers the odds of SGA[6,38,209,230] and increases the odds of LGA[6,38,209] and macrosomia[6]. Reduced odds of SGA was consistent across all BMI categories in one systematic review that included 23 studies incorporating over one million women[6], but was only significant in women with overweight within a separate individual participant data analysis[209]. When considering the different classes of obesity, one review noted SGA to decrease with increasing GWG across all obesity classes, although the reduction was most notable in women with class I obesity[230] and a different review only noted a significant effect of excessive GWG on SGA in women with class I or class II obesity(6). The effect of excessive GWG on LGA is however consistent across all BMI categories(6,209), as well as all classes of obesity(6,230). For women with class I obesity the risk of LGA was only >10% with GWG above IOM recommendations, for women with class II obesity the risk of LGA was consistently >10% even in women who gained weight within the IOM recommendations and for women with class III obesity LGA was >10% unless there was no weight gain or a weight loss(230). Within the review that explored fetal weight outcomes according to continent, decreased odds of SGA and increased odds of LGA with GWG above IOM recommendations remained consistent across continents, even when regional BMI categories were applied to GWG recommendations(248). A further review split GWG above IOM recommendations into quartiles and found that LGA was particularly increased in women with the highest GWG(209). A cohort study that exclusively recruited 1,263 women with GDM, still found that excessive GWG was associated with increased odds of LGA and macrosomia compared to GWG in the recommended range(133). It has been estimated within one individual participant meta-analysis that 31.6% of all LGA infants are attributable to maternal excessive GWG(38).

It is suggested that excessive GWG leads to increased maternal concentrations of glucose, amino acids and fatty acids leading to increased transfer of nutrients to the fetus(38). This increases synthesis of insulin and insulin-like growth factors within the fetus both of which promote fetal growth and therefore increase fetal size at birth, resulting in LGA and macrosomia(38). In contrast, lack of maternal nutrition associated with inadequate GWG results in lower concentrations of glucose to the fetus which prevent normal growth and development(247).

#### 2.3.5.2 Mortality

Numerous population-based cohort studies have recently been undertaken to explore the association between GWG and perinatal and infant mortality.

A retrospective cohort study of 2,230,310 births found inadequate GWG or weight loss was associated with increased risk of stillbirth for all BMI classes except for women with class III obesity(249). A further cohort of 722,839 women with a singleton pregnancy also found inadequate GWG was associated with increased odds of perinatal mortality (stillbirth and neonatal mortality) and severe neonatal morbidity across women of all pre-pregnancy BMI categories, after adjusting for numerous confounders including: congenital abnormalities, maternal age, maternal education, marital status, ethnicity, parity, smoking, fetal gender[(250)]. Inadequate GWG compared to GWG in the recommended range has also been associated with higher risk of neonatal mortality (death within the first 28 days) and infant mortality (death within the first year) within a final cohort of 8,656,791 live births, although once adjusting for multiple confounders the effect was only seen in women with a BMI in the recommended range[(251)]. While the exact mechanism for the influence of inadequate GWG on stillbirth is unclear, it is likely that inadequate GWG, especially in women of lower BMI, is linked to undernutrition and may also be associated with other medical complications such as hyperemesis gravidarum, malabsorption, and undiagnosed or untreated hyperthyroidism all of which could increase the risk of stillbirth[(249)]. Undernutrition is also more likely among women from areas of high socioeconomic deprivation which itself is linked to increased rates of stillbirth[(249)].

Evidence of the impact of excessive GWG compared to recommended GWG is less clear. In one cohort study excessive GWG was associated with increased risk of stillbirth after 28 weeks gestation in women with obesity or severe obesity[(249)]. However, in other cohort studies a reduction in the odds of perinatal mortality[(250)] and neonatal mortality[(251)] were noted for women with obesity prior to pregnancy, although excessive GWG was linked to increased odds of perinatal mortality for women with a pre-pregnancy BMI in the recommended range[(250)]. Any association between excessive GWG and stillbirth is likely due to different physiological processes than the link with inadequate GWG[(249)]. Excessive GWG is associated with increased levels of inflammatory markers in the blood, with this inflammation most likely to be the link between excessive GWG and stillbirth[(249)].

## 2.3.6 Long-term child outcomes

### 2.3.6.1 Obesity

Multiple meta-analyses have explored the impact of GWG on childhood weight. While overlapping in date, these meta-analyses all included at least one study that was not included in other meta-analyses.

The effect of excessive GWG compared to GWG in the recommended range was inconsistent in one review, with 6 of the 8 included studies reporting a statistically significant increase in child body weight outcomes(252). All other reviews however showed a link between excessive GWG and higher risk of childhood obesity at all stages of childhood, from less than 5 years to over 18 years old(164,253). When classifying child weight into BMI categories, all studies agreed that the risk of childhood overweight or obesity increased with increasing GWG(164,252), regardless of whether total GWG was analysed as a continuous or categorical variable(252). A high rate of weight gain in early and mid-pregnancy were also particularly associated with later childhood overweight or raised BMI z-score(252). However, as noted above when considering the impact of maternal obesity on child weight outcomes, there are difficulties in controlling for confounders such as familiar characteristics that could increase the likelihood of both the mother and the infant having higher weights(252). Excessive GWG has also been associated with earlier onset of puberty in female offspring, however this may be mediated through the increased likelihood of childhood obesity(175). It has been suggested that excess GWG could influence the fetus through an increased transfusion of fatty acids across the placenta from the mother to the fetus(252). Additionally, excessive maternal fat deposits during early pregnancy may reduce maternal insulin sensitivity and therefore increase availability of glucose to the fetus(252). It is hypothesised that these pathways may alter fat cell development within the fetus, leading to permanent changes to the infant's capacity to form adipose cells(252), as well as influencing the infant's energy metabolism and appetite regulation(164). It is also suggested that the mother's predisposition to weight gain may be inherited by her offspring, resulting in higher offspring BMI later in life(253). There may also be an environmental link as women with excessive GWG may have lifestyles that are lower in physical activity and diets higher in energy which if shared with their offspring could account for their higher levels of childhood obesity(253).

Discrepancies were noted within the reviews over the impact of inadequate GWG. Compared to adequate GWG, inadequate GWG was linked to higher risk of childhood obesity for children over 5 years of age and adults within one review(253). Another review noted that one of their included studies found childhood risk of overweight was U shaped, with risk raised both for mothers gaining excessive GWG, but also for mothers gaining less than 4.5kg(252). In contrast the final review found higher odds of childhood underweight and lower odds of childhood overweight or obesity in early (2-5 years) and mid (5-10 years) childhood but not in late childhood (10-18 years) with inadequate GWG(164).

Overall, 11.4% of overweight and obesity in early childhood (2-5 years), 15.4% in mid childhood (5-10 years) and 19.2% in late childhood (10-18 years) was estimated to be attributable to GWG(164).

#### 2.3.6.2 Neurodevelopment

One systematic review found excessive GWG increased the risk of a child with autism spectrum disorder (ASD) in all 7 included studies reporting this outcome(254), with the association being independent of maternal BMI. In contrast, inadequate GWG was not associated with increased risk of ASD in 4 out of 5 studies reporting this outcome(254). All included studies adjusted for multiple confounders, although factors varied within the individual studies they included parental age, maternal education, socio-economic status, familial risk for ASD, gestational age and infant gender.

A meta-analysis of thirteen studies also suggested that GWG above recommendations is associated with an increased intelligence quota in the offspring, although it did not quite reach significance(255). All but two of the included studies within the review had adjusted for multiple confounders.

#### 2.3.6.3 Atopic diseases

Compared to GWG within the recommended range, the odds of childhood asthma or wheeze increase with either excessive GWG or inadequate GWG(192). Atopic dermatitis also increases with GWG above recommendations

(OR 1.05, 95% CI 1.01-1.10); however, it decreases with inadequate GWG (OR 0.87, 95% CI 0.83-0.91)[193].

#### 2.3.6.4 Cancer

One review found no association between GWG and childhood leukaemia[195]. However, a separate systematic review suggested increased risk of cancer in infants born to mothers with high GWG, but not for low GWG[194].

### 2.3.7 Interaction between maternal BMI and gestational weight gain

Given that many of the adverse outcomes associated with maternal BMI overlap with the adverse outcomes associated with GWG, several studies have explored the interaction between maternal BMI and GWG.

One individual participant meta-analysis that included 39 cohort studies undertaken in Europe, Australia and North America with a total of 265,270 births, showed that compared to women with a BMI in the recommended range and a recommended GWG, women with overweight or obesity prior to pregnancy had a higher risk of pregnancy complications independent of their GWG[38]. Women with obesity and excessive GWG were at the highest risk of pregnancy complications, including for gestational hypertension, pre-eclampsia, GDM, preterm birth and having an LGA infant[38]. A further meta-analysis of 37 cohorts from Europe, North America and Australia also found higher maternal pre-pregnancy BMI alongside increased GWG was associated with higher risk of childhood overweight and obesity, with the strongest effect in late childhood[164]. GWG caused an additional increase in childhood obesity over and above the impact of maternal overweight or obesity pre-pregnancy[164]. However, a limitation of the meta-analysis was the use of self-reported BMI and GWG in many of the included cohort studies[164].

## 2.4 Weight management during pregnancy

The multiple adverse effects of excessive GWG during pregnancy and the life course impact of excessive GWG on weight retention highlights the need for interventions and strategies in women of reproductive age to effectively manage GWG. In view of the additional impact of excessive GWG for those starting pregnancy with obesity, this research programme focussed on gestational weight management in women with obesity. The most frequently used interventions are discussed below.

## 2.4.1 Interventions

### 2.4.1.1 Lifestyle interventions

Management of GWG to date has largely revolved around lifestyle interventions. These interventions typically include healthy eating or physical activity or a combination of the two. Occasionally these interventions will also incorporate a psychological component.

The most recent Cochrane review of randomised controlled trial (RCT) evidence of interventions that included healthy diet or exercise or a combination of healthy eating and exercise showed a modest effect on reducing excessive GWG(9). However, there was some evidence that these types of interventions may be less effective among high-risk women for example those with obesity, with GDM or at high risk of GDM(9). More recent international studies(256-258) and systematic reviews(7,8,259-261) have given inconsistent results when evaluating interventions designed to control GWG. Within the international studies, an RCT of 399 women with overweight or obesity in the USA found women in the intervention group who received 11 telephone consultations were less likely to gain weight in excess of IOM recommendations than women in the control group and had lower overall GWG(257). In contrast, a cluster randomised study of 2,286 women with overweight or obesity from Germany did not show a reduction in GWG above IOM guidance in women receiving a face-to-face intervention compared to a control group who received usual care(256). A further RCT undertaken in Sweden with 305 participants also found no overall impact on GWG in women who received a HealthyMoms application compared to those with usual care(258). There was however some evidence that the intervention may have been effective among women with overweight and obesity, although the numbers of women with obesity included within this study were very low (n=14 in the intervention group and n=6 in the control group)(258).

As well as the low numbers of women with obesity within the Swedish study, neither of the other studies included women with a BMI ≥40kg/m² [256,257].

Within the reviews, one which included 66 studies found nutrition only interventions decreased GWG, but that with exercise only and combined exercise and nutrition interventions there was only a trend towards GWG within IOM recommendations[260]. Similar results were seen within the sub-analysis of only women with overweight or obesity[260]. In contrast, a separate review of 84 studies found exercise only interventions reduced total GWG[259]. Furthermore, both exercise only interventions and exercise interventions combined with other types of interventions such as diet reduced excessive GWG[259]. However, the subgroup analysis for exercise only interventions was no longer significant when exclusively looking at women with overweight or obesity[259].

There is also inconsistency across the literature around the effect of antenatal lifestyle interventions on infant birthweight. One review found that the majority of interventional studies currently suggest limited impact on birthweight outcomes[239]. When looking at exercise only interventions several reviews showed exercise only compared to control reduced the odds of macrosomia[8,262], but had no impact on overall birthweight[262] or LGA[8] including when only looking at women with overweight and obesity[8]. However, another review of 99 studies found exercise only interventions reduced preterm birth, SGA, LGA and childhood obesity in the offspring[263]. SGA, LGA and childhood obesity did not however reach significance when looking exclusively at women with overweight or obesity[263]. Furthermore, interventions that combined exercise with another intervention such as diet had no impact on macrosomia[8,262], overall birthweight[262] or LGA[8]. Other reviews of nutritional or lifestyle interventions during pregnancy have also noted that while dietary interventions reduced overall birthweight compared to control[262], they were ineffective at reducing the incidence of fetal macrosomia[40,262].

The evidence around the impact of lifestyle interventions during pregnancy on other outcomes is also mixed. When considering exercise interventions combined with other interventions during pregnancy compared to control a review suggested reduced odds of instrumental birth and Caesarean birth, but no impact of exercise on other maternal outcomes such as preterm rupture of the membranes, induction of labour or perineal trauma[7]. When considering

GDM among women with overweight or obesity, one review found exercise interventions did not significantly reduce the incidence of GDM compared to no intervention(261).

Some of the discrepancy seen within the literature about the potential impact of lifestyle interventions may be due to the fact that current interventions are very heterogeneous. Interventions can vary in terms of their method of delivery, gestation at commencement, frequency, duration of the intervention and contact time, resulting in the ideal format for an effective lifestyle intervention to manage GWG being largely unclear. A systematic review that has specifically looked at intervention content included 89 RCTs of interventions to minimise GWG(264). They showed that interventions delivered as a group or which combined group and individual elements were more effective, particularly for physical activity interventions(264). While little has been done to compare different intensities of interventions directly, the same review found that interventions delivered 1-3 times can be equally effective as those delivered 4-7 or 8 or more times(264). The review also compared different durations of interventions, trimester of starting the intervention, hours of intervention delivery and type of diet advised and found no current optimal intervention characteristics. They suggested that interventions where professionals are trained to initiate conversations around weight management during pregnancy may be effective(264). Another study that looked at the behavioural change technique (BCT) components incorporated within interventions aimed at managing GWG found the most commonly used BCTs categories were 'feedback and monitoring', 'shaping knowledge', 'goals and planning', and 'repetition and substitution'(265). For diet only and lifestyle interventions that included both diet and physical activity elements, 'feedback and monitoring', 'shaping knowledge' and 'goals and planning' appeared the most successful BCT categories for reducing GWG(265). The physical activity only interventions were largely unsuccessful at reducing GWG so it was not possible to determine effective BCTs for physical activity interventions(265).

Given the inconsistencies within the literature highlighted above, this programme of research presents a comprehensive summary of current evidence within an overview of systematic reviews of the impact of lifestyle interventions on GWG and other clinically relevant outcomes (see Chapter 3).

### 2.4.1.2 Routine weighing during pregnancy

More recently routine weighing has been considered as an intervention to assist women to reduce GWG. It is recognised that weighing during pregnancy provides an opportunity to provide feedback regarding weight gained compared to recommendations(16). Where required an individual can therefore be offered advice around lifestyle modifications to manage their GWG(16). However, the value of routine weighing in pregnancy is debated as current studies largely show it to be ineffective. An Australian RCT of 782 women suggested that women who were routinely weighed at each antenatal visit coupled with counselling around IOM GWG recommendations, compared to women in a routine care group who were not regularly weighed, had no benefits in terms of total GWG or reductions in the number of women gaining excessive GWG or any maternal or infant adverse outcomes(266). A further RCT undertaken in Australia recruited 396 women where all women were provided with written and verbal advice around appropriate GWG, as well as women in the intervention group being given some digital scales and asked to record their weight daily(267). Again, no significant differences in GWG or in any other maternal or infant adverse outcomes were seen in the routine weighing group(267). In a UK based feasibility trial of 76 women, women who were routinely weighed alongside being provided with support to set GWG targets and receiving brief feedback from their community midwife showed slight benefits in terms of a reduction in excessive GWG(268). This study however did not include women with obesity. Women included in the intervention group within this feasibility trial reported that being in the intervention group was useful for encouraging them to think more about their weight gain during pregnancy(268). Despite initially promising results in the feasibility trial, once progressing to a full trial of 656 women, no differences were seen between the intervention and control groups in the proportion of women gaining excessive GWG compared to IOM recommendations, in physical activity levels or in anxiety and depression scores once adjusting for maternal BMI at study recruitment(269).

The above literature highlights the current uncertainties over the best interventions to offer women. UK based research into the efficacy of weight management interventions in pregnancy is particularly limited. The National

Institute for Health and Clinical Excellence (NICE) has therefore recommended more research, especially UK based investigations, into ways of managing maternal obesity and GWG to optimise pregnancy outcome[10]. Furthermore, little has been done to date to understand the most effective interventions for the different classes of obesity[2], with those with class III obesity being the most commonly missing cohort within the current evidence.

## 2.4.2 Current guidance

### 2.4.2.1 UK guidance

Given the additional risks for women with obesity during pregnancy separate guidance exists for these women from the Royal College of Obstetricians and Gynaecologists (RCOG)[11] to ensure appropriate care pathways. Other national guidance contains specific subsections for this group of women[10,270,271]. The current guidance is discussed below.

The NICE (2010) weight management guidance for women before, during and after pregnancy advises that women are more likely to achieve or maintain a healthy weight if they: base meals on starchy foods, eat fibre rich foods, eat five portions of fruit and vegetables a day, eat a low fat diet, limit fried food and high sugar foods, eat breakfast, watch portion sizes and build physical activity into everyday life while minimising sedentary activities[10].

Specific UK based guidance for women with overweight or obesity prior to pregnancy is provided in Box 2.1.

**Box 2.1 Recommendations within current UK based guidance for women with overweight and obesity prior to pregnancy:**

- Provide women with opportunities to lose weight prior to conception[10,11] with every opportunity taken by healthcare providers to advise regarding the health benefits of weight loss prior to pregnancy[271].
- Discuss weight and lifestyle[11].
- Offer access to diet and physical activity weight loss support programmes[10,271].
- Advise women that losing 5-10% of their weight has health benefits[10]. The greater the weight loss the greater the health benefits, particularly if 5% weight loss is achieved and maintained for life[271].
- Inform women to check their weight and waist measurements periodically[10].
- Provide women with information about the health risks of obesity during pregnancy for both them and the child[10].

UK based guidance for all women during pregnancy is summarised in Box 2.2. While no weight gain recommendations were given within the original NICE (2010) guidance[10] and a lack of consensus regarding appropriate GWG was noted within the RCOG guidance[11]; the update NICE guidance recognised increasing international evidence of the adverse outcomes associated with GWG outside of IOM recommendations[271]. IOM GWG guidelines may therefore be relevant to the UK population, although further clarification is required for women under 18 years old and those with different classes of obesity[271].

**Box 2.2. Recommendations within current UK based guidance for women during pregnancy:**

- Measure weight and height of all women at their first contact with a health professional[10,11].
- Repeated weighing in pregnancy is not advocated as it may cause unnecessary concern for women[10], but re-weighing can be considered in the third trimester for women with obesity[11].
- Explain to women with obesity how their BMI poses risks to them and the unborn infant[10,11].
    - Offer women an opportunity to discuss these risks and inform women how to minimise them[11].
    - Empower women through sensitively providing information so that they remain engaged with professionals[11].
- IOM weight gain guidelines may be relevant to a UK population[271].
    - Weight loss is not recommended during pregnancy[10], especially not through using weight loss drugs[11].
- Focus on a healthy diet rather than weight gain targets[11].
    - Discuss eating habits with women at the first antenatal clinic visit[10].
    - Discuss women's pre-existing views around diet in pregnancy and weight gain[11].
    - Inform women an additional 200kcal is needed per day in the last three months of pregnancy only, there is no need to 'eat for two'[10].
- Regarding physical activity:
    - Ask women how active they are at the first antenatal visit[10].
    - Provide women with information on how to exercise safely and how to build physical activity into everyday life e.g. take the stairs not the lift[10].
    - Advise women to aim for 150 minutes of moderate intensity physical activity each week during pregnancy[272].
    - Advise women moderate intensity physical activity will not harm the unborn child[10].
- Ask women if they have any concerns about diet or physical activity and how they plan to address these concerns[10].
- Offer women with obesity referral to a dietitian or appropriately trained professional for personal advice on healthy eating and physical activity[10].

Weight loss during pregnancy has generally not been recommended[10]. However, more recently it has been acknowledged that while weight loss diets should be avoided in pregnancy some weight loss may occur if a woman follows the advice around healthy eating, physical activity and alcohol consumption in pregnancy, which could provide health benefits for the mother and fetus[271].

Specific UK based guidance for women in the postpartum period is provided in Box 2.3.

**Box 2.3. Recommendations within current UK based guidance for women during the postpartum period:**

- Discuss weight with women at their 6-8 weeks appointment and ask if they want support with their weight[10].
- Encourage all women to breastfeed[10] and inform women that weight loss by following a healthy diet and undertaking regular exercise will not affect breastmilk quality or quantity[10,273].
    - Women with obesity may require additional support to establish and maintain breastfeeding[11].
- Provide clear tailored advice on how to lose weight post childbirth[10].
    - Ensure that women have realistic expectations regarding postpartum weight loss[10].
    - Provided details of appropriate local community services[10].
- Tailor healthy eating and physical activity advice to the woman's personal circumstances for example tiredness levels and health problems[10].
- Physical activity guidance:
    - Inform women to aim for 150 minutes of moderate intensity physical activity each week from birth to 12 months postpartum[272] e.g. a brisk walk or moderate exercise for at least 30 minutes 5 days a week[273].
    - Advise that exercise is safe while still breastfeeding[272].
- Offer referral to available structured weight loss programmes to women with obesity[10,11].
    - These should be tailored to the needs of the individual or a group of women[273].
    - Support should include advice on diet, physical activity and goal setting with the use of evidence-based behaviour change techniques[10], with a view to weight reduction[11].
    - Address why weight loss may be difficult and help women to identify and address individual barriers to change[273].
    - Offer ongoing support over a sufficient length of time to allow for sustained lifestyle change[273].
    - If women with obesity are not ready at the 6-8 weeks appointment to start trying to lose weight, provide them with information of where to get support when they are ready[10].

### 2.4.2.2 Comparison with international guidance

A review of policies across 66 separate countries found that 53 countries, such as the UK, had either an informal policy or a formal one around maternal weight that had been adopted by the government or a professional organisation(274). In total, 90% of international guidelines, including the UK, recommend weighing women when they booked for antenatal care. However, in contrast to the UK where routine weighing is not recommended and specific GWG guidance is not provided(10), 81% of international guidelines recommended monitoring GWG and 62% recommended providing women with information around healthy GWG(274). Of the international policies with GWG recommendations, there were variations over the amount of GWG recommended and whether this was linked to pre-pregnancy BMI(274). Although a more recent review of current clinical practice guidelines for nutrition and weight gain during pregnancy found GWG guidance was largely around IOM recommendations(275). While the UK guidance covers the whole perinatal period, few international policies covered supporting women in the preconception period (42%) or to return to a healthy weight in the postpartum period (13%)(274). When key informants within each country were surveyed, their perception was that policies were not well known by health professionals, with this varying by phase of the childbearing cycle from 27% preconceptionally, 52% during pregnancy and 37% postnatally(274). Physical activity was generally less well discussed within guidelines than healthy eating(274). Nutritional advice during pregnancy was however heterogeneous and geographically scattered, despite the numerous advising bodies publishing such guidance, with a lack of dieticians providing advice in over half of the guidelines(275).

When looking specifically at guidelines for the management of women with obesity during the perinatal period, 32 guidelines were found from different countries(276). Similarly to the UK guidance, nine international guidelines recommended counselling women with obesity prior to pregnancy about the risks of obesity during pregnancy and 13 recommended stabilising weight before conception or in between pregnancies(276).

During pregnancy nutritional advice was provided by fifteen guidelines and physical activity advice within 11 guidelines for women with overweight and obesity. Nutritional and physical activity advice were both provided by five guidelines in the pre-pregnancy period and six postpartum[276]. Only 13 of the 32 guidelines advised providing counselling around the importance of controlling GWG[276]. When undertaking multiple systematic reviews, the Early Nutrition Project systematic review group found that current recommendations for pregnant women, particularly for women with obesity, do not take long-term health consequences of early nutrition into account[277]. This is despite increased understanding of the long-term consequences of maternal diet on later life health and disease for the infant[277]. Given that current evidence is insufficient to recommend specific weight gain limits to women across all BMI categories, particularly with respect to the outcomes of pre-eclampsia and GDM, health professionals should advise a balanced healthy diet and lifestyle rather than optimising GWG[277]. As part of this pregnant women should be advised to only increase intake in late pregnancy by no more than 10% above that of a non-pregnant woman[277]. When focussing on the long-term health consequences for affluent countries such as those in Europe, recommendations for nutrition during pregnancy should suggest that pregnant women consume a balanced diet during pregnancy that includes at least 2 portions of oily fish a week, adequate intake of folate in early pregnancy and adequate intake of other micronutrients such as iron, vitamin D, vitamin B12, vitamin A and iodine[277]. Such diets, with high consumption of fruit, vegetable, seafood, legumes and milk products have been associated with reduced risk of SGA within a systematic review[278]. Diets rich in protein and fruit and low in sugar and saturated fat may also reduce the risk of preterm birth[278].

#### 2.4.2.3 Current practice in England

Provision of maternity services for women with obesity is variable within the UK, despite pregnancy being recognised as a good opportunity to influence behaviour change for mothers and families[279]. A Northeast of England regional audit identified a need for more antenatal maternal obesity services[279]. Additionally, a recent survey of maternal weight management services in England found wide geographical variations in availability, with few services that focussed on women with a raised BMI[12]. For some this lack of focus was due to an intentional move to make services universal as poor nutrition is not just limited to women with obesity. For others it was because of funding cuts preventing service provision[12]. The interviews that were undertaken as a follow up to the survey, identified uncertainty among professionals about what constitutes the most suitable service to tackle maternal obesity[12]. Providers and commissioners therefore described a desire for more clarity within guidelines on which to base their practice[12].

The inconsistent service availability seen within the UK is similar to the situation in Canada, where one study showed that GWG guidance provided by healthcare providers was inconsistent between different providers, in different geographical regions and for women with different background characteristics[280]. They particularly found that women of higher socioeconomic status, who were older, or classified as overweight or obese during pregnancy were more likely to receive GWG advice[280].

### 2.4.3 Women's views on gestational weight management

As well as focussing on the clinical effectiveness of interventions, it is also necessary to consider women's views of interventions and of gestational weight management in practice. A meta-ethnography of the experience of maternity care among women with obesity found many women were dissatisfied with the way that weight management had been addressed during their pregnancy[281]. Women were expecting discussions around their weight when meeting healthcare providers; when this was not the case women could be left feeling stigmatised for example through onward referral to specialist services with no explanation or through comments in their notes about difficulties due to their size[281]. When weight was addressed in could be equally distressing for women, with women describing an excessive focus on risk during their pregnancy which left them feeling disenfranchised and denied a 'normal' pregnancy experience[281]. Health professionals who provided the woman with options and were proactive without being risk focussed were appreciated by the women[281].

Another scoping review into the maternity care experiences of women with obesity similarly found women to report stigma in their encounters with professionals, with professionals seen as judgemental[282]. The review also found women with obesity to report receiving inadequate information regarding weight management in pregnancy, with the information received frequently being inconsistent, inaccurate or excessively emphasising the risks of obesity during pregnancy[282]. Women also reported feeling that their pregnancies were overly medicalised as they were automatically classified as high-risk during pregnancy and therefore requiring additional surveillance[282]. Indeed, a review looking at intervention outcomes considered important to women with obesity found that clinical outcomes which are considered important to healthcare providers and mainly covered when reporting trials were only a small minority of the outcomes deemed important by women[283]. Factors such as emotional wellbeing, social support and satisfaction with care were rated as important by women[283].

While numerous studies explored women's experiences, out of the 12 studies included within the meta-ethnography[281] and the 17 included in the scoping review[282] only one focussed specifically on women with a BMI ≥40kg/m² despite increasing understanding of the differences in gestational weight management between women of different classes of obesity.

## 2.5 Summary

This chapter has summarised the key literature relevant to the research topic. The literature has clearly shown that women with a BMI ≥40kg/m² are most at risk of adverse outcomes during pregnancy. While the adverse impact of weight gain above recommendations is also well documented, there is currently much uncertainty over the most effective strategies to help women manage weight gain effectively during pregnancy. There is particularly a clear call for more UK based studies within this area. Furthermore, women with a BMI ≥40kg/m² are the group most commonly missing within the evidence base around effective weight management during pregnancy. Therefore, a need for better understanding of the most effective services to support women with obesity during pregnancy to manage their weight has been clearly identified. Additionally, the evidence has demonstrated the growing awareness of the importance of maternal diet during pregnancy on long-term infant wellbeing, particularly weight throughout childhood and into adulthood. Previous disparities in the effectiveness of maternal weight management interventions and services have also clearly identified a need to explore the voice of women themselves around weight management services during pregnancy. Therefore, quantitative studies are not enough to just describe the effectiveness of weight management interventions, but qualitative studies of women's experiences are also required.

To begin to address the current uncertainty over the most effective lifestyle interventions in women with overweight and obesity, the next chapter presents an overview of systematic reviews of lifestyle interventions on GWG and other clinically relevant outcomes.

# Chapter 3: Overview of systematic reviews of lifestyle interventions to reduce gestational weight gain in women with overweight or obesity

## 3.1 Introduction

This chapter presents Article A, an overview of systematic reviews of lifestyle interventions to reduce GWG among women with overweight and/or obesity. The aims of the overview are given alongside the details of publication and impact of the article, followed by the full published article. The chapter concludes by summarising the key findings of the overview.

## 3.2 Aim of the overview of systematic reviews

Given the increasing number of systematic reviews that have considered the effectiveness of lifestyle interventions in women with overweight and obesity, often with conflicting results, it was considered important to provide a synthesis of the current evidence in this area. The review question for the overview of systematic reviews was: What is the extent of evidence regarding the effectiveness of lifestyle interventions on GWG in women with overweight or obesity? Lifestyle interventions included dietary interventions, physical activity or a combination of both. This addressed the first aim of this programme of research: "*To establish from the current research literature the effectiveness of lifestyle interventions for women with overweight or obesity for reducing GWG and other adverse outcomes for the mother and the infant*."

## 3.3 Published article: Article A

The published article was entitled "*A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity*." It is reproduced on the following pages in full in the format in which it was published[284]. The protocol for this review was registered in the PROSPERO database and can be viewed in Appendix B. The supplementary data associated with this article are provided in Appendix C.

## 3.4 Publication and impact

The systematic review was accepted for publication in Obesity Reviews. It was published online in 'Early View' format in January 2021, before full publication in the May 2021 edition.

Obesity Reviews is a highly esteemed, peer reviewed journal, being the highest ranked journal by impact factor within the discipline of obesity. In 2022 Obesity Reviews had an impact factor of 8.9. It is the official publication of the World Obesity Federation.

Since publication online according to Google Scholar the article has been cited 34 times (as of 31st January 2024). It has an Altmetric score of 9 and is therefore in the top 25% of all research outputs scored by Altmetric.

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PREGNANCY/WEIGHT GAIN

OBESITY Reviews WILEY

# A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity

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**Summary**

Women with overweight or obesity are twice as likely to gain excessive gestational weight than women of normal weight. Identifying effective interventions to support this group achieve healthy gestational weight gain is important. An overview of systematic reviews regarding the effectiveness of lifestyle interventions on gestational weight gain in women with overweight or obesity was undertaken, including searching eight electronic databases. Quality of included reviews was assessed by two independent researchers. A narrative data synthesis was undertaken, with subgroup and sensitivity analyses by type of intervention and quality of the included reviews. A total of 15 systematic reviews were included within this meta-review. A small reduction in gestational weight gain of between 0.3 and 2.4 kg was noted with lifestyle interventions compared with standard care. There was some evidence that dietary only or physical activity only interventions may reduce the odds of gestational diabetes. No differences were noted in the odds of other maternal or infant health outcomes. Although lifestyle interventions appeared to decrease gestational weight gain, current evidence does not show a clear benefit on maternal and infant outcomes from the small nature of the reduction in gestational weight gain produced by lifestyle interventions in women with overweight or obesity.

**KEYWORDS**
gestational weight gain, healthy lifestyle, maternal obesity

## 1 | BACKGROUND

Overweight (body mass index [BMI] ≥ 25 kg/m$^2$) and obesity (BMI ≥ 30 kg/m$^2$) are estimated to affect 38% of women globally.[1] Managing the consequences of obesity presents an economic burden to global healthcare services, with overweight- and obesity-related healthcare costs estimated to reach 425 billion U.S. dollars a year across the 52 countries within the Organisation for Economic Co-operation and Development (OECD), European Union, and G20.[2] Data from 37 U.K. maternity units indicate first trimester maternal

**Abbreviations:** AMSTAR-2, Assessment of Multiple Systematic Reviews v2; BMI, body mass index; CI, confidence interval; DARE, Database of Abstracts of Reviews of Effects; GDM, gestational diabetes mellitus; GWG, gestational weight gain; IOM, Institute of Medicine; LGA, large for gestational age; NICE, National Institute for Health and Care Excellence; RCT, randomized controlled trial; SGA, small for gestational age.

obesity has more than doubled over the last 2 decades,[3] with similar trends also noted elsewhere in the world.[4] Raised BMI is associated with increased short- and long-term adverse outcomes for mothers such as increased risk of maternal mortality, pregnancy induced hypertension, gestational diabetes, primary postpartum hemorrhage, and interventional birth.[5–7] For babies, there are additional risks of stillbirth, large for gestational age, admission to neonatal units, and neonatal mortality.[6–10]

A number of systematic reviews[11,12] have evaluated interventions designed to control weight gain in pregnancy among the general pregnancy population, with various results. Women with overweight or obesity are twice as likely to gain excessive gestational weight than women with a BMI in the normal range,[13] therefore establishing effective interventions for this group is particularly important.

National Institute for Health and Care Excellence (NICE) guidelines[14,15] emphasize the importance of limiting gestational weight gain (GWG) by healthy eating and physical activity. However, they highlight insufficient robust evidence in this area, particularly on ideal GWG or effective strategies to encourage healthy GWG. The Institute of Medicine (IOM) has recommended weight gain ranges according to pre-pregnancy BMI category, including 7–11.5 kg for women with overweight and 5–9 kg for women with obesity.[16] However, their review of the evidence was based on a mixture of study designs including observational projects that were not consistently of a high quality, statistically powered, prospective, controlled trial nature. Limiting GWG in women with overweight or obesity is viewed as important due to the multiple risks associated with excessive weight gain.[17] Pregnant women and their healthcare providers require clear guidance around GWG and appropriate interventions to achieve healthy pregnancy and birth outcomes. Systematic reviews originally evolved within healthcare due to the large volume of primary research making decision making for policy makers and practitioners difficult, especially in the face of contradictory evidence.[18,19] As systematic reviews are increasingly published, clinicians again can be left feeling overwhelmed by the plethora of evidence; therefore, the requirement for overviews of reviews is increasingly recognized, which can compare and contrast current systematic reviews and provide an overall body of available information on a given topic.[18] Given the rising number of systematic reviews in this area, a systematic synthesis of current reviews was deemed imperative to provide an overall body of evidence that evaluates the most appropriate interventions for assisting women with overweight or obesity to avoid excessive GWG.

### 1.1 | Review question

What is the extent of systematic evidence regarding the effectiveness of lifestyle interventions on GWG in women with overweight or obesity? Lifestyle interventions include dietary interventions, physical activity, or a combination of both.

## 2 | METHODS

### 2.1 | Search strategy

The review was undertaken in accordance with the pre-published protocol in PROSPERO CRD42019156883. A systematic search was conducted in CINAHL, MEDLINE, Maternal and Infant Health, PsycInfo, Scopus, Database of Abstracts of Reviews of Effects (DARE), Prospero and the Cochrane Library. The search strategy included search terms and index headings around "pregnancy," "lifestyle interventions," "obesity," and "systematic review." Table S1 provides an example of the full search. References of included systematic reviews and other relevant literature were searched for further relevant citations. Databases were searched from inception. Initial searches were undertaken in December 2019 and updated on April 30, 2020, prior to the final analysis. Studies were limited to those published in the English language.

### 2.2 | Study selection and data extraction

Studies were screened for inclusion against the following inclusion criteria; systematic reviews that only included randomized controlled trial (RCT) evidence; reviews compared antenatal lifestyle interventions, including dietary, physical activity, or a combination of dietary and physical activity interventions to standard antenatal care; the review focused exclusively on women with overweight and/or obesity or reported this as a subgroup and the review reported our primary outcome of GWG. Interventions exclusively undertaken during the pre-conception or postnatal periods were excluded. Studies were limited to those where the full text version of the review could be obtained, with authors of protocols and conference abstracts contacted regarding full text availability. All citations were screened for inclusion by title and abstract by one reviewer. A random sample of 10% of retrieved citations were screened by a second researcher. Two independent researchers screened the full text of potentially relevant citations, with consensus over inclusion agreed through discussion.

Two researchers used a pre-defined data extraction tool to extract: author, date of publication, type of intervention, number of trials, number of women included, and review outcomes. All RCTs included within the systematic reviews were obtained for clarification of the results, due to discrepancies discovered between the results of included reviews. Authors of the original trials and systematic reviews were contacted where necessary for clarification.

### 2.3 | Risk of bias assessment

Included systematic reviews were assessed by two researchers for risk of bias using the Assessment of Multiple Systematic Reviews v2 (AMSTAR-2) checklist[20] (Table S2 contains the full checklist). Where there was disagreement in the scoring, consensus was reached through discussion. To assess confidence in the results, we considered eight AMSTAR-2 domains as critical. These were item 2: review methods established prior to conducting the review; item 4: comprehensive literature search; item 6: data extraction in duplicate; item 9: risk of bias satisfactory assessed; item 11: appropriate methods for statistically combining results; item 12: impact of risk of bias on meta-analysis results considered; item 13: risk of bias considered when interpreting/discussing review results; and item 14: heterogeneity of included studies discussed. An overall rating of confidence in the results of each review, of high, moderate, low, or critically low, was given. This depended on the presence of flaws in the above critical domains or other weakness within the systematic review.

The quality of the primary RCTs, as judged by the authors of the included systematic reviews, was taken into consideration, particularly random sequence generation, allocation concealment, and attrition bias.

### 2.4 | Outcomes

The primary outcome for this overview of reviews was GWG. Secondary outcomes included adherence to IOM weight gain recommendations[16]; gestational diabetes (GDM), pre-eclampsia, cesarean section, and preterm birth (prior to 37 weeks gestation); birthweight, large for gestational age (LGA), small for gestational age (SGA), macrosomia (birthweight >4000 g), and low birthweight (birthweight <2500 g); changes in dietary intake; and changes in physical activity outcomes.

### 2.5 | Data synthesis

A meta-synthesis using statistical methods[21] was planned if the percentage of the variability in the effect estimate due to heterogeneity rather than sampling error calculated using $I^2$ was ≤50%. It is recognized that $I^2$ values of 50%–90% may represent substantial heterogeneity and values of 75%–100% represents considerable heterogeneity.[22] As heterogeneity between studies was considerable within many included systematic reviews, a formal narrative analysis was undertaken.

Where individual primary studies were incorporated into multiple systematic reviews, the overlap was considered within the analysis. Any meta-analysis only analyzing a subset of RCTs present in another systematic review was excluded from the narrative synthesis.

Effect sizes within individual systematic reviews were converted to weighted mean differences with 95% confidence intervals (CI) for continuous outcomes and to odds ratios and 95% CI for categorical outcomes, to allow comparison between systematic reviews. The overall effect size, the number of studies that informed the outcome, the number of participants, and the percentage of variability in the effect estimate due to heterogeneity within each systematic review were reported.

To detect any evidence of small study effects (where small studies give substantially larger estimates of effect sizes than larger studies), Egger's regression asymmetry test was undertaken for continuous variables and Harbord-Egger's test for categorial variables,[23] for any outcome that included six or more RCTs. A more conservative effect size in the largest study (study with the smallest standard error) than in the random-effects model summary estimate alongside a $p$ value in Egger's test <0.10 was regarded as indicative of small study effects.

To assess whether the observed number of studies with nominally significant results ($p < 0.05$) within a meta-analysis was larger than the expected number, the excess of significance test was undertaken.[24] An excess of significant findings within a meta-analysis can be an indication of publication bias, selective analysis or bias in outcome reporting, resulting in underpowered small studies with spurious significant findings more likely to be published within the field. The expected number of significant studies within a meta-analysis was calculated by summing the statistical power estimates for each study included within a meta-analysis. As the true effect size is not known, the effect size of the study with the smallest standard error was used to calculate the power of each study using Stata 15.1. Excess significance for each meta-analysis was considered if $p$ was <0.10 using the binomial probability test.

A "Summary of Findings" table was produced using the GRADE approach.[25] This considers risk of bias, inconsistency, indirectness, imprecision, small study effects, and reporting bias. An overall grade of high, moderate, low, or very low was assigned to reflect confidence in the evidence for each outcome.

### 2.6 | Analysis of subgroups

Subgroup and sensitivity analyses were planned "a priori" for different types of interventions: dietary only, physical activity only, or combined lifestyle interventions and for reviews where a rating of high overall confidence in the results was achieved on the AMSTAR-2.

## 3 | RESULTS

A total of 3416 citations were identified (Figure 1). After removing duplicates, 2512 citations were screened against inclusion criteria. The title and abstract of a subset of 265 citations were double screened, with over 98% agreement. Of the 75 full text articles screened, 16 (covering 15 separate reviews) were included.[12,26–40] Table S3 provides reasons for exclusion at full text.

### 3.1 | Characteristics of included systematic reviews

Characteristics of the included systematic reviews are given in Table 1. The systematic reviews were published between 2010 and

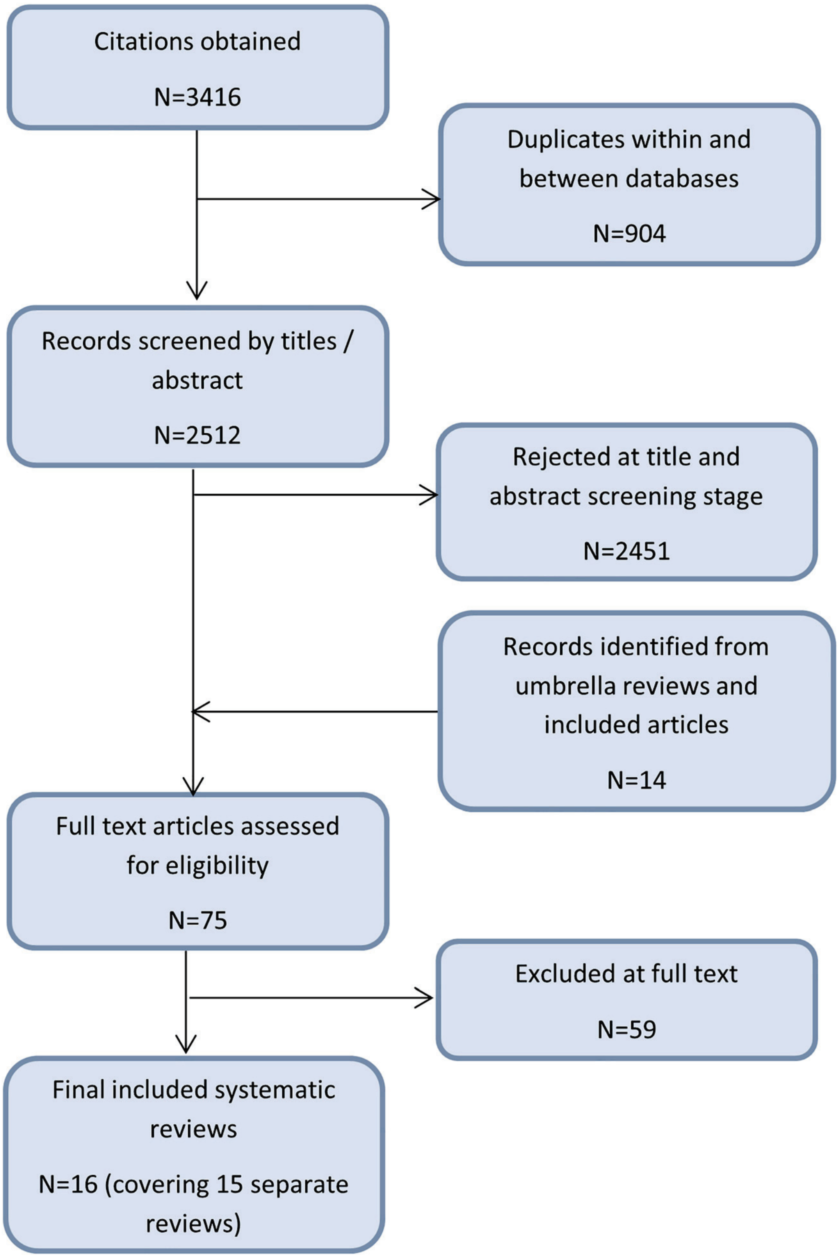


**FIGURE 1** Flowchart of study selection

2019, with the latest search within the included reviews run in January 2019.

Two included systematic reviews focused on dietary interventions, one exclusively so[34] and one on dietary interventions that may also include physical activity components.[31] Four reviews focused on physical activity interventions, two exclusively,[29,39] with one of these only looking at supervised physical activity,[39] and two at physical activity interventions that may also include dietary components.[27,30] One review included interventions with both dietary and exercise components,[26] and eight reviews included interventions with any physical activity or dietary lifestyle components,[12,28,32,33,36–37,40] with one looking exclusively at e-based interventions.[33]

All included systematic reviews had "usual or standard care" as the comparator; however the description of what constituted usual care within the studies in many systematic reviews was minimal.

The majority of reviews only included RCTs of women with overweight or obesity prior to pregnancy or when booking for antenatal care.[27–34,36,37,40] The other four reviews incorporated women of all BMIs but providing subgroup analysis for women with overweight or obesity.[12,26,38,39] Three reviews excluded RCTs that exclusively recruited women diagnosed with GDM,[27,31,38] and three reviews only incorporated women with singleton pregnancies.[29–31]

Some reviews included multiple primary outcomes. Primary outcomes included GWG or maternal weight changes,[12,27,29,33,34,36,38,40] GDM,[26,29] LGA or other infant growth outcomes,[12,26,28,39] pre-eclampsia,[32,37] mode of birth,[26] infant mortality/morbidity,[26,38] maternal morbidity,[38] physical activity outcome measures,[30,33] dietary intake,[33,36] and methodological design of the studies.[31]

The systematic reviews incorporated between four[34] and 103 RCTs[38] in total or between two[30] and 32[40] RCTs that reported GWG

**TABLE 1** Characteristics of included systematic reviews of randomized controlled trials evaluating the effect of lifestyle interventions on gestational weight gain and other pregnancy and birth outcomes

| First author (year) | Primary outcome(s) of the review | Search Strategy | Risk of bias assessment tool<br>Quality of included studies | Number of RCT total [number for overweight/obese subgroup and reporting GWG if different] | Participants [*n* = total number included in review (*o* = total number in GWG outcome for overweight/obese subgroup[a])]<br>Intervention<br>Control | Conclusions of SR |
|---|---|---|---|---|---|---|
| Bain et al. (2015)[26] | GDM, mode of birth, LGA and infant mortality | Four databases including trials register and references searched. Handsearching 30 journals, major conference proceedings, and weekly alerts from 44 journals<br>No language or date restrictions<br>Dates searched: Inception–Feb 2014 | Cochrane Collaboration tool for assessing risk of bias<br>Moderate risk of bias across all included trials | 13 [3] | *Participants*: All pregnant women excluding pre-existing diabetes [*n* = 4983 (o = 1980)]<br>*Intervention*: Combined diet and exercise interventions<br>*Control*: No interventions (standard care) | Limited evidence for the effect of combined diet and exercise interventions on GDM or other outcomes such as GWG |
| Choi et al. (2013)[27] | Weight change in pregnancy or postpartum | Four databases and references searched<br>Published in English or Korean<br>Dates searched: Jan 2000–Dec 2011 | Cochrane Collaboration tool for assessing risk of bias<br>Risk of bias was judged to be mixed | 11 [7] | *Participants*: WWOO [*n* = 1268 (*o* = 721)]<br>*Intervention*: PA or PA plus diet<br>*Control*: Usual care | Supervised PA with dietary advice was most effective for decreasing GWG, especially alongside goal setting |
| Dodd et al. (2010)[28] | LGA | Four databases including trials register and references searched<br>No date or language restrictions<br>Dates searched: Inception–Jan 2010 | Cochrane Collaboration tool for assessing risk of bias<br>Studies judged at mixed risk of bias—from poor to fair | 9 [4] | *Participants*: WWOO [*n* = 743 (*o* = 416)]<br>*Intervention*: AN dietary and/or lifestyle interventions<br>*Control*: standard care | Unclear effect of providing AN lifestyle interventions for WWOO |
| Du et al. (2019)[29] | GWG and risk of GDM | Five databases including trials register searched<br>English language only<br>Dates searched: Inception to April 2018 | Cochrane Collaboration tool for assessing risk of bias<br>Risk of bias was judged to be mixed | 13 [12] | *Participants*: WWOO (according to author definitions) [*n* = 1439 (o = 1158)]<br>*Intervention*: Physical exercise in AN period (without dietary component)<br>*Control*: Standard AN care or recommended not to undertake exercise | Prenatal exercise reduces GWG and GDM in pregnant WWOO |

(Continues)

**TABLE 1** (Continued)

| First author (year) | Primary outcome(s) of the review | Search Strategy | Risk of bias assessment tool<br>Quality of included studies | Number of RCT total [number for overweight/obese subgroup and reporting GWG if different] | Participants [*n* = total number included in review (*o* = total number in GWG outcome for overweight/obese subgroup[a])]<br>Intervention<br>Control | Conclusions of SR |
|---|---|---|---|---|---|---|
| Flannery et al. (2019)[30] | Change in physical activity level. The review also identified which BCTs were most frequently used | Eight databases and references searched<br>English language only<br>Studies excluded if only in the grey literature or no discernible BCT within the intervention<br>Dates searched: Inception–Jan 2019 | Cochrane Collaboration risk of bias assessment tool<br>Overall high risk of bias | 19 [3] | *Participants*: WWOO with singleton pregnancy [*n* = 5181 in largest meta-analysis (*o* = NR)]<br>*Intervention*: At least one intervention component aimed at maintaining or increasing PA levels<br>*Control*: Comparison interventions or usual care | PA interventions slightly increase PA in WWOO, however many studies were high risk of bias |
| Flynn et al. (2016)[31] | Methodological design of interventions | 12 databases including trials registers and references searched<br>English language only<br>Dates searched: 1990–March 2015 | Cochrane Collaboration tool to assess risk of bias<br>Most studies mixed or low risk of bias, 2 studies high risk of bias | 13 | *Participants*: WWOO (including BMI ≥ 23 kg/m$^2$ if high risk ethnicity), excluding multiple pregnancies, or receiving interventions to treat GDM [*n* = 4276 (*o* = NR)]<br>*Intervention*: Dietary or dietary and PA interventions<br>*Control*: Standard AN care | There is considerable methodological variability in design, assessment, and outcomes evaluated in dietary interventions to control GWG in WWOO |
| Ho et al. (2012)[32] | Pre-eclampsia | Six databases including trials register and references searched.<br>English language only<br>Dates searched: 1970–May 2011 | CASP RCT checklist and a modified version of the SIGN 50 checklist<br>Two studies high quality, one low quality, and the others of mixed quality | 6 | *Participants*: WWOO (BMI ≥ 26 kg/m$^2$) [*n* = 867 (*o* = NR)]<br>*Intervention*: AN weight management interventions (dietary, exercise, behavioral, or awareness-based interventions)<br>*Control*: Routine care | No evidence that AN weight management interventions effectively reduce pre-eclampsia in WWOO |
| International Weight Management in | GWG and composite maternal and fetal/ | Six databases including trials register and | Cochrane risk of bias tool | 103 eligible studies of which 33 had | *Participants*: Pregnant women of normal | Diet and lifestyle interventions in |

(Continues)

**TABLE 1** (Continued)

| First author (year) | Primary outcome(s) of the review | Search Strategy | Risk of bias assessment tool<br>Quality of included studies | Number of RCT total [number for overweight/obese subgroup and reporting GWG if different] | Participants [*n* = total number included in review (*o* = total number in GWG outcome for overweight/obese subgroup[a])]<br>Intervention<br>Control | Conclusions of SR |
|---|---|---|---|---|---|---|
| Pregnancy Collaborative Group (2017)[38]<br>Rogozińska et al. (2017)[35] | neonatal outcomes in subgroups of women (e.g., according to BMI, age, parity, ethnicity, and pre-existing medical conditions) | internet, and references searched. Contacted experts in the field<br>No language restrictions<br>Dates searched: 1990–Feb 2017 | Mixed quality of studies | Individual Participant Data for GWG outcome [31] | BMI, or WWOO [*n* = 9320 with individual participant data for GWG outcome (*o* = 5909)]<br>*Intervention*: Diet and/or PA interventions in pregnancy<br>*Control*: Routine AN care | pregnancy reduce GWG in women with normal, overweight or obese BMI status |
| Lau et al (2017)[33] | GWG, postnatal weight change, moderate and vigorous PA and calorie intake | Seven databases, trial registries and references searched<br>English Language only<br>Dates searched: Inception–July 2016 | Cochrane risk of bias tool<br>Moderate to high risk of bias within included studies | 14 [7] | *Participants*: WWOO [n=3169 (o=1636)]<br>*Intervention*: E-based lifestyle interventions with at least one dietary, PA or weight management intervention<br>*Control*: minimal intervention or usual care | E-based interventions limited GWG – especially e-based interventions with additional contact in person/by phone/both. However considerable intervention variability |
| Quinlivan et al. (2011)[34] | GWG | Two databases including trial register and references searched<br>No date or language restrictions<br>Dates searched: Inception–March 2011 | Not reported | 4 | *Participants*: WWOO [*n* = 537 (*o* = 537)]<br>*Intervention*: Dietary interventions<br>*Control*: standard care | AN dietary interventions can reduced GWG in pregnant WWOO without effecting newborn weight |
| Shieh et al. (2018)[36] | GWG and calorie/macronutrient intake | Five databases and references searched<br>English language only<br>Dates searched: Inception–June 2016 | Risk of bias based on Cochrane risk of bias tool<br>Two studies were low risk, 19 moderate, and two high risk of bias | 23 [21 compared to routine care not different intervention type] | *Participants*: WWOO [*n* = 7056 (*o* = 6473)]<br>*Intervention*: Healthy eating and/or PA interventions<br>*Control*: usual care | Healthy eating interventions with/or without PA are effective at limiting GWG, especially when including clear goal setting |
| Syngelaki et al. (2019)[37] | Pre-eclampsia and hypertensive disorders | Five databases including trials register and references searched<br>No language restrictions | Cochrane handbook used to assess risk of bias<br>Risk of bias was judged to be mixed | 23 [18] | *Participants*: WWOO [*n* = 7236 (*o* = 5117]<br>*Intervention*: Diet and/or exercise | Diet and exercise are effective at reducing GWG in WWOO, but do not reduce the risk |

(Continues)

**TABLE 1** (Continued)

| First author (year) | Primary outcome(s) of the review | Search Strategy | Risk of bias assessment tool<br>Quality of included studies | Number of RCT total [number for overweight/obese subgroup and reporting GWG if different] | Participants [*n* = total number included in review (*o* = total number in GWG outcome for overweight/obese subgroup[a])]<br>Intervention<br>Control | Conclusions of SR |
|---|---|---|---|---|---|---|
| | | Dates searched: Inception–November 2017 | | | *Control*: "expectant management" | of pre-eclampsia or hypertensive disorders |
| Thangaratinam et al. (2012)[12] | Weight related changes for mother and infant | 13 databases including trial registers searched<br>No language restrictions<br>Dates searched: Inception to Jan 2012 | Examines: allocation concealment, sequence generation, blinding, incomplete outcome data, selective reporting and other potential biases<br>Studies were of mixed quality | 44 [11] | *Participants*: Women with normal BMI or WWOO [*n* = 7278 (*o* = 2149)]<br>*Intervention*: Any dietary or lifestyle intervention with potential to influence maternal or fetal weight or pregnancy outcomes<br>*Control*: Only described as "control" | Dietary and lifestyle interventions can improve pregnancy outcomes and reduce GWG, with dietary interventions most effective for women of all BMIs |
| Wiebe et al. (2015)[39] | Neonatal size at birth (birthweight, small at birth and large at birth) | Six databases including trials register and references searched<br>No language restrictions<br>Dates searched: Inception–Jan 2015 | Jadad Scale (and allocation concealment as recommended by Cochrane Collaboration)<br>Studies were at moderate to high risk of bias | 28 [3] | *Participants*: Women of all BMIs [*n* = 5322 (*o* = 439)]<br>*Intervention*: Supervised prenatal exercise (minimum of one exercise session with study personnel every 2 weeks throughout intervention)<br>*Control*: standard care | Additional research in WWOO is warranted |
| Yeo et al (2017)[40] | GWG | Three databases and references searched<br>Restricted to the last 10 years<br>Dates searched: January 2005–June 2016 | Consolidated Standards of Reporting Trials statement and Cochrane Collaboration tool for assessing risk of bias<br>Studies were of mixed risk of bias | 32 | *Participants*: WWOO [*n* = 5869 (*o* = 5418)]<br>*Intervention*: Lifestyle interventions targeting GWG initiated prior to the 3rd trimester<br>*Control*: Only described as "control" | WWOO have greater success meeting GWG targets when prenatal care providers deliver nutrition or PA counsel |

Abbreviations: AN, antenatal; BCT, behavior change techniques; BMI, body mass index; GDM, gestational diabetes; GWG, gestational weight gain; LGA, large for gestational age; NR, not reported; PA, physical activity; WWOO, women with overweight or obesity.

[a]Overweight taken as BMI = 25.0–29.9 $kg/m^2$ and obesity as BMI ≥ 30 $kg/m^2$ unless otherwise stated.

in women with overweight and/or obesity. Between 416[28] and 6473[36] participants with overweight or obesity and for whom GWG was reported were included within the reviews. The individual studies reporting outcomes were not clearly identified within the analysis in one review.[38] A total of 56 different trials reporting outcomes in women with overweight or obesity were included within the other systematic reviews. The vast majority of these were undertaken in very high human development countries[41]: 17 in the United States, 12 in Australia, three in Canada and Demark, two in Belgium, Ireland, Italy, the Netherlands, Spain, and the United Kingdom, and one in Finland, New Zealand, and Norway. One further study was undertaken across different European countries. Just five studies were undertaken in high human development countries: two in Brazil, one in China, one in Egypt, and one in Colombia and none in medium or low human development countries.

The RCTs within the included systematic reviews incorporated a diverse range of interventions. Many RCTs included more than one dietary component. These included calorie restriction, with some personalizing targets according to pre-pregnancy weight but others providing uniform advice; macronutrient goals; replacing carbohydrates with lower glycemic foods; reducing fat or cholesterol intake; increasing beneficial food intake such as fruit, vegetables, fiber, fish, and vegetable oils; providing meal plans and/or recipes; portion size advice; information on how to check nutrition labels; eating out options; limiting or swapping high energy snacks for healthy alternatives; eating a Mediterranean style diet; advice on adjusting dietary intake to activity levels and dietary supplements of vitamins and trace elements. Some interventions were delivered through written information but most involved counselling sessions, either individually or as a group. Counselling could be provided by dieticians, nutritionists, health coaches, or other healthcare professionals, through between one and 16 sessions, lasting from 5 min to 2 h. Many interventions encouraged women to set goals to change their diet or provided logs to self-monitor diet.

Physical activity interventions were similarly diverse. Physical activity was either supervised or unsupervised, with some interventions combining the two. Supervised sessions included aerobic training, such as dance, treadmill walking or stationary cycling, or resistance training such as pelvic floor or large muscle training or a combination of both aerobic and resistance training. Some interventions determined exercise intensity through heart rate monitoring, while others used self-perceived exertion. Structured programs varied from once a month to five times a week throughout pregnancy in sessions lasting up to 60 min, with an estimated 85 sessions in one RCT. Unsupervised physical activity interventions included being encouraged to "be active," for example, walking more by not driving short distances; discussions around increasing physical activity; individual exercise plans with time and/or frequency goals; providing an exercise DVD or video; step count monitors; provision of treadmills or home cycles or 6 months free gym membership. Some women were given logs to self-monitor physical activity and some interventions used social learning theory to promote change. Physical activity interventions were delivered through written information; face-to-face contact either individually or in a group; telephone contact; or e-based contact such as websites, applications, texts, email, Facebook groups, or support forums. Contact was daily in some studies, for example, via text messages.

Combined interventions incorporated aspects from both diet and physical activity. Of the 33 RCTs deemed within the systematic reviews to have incorporated combined interventions, eight focused mainly on diet and six mainly on physical activity with the others having an equal emphasis. Weight management was reported as an element of 18 interventions. Self-monitoring of weight gain was the exclusive focus of one RCT and an aspect incorporated into three further RCTs. Provider monitoring and feedback around GWG was a feature of a further four RCTs. Relatively few trials incorporated psychosocial factors as part of their intervention, with one RCT each incorporating stress management, anxiety management, or management of emotional binge eating. A further five RCTs were reported to use other behavioral strategies, for example, identification of barriers, problem solving, using social support, or increasing self-efficacy.

## 3.2 | Methodological quality of systematic reviews

Table 2 provides AMSTAR-2 quality assessment scores. Four reviews[27,28,34,36] did not explicitly report that review methods were established prior to conducting the review, and a further five[12,31,32,39,40] only partially reported elements of their protocol or the protocol was not reported to be registered. One review[33] was noted to have unjustified protocol violations, as several included trials incorporated women without overweight or obesity, so was also considered to have a critical flaw within this domain.

Only three reviews[12,31,38] were judged to have undertaken a fully comprehensive literature search. All of the other reviews partially met the criteria due to none reporting consulting with experts in the field; some also did not report searching trial registries[27,30,36,40] or searching references of included studies or other relevant literature.[29] Two reviews[34,37] did not report undertaking data extraction in duplicate.

All reviews that included meta-analysis justified its use and undertook appropriate methods. All but one review[34] reported adequately assessing the risk of bias within included studies. However, of those that undertook meta-analysis, seven reviews[27–29,34,36,37,40] did not report assessing the impact of risk of bias within the included studies on the results of the meta-analysis, for example, through sensitivity analysis. Furthermore, five reviews[27,32,34,36,37] did not discuss the likely impact of risk of bias within included studies when interpreting or discussing the reviews' results. Only one review[34] was judged to provide inadequate exploration, explanation, and discussion around heterogeneity.

Overall confidence in the results of the review was rated as high for three reviews,[26,30,31] moderate for three reviews,[12,38,39] low for four reviews,[29,32,33,40] and critically low for five reviews.[27,28,34,36,37]

**TABLE 2** AMSTAR-2 checklist assessment for each included systematic review

| Item study | 1 | 2[a] | 3 | 4[a] | 5 | 6[a] | 7 | 8 | 9[a] | 10 | 11[a] | 12[a] | 13[a] | 14[a] | 15 | 16 | Overall confidence in the results of the review |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bain et al. (2015)[26] | ✓ | ✓ | X | / | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | High |
| Choi et al. (2013)[27] | ✓ | X | ✓ | / | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | X | X | ✓ | ✓ | ✓ | Critically low |
| Dodd et al. (2010)[28] | ✓ | X | X | / | ✓ | ✓ | X | ✓ | ✓ | X | ✓ | X | ✓ | ✓ | X | ✓ | Critically low |
| Du et al. (2019)[29] | ✓ | ✓ | X | / | ✓ | ✓ | / | ✓ | ✓ | X | ✓ | X | ✓ | ✓ | X | X | Low |
| Flannery et al. (2019)[30] | ✓ | ✓ | X | / | ✓ | ✓ | / | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | High |
| Flynn et al. (2016)[31] | ✓ | / | X | ✓ | ✓ | ✓ | / | ✓ | ✓ | X | NA | NA | ✓ | ✓ | NA | ✓ | High |
| Ho et al. (2012)[32] | ✓ | / | ✓ | / | NR | ✓ | / | ✓ | ✓ | X | NA | NA | X | ✓ | NA | ✓ | Low |
| I-WIP (2017)[38] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | / | / | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Moderate |
| Lau et al. (2017)[33] | ✓ | X | X | / | ✓ | ✓ | / | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Quinlivan et al. (2011)[34] | ✓ | X | X | / | ✓ | NR | X | / | X | X | ✓ | X | X | X | ✓ | ✓ | Critically low |
| Shieh et al. (2018)[36] | ✓ | X | ✓ | / | ✓ | ✓ | / | / | ✓ | X | ✓ | X | X | ✓ | X | ✓ | Critically low |
| Syngelaki et al. (2019)[37] | ✓ | ✓ | X | / | ✓ | NR | X | / | ✓ | X | ✓ | X | X | ✓ | ✓ | ✓ | Critically low |
| Thangaratinam et al. (2012)[12] | ✓ | / | X | ✓ | ✓ | ✓ | / | / | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Moderate |
| Wiebe et al. (2015)[39] | ✓ | / | X | / | ✓ | ✓ | / | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | X | ✓ | Moderate |
| Yeo et al. (2017)[40] | ✓ | / | X | / | ✓ | ✓ | / | / | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | Low |

Abbreviations: X, not met; /, partial yes; ✓, full yes; i-WIP, International Weight Management in Pregnancy Collaborative Group; NA, no meta-analysis; NR, not reported.

*Note*: Item 1: research question; item 2: protocol development; item 3: included study design explained, item 4: comprehensive literature search; item 5: study selection in duplicate; item 6: data extraction in duplicate; item 7: list of excluded studies; item8: included study description; item 9: risk of bias assessment; item 10: sources of funding of included studies; item 11: appropriate methods for statistically combining results; item 12: risk of bias impact on meta-analysis considered; item 13: risk of bias considered when interpreting/discussing results; item 14: heterogeneity of included studies discussed; item 15: publication bias assessment; item 16: author conflict of interest.

[a]Domains considered as critical.

## 3.3 | Risk of bias assessed within the reviews

As well as the quality of the systematic reviews, it is important to consider risk of bias within the included RCTs. Ten reviews assessed risk of bias using the Cochrane Collaboration risk of bias assessment tool, with a further review combining this with the Consolidating Standards of Reporting Trials statement.[40] Another review[12] did not report using a specific tool but assessed the same areas of bias as the Cochrane Collaboration risk of bias tool. One review[32] used the CASP RCT checklist, one the Jadad Scale,[39] and one review did not report undertaking any risk of bias assessment.[34] Most reviews judged their included studies to be of mixed quality, with one[30] judging them to be at high risk of bias.

Three reviews did not provide the scores attributed to individual studies.[12,37,39] However, scores for nine of the studies included in one of these reviews[12] were obtained from the full health technology review report by the same authors.[42] Individual risk of bias scores could not therefore be obtained for only one of the 56 included RCTs.[43] Where an RCT was incorporated into multiple reviews, the risk of bias judgements could vary widely. On overall risk of bias for each domain was therefore given according to the criteria in Table S4. Figure 2 provides the overall ratings for individual RCTs included in the reviews.

Out of 55 RCTs with reported risk assessment scores, the judgement of low risk of bias was made for random sequence generation in 40, allocation concealment in 22, attrition bias in

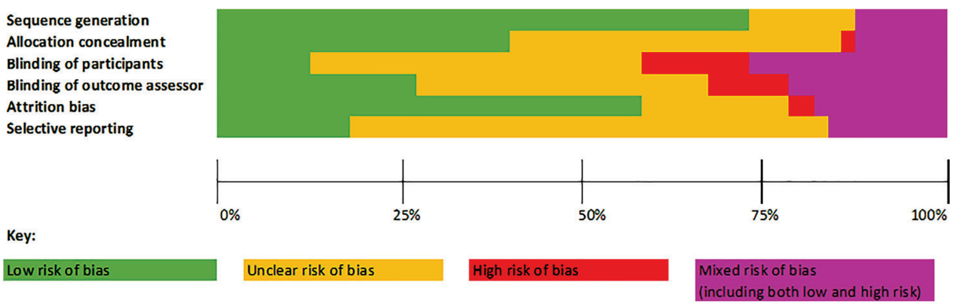


**FIGURE 2** Combined risk of bias from the different systematic reviews across the 55 included RCTs

32, and selective reporting in only 10 included studies. Due to the nature of the intervention, blinding of participants was deemed not possible or inadequate across the majority of the reviews. Blinding of assessors was judged to be low risk of bias in just 15 RCTs. Other bias was reported to be high for four RCTs. This was due to baseline imbalances for one RCT within Ho et al.,[32] but no explicit reason was given for the other three judgements by review authors.

#### 3.3.1 | Publication and excess of significance biases

Publication bias was considered by eight of the included reviews, two visually inspected for funnel plot asymmetry,[26,37] and the rest assessed funnel plot asymmetry alongside statistical tests, for example, Begg's, Egger's, and Peter's tests.[12,27,30,34,38,40] When assessing small study effects further within this overview of reviews, for meta-analyses with six or more included RCTs, statistical evidence ($p < 0.10$) suggested potential publication bias in four out of eight reviews within the GWG outcome,[29,36,38,40] one review reporting birthweight,[12] and both reviews with more than six RCTs reporting LGA.[12,29] Once considering this alongside a more conservative effect size in the largest study than the random-effects model summary estimate, concerns regarding small study effects only remained within two reviews[36,40] for the GWG outcome (Table S5).

When the overall effect size was assumed to be equal to the effect of the largest study, two meta-analyses had evidence of an excess of statistically significant studies ($p < 0.10$) for the GWG outcome[33,37] (Table S5). No evidence of excess of significant studies was observed within any other meta-analysis included within the reviews. Excess of significant findings alongside small study effects can provide evidence of selective reporting biases; however, no meta-analysis included in this overview indicated both small study effects and excess of significance. Small study effects and excess significance were however not calculated for outcomes reported narratively within reviews[30–32] and could not be calculated within one review[38] due to lack of clarity over included trials for each outcome.

## 3.4 | Synthesis of findings

### 3.4.1 | Gestational weight gain

All 15 systematic reviews included the outcome of GWG. Of these three[26,28,34] only included a subset of studies incorporated into a newer systematic review, so were excluded from the data synthesis for this outcome. Three further reviews[27,32,39] did not include any unique studies; however, all of their studies were not included as a subset within another systematic review, so remained within the data synthesis. It was not possible to evaluate the studies included within one review[38] as individual participant data were utilized. The other included systematic reviews incorporated 49 different RCTs, and 10,291 participants contributed to the analyses.

Three reviews provided a narrative synthesis of the results.[30–32] One review[30] reported GWG to be lower in the intervention than control groups in three of their included studies, of which one was noted to not exclusively recruit participants with overweight or obesity. Furthermore, it was unclear how many of their included studies reported this outcome but did not find a reduction in GWG. GWG was reported to be significantly lower in two of the six included studies within another review with narrative results[32] and nine of the 13 studies included within the other.[31] In this final review,[31] GWG was not significantly lower in the intervention group in the RCT that was not reported within other systematic reviews. A graphical representation of the results of the nine systematic reviews that undertook a meta-analysis can be seen in Figure 3, with full results provided in Table S5. Lifestyle interventions significantly reduced GWG in all but one included meta-analysis. The weighted mean difference in weight gain between control and intervention groups varied from −2.41 to −0.3 kg. The

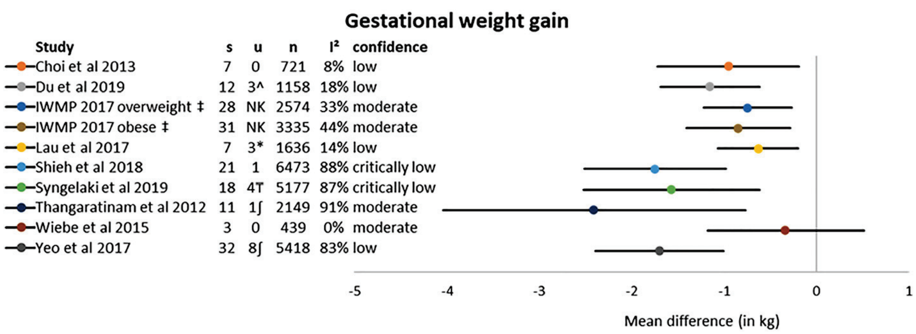


**FIGURE 3** Graphical representation of gestational weight gain meta-analysis results. $s$ = number of included studies, $u$ = number of unique studies, $n$ = number of participants, $I^2$ = percentage of variability in the effect estimate due to heterogeneity, confidence = AMSTAR-2 confidence in the results of the review. ^compares different arms in Renault et al.[44] to other reviews. ‡ adjusted for baseline weight and clustering effect. * this review was noted to include two RCTs that incorporated women of normal BMI, despite review inclusion criteria being exclusively women with overweight/obesity. compares different arms in Bogarts et al.[45] to other reviews. ∫ this review was noted to include 1 RCT in their overweight/obese meta-analysis that did not exclusively recruit participants with overweight/obesity

percentage of variability in the effect estimate due to heterogeneity was considerable within four included systematic reviews. Confidence in the findings of the systematic reviews was rated as low or critically low in seven included systematic reviews, moderate in three systematic reviews and high in two reviews that reported this outcome narratively.

Only one review considered adherence to IOM GWG guidelines.[38] Adherence to IOM guidelines was given as overall proportions rather than according to group allocation within trials. Within the overweight subgroup, 19% had GWG below recommendations, 29% within recommendations, and 51% over recommendations ($n$ = 1245). Within the obese subgroup, 26% had a GWG below recommendations, 30% within recommendations, and 44% over recommendations ($n$ = 1562).

### 3.4.2 | Dietary intake assessments

Three included reviews assessed changes in dietary intake.[32,33,36] Two reviews reported calorie intake.[33,36] Of the five included RCTs, four reported some reduction in calorie intake in the intervention group; however, they measured change in calorie intake at different time points including at 27–28 weeks, 32 and 36 weeks, over all three trimesters, and from study enrolment to 36 weeks. Neither of the two studies that assessed calorie intake at 15–18 weeks' gestation found differences at this timepoint.

Four out of five RCTs incorporated into two separate reviews[31,33] reported decreased energy intake from saturated fat in the intervention group. Six studies across two reviews[31,33] assessed intake of fruit and vegetables. Intake increased in both the intervention and control groups in one study and increased only in the intervention groups in the other five studies; however, one of these studies was noted not to have exclusively recruited women with a raised BMI. One review[31] also reported that sugar/fizzy drink consumption decreased in two studies and protein intake increased in two studies. In the two studies that assessed dietary fiber intake within that review,[31] one found increased consumption with the intervention, while the other found no difference.

### 3.4.3 | Physical activity assessments

Two included reviews assessed changes in physical activity.[30,33] One review[30] found no differences in step count between intervention and control groups in two included studies. Similarly, the other review[33] that included three studies found no differences in step count; however, out of these three studies it was noted that one recruited postnatal women and two studies did not exclusively recruit women with a raised BMI. One review[30] reported meta-analyses showing compared with the control group, intervention groups had increased metabolic equivalent (minutes/week) across eight studies and increased amount of oxygen used during exercise ($VO_2$ max) across two studies.

One review[33] reported no differences in the number of moderate to vigorous physical activity minutes per week between intervention and control groups when using either self-reported or an objective measure, SenseWear. However, the study using SenseWear technology was noted to include women with a BMI in the normal range not just those with overweight or obesity. Self-reported exercise was not significantly different between intervention and control groups in one review including four studies,[33] but was increased in another review[30] incorporating two studies. Both reviews however were noted to include studies for this outcome despite them not exclusively incorporating women with overweight or obesity.

### 3.4.4 | Maternal morbidity

Seven of the included systematic reviews reported the outcome of gestational diabetes (see Figure 4). One meta-analysis with low confidence in the findings[29] found physical activity interventions reduced the risk of GDM, and a second meta-analysis with moderate confidence in the findings[12] found dietary interventions reduced the risk of GDM. One review[30] reported narratively that GDM reduced in two included studies; however, it was not clear how many of their included studies reported this outcome but did not find a reduction in GDM; furthermore, one of the trials that reported a reduction in GDM with physical activity was noted to not exclusively recruit participants with overweight or obesity. None of the meta-analyses reporting any lifestyle intervention (dietary and/or physical activity) found a difference in risk of GDM between intervention and control groups.

For the outcome of pre-eclampsia, two systematic reviews only included a subgroup of trials included in a subsequent review,[28,33] so were not included in the analysis for this outcome. The remaining five meta-analyses found no evidence that lifestyle interventions impacted on the risk of pre-eclampsia for women with overweight or obesity. The review undertaking narrative analysis found none of their included studies reduced pre-eclampsia.

There was no evidence of an impact of lifestyle interventions in women with overweight or obesity on the incidence of cesarean section or preterm delivery.

### 3.4.5 | Infant outcomes

Eight systematic reviews included the outcome of birthweight. Of these three[26,28,34] only included a subset of studies incorporated into a newer systematic review, so were excluded from the data synthesis for this outcome.

A graphical representation of the results of the four systematic reviews that undertook a meta-analysis can be seen in Figure 5. Lifestyle interventions had no significant impact on birthweight. The weighted mean difference in birthweight between control and intervention groups varied from −40 to 10 g. The percentage of variability in the effect estimate due to heterogeneity was likely to be unimportant (0%–27%) within the included meta-analyses.

One review[31] also provided a narrative synthesis of results. They reported no difference between lifestyle intervention and control groups within 11 included studies and a significant increase in birthweight with lifestyle interventions in the remaining two studies.

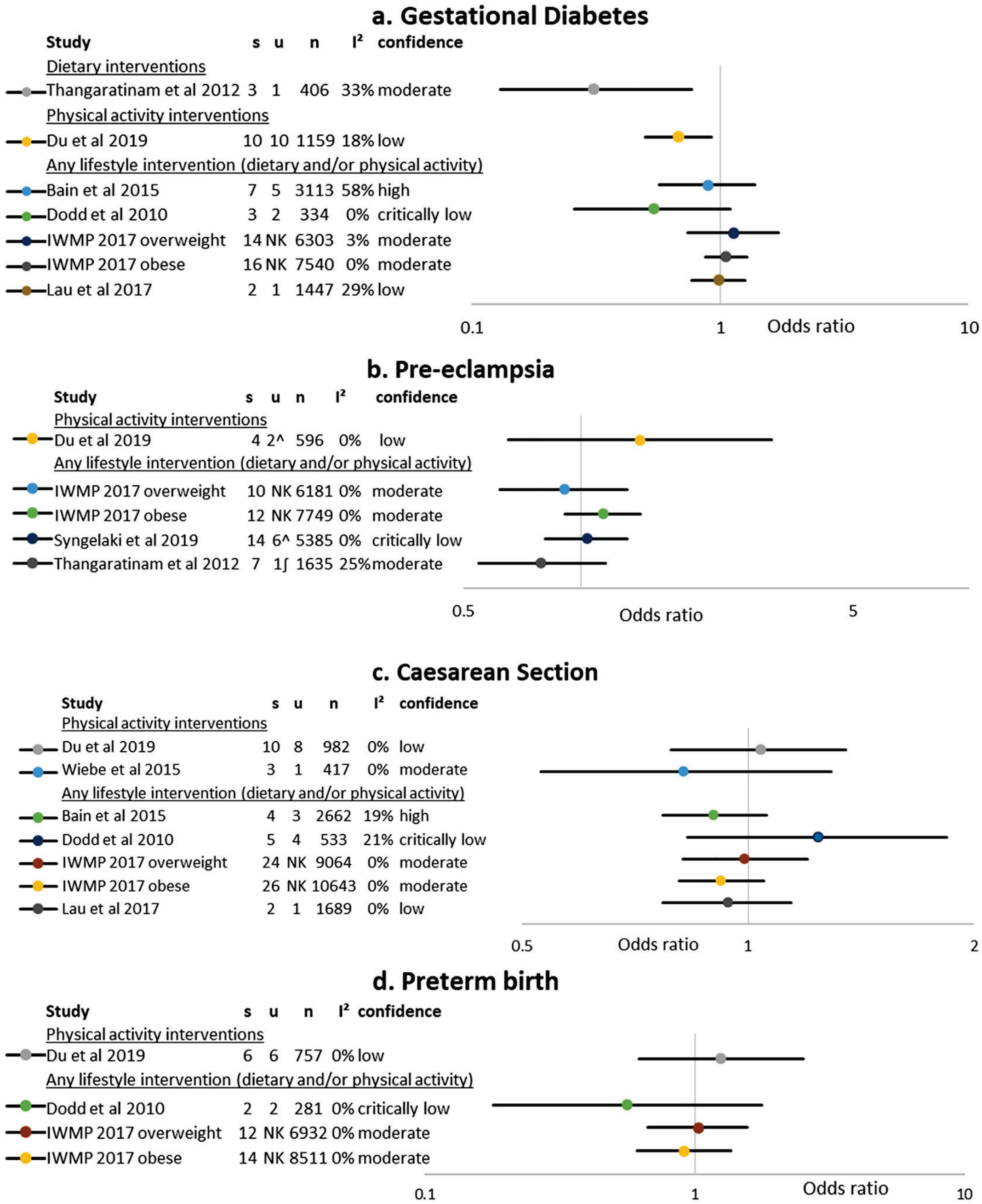


**FIGURE 4** Graphical representation of other maternal outcomes (odds ratios with 95% confidence intervals) within included systematic reviews. *s* = number of included studies, *u* = number of unique studies, *n* = number of participants, $I^2$ = percentage of variability in the effect estimate due to heterogeneity, confidence = AMSTAR-2 confidence in the results of the review. ^Systematic reviews compared different arms of Renault et al.[44] within their meta-analyses, so taken as non-overlapping study. ʃ this review was noted to include one RCT in their overweight/obese meta-analysis that did not exclusively recruit participants with overweight/obesity

One of the included studies that showed a lack of significance was noted to actually report LGA and macrosomia, not birthweight. Confidence in the results of the systematic reviews was judged to be low within two meta-analyses, moderate within the other two meta-analyses, and high in the review reporting narrative results.

There was no evidence of an impact of lifestyle interventions in women with overweight or obesity on the incidence of macrosomia, LGA, low birthweight, or SGA (Figure 5).

## 3.5 | Subgroup and sensitivity analyses

### 3.5.1 | Subgroup analysis

Subgroup analysis by type of intervention, dietary only, physical activity only, or combined interventions incorporating both physical activity and dietary components was undertaken for the primary outcome GWG. Full results are given in Table S6. Physical activity

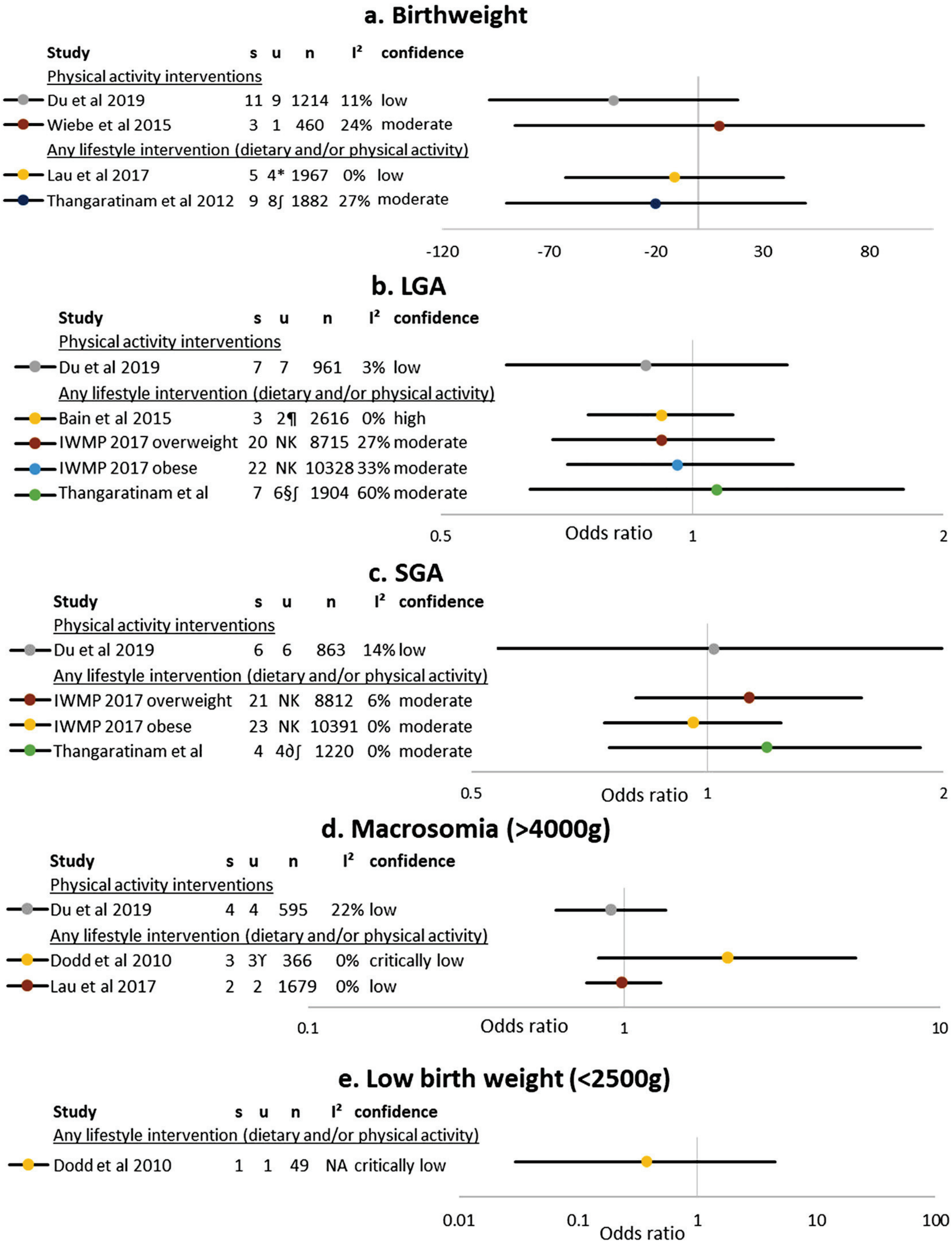


**FIGURE 5** Graphical representation of birthweight and birthweight related outcomes within meta-analysis results within included systematic reviews. *s* = number of included studies, *u* = number of unique studies, *n* = number of participants, $I^2$ = percentage of variability in the effect estimate due to heterogeneity, confidence = AMSTAR-2 confidence in the results of the review. * this review was noted to include two RCTs that incorporated women of normal BMI, despite review inclusion criteria being exclusively women with overweight/obesity. ∫ this review was noted to include one RCT in their overweight/obese meta-analysis that did not exclusively recruit participants with overweight/obesity. ¶ one trial reported birthweight >4000 g not LGA. § Three included trials report birthweight >4000 g and one trial reported birthweight >4500 g rather than LGA. ∂ Three of the included trials report birthweight <2500 g not SGA. ϒ One trial reported birthweight >4500 g not >4000 g

only and combined interventions had varied results, with some reviews finding GWG to significantly decrease with the intervention compared with the control and other reviews not. Only for dietary interventions did the reviews unanimously find GWG to decrease in the intervention groups. These results should however be treated with caution, as it was noted there was a lack of consistency between the reviews over which subgroup an individual study belonged to, for example, some reviews would attribute an RCT to physical intervention only, but others would attribute it to a combined intervention.

### 3.5.2 | Sensitivity analysis on AMSTAR quality

Overall confidence in the findings of the reviews was only judged to be high in three reviews.[26,30,31] All of these evaluated the impact of diet and/or physical activity interventions. The impact of lifestyle interventions on GWG was unclear within these reviews. In the two reviews[30,31] reporting narrative results GWG was reduced in some but not all included studies and in the review incorporating meta-analysis[26] GWG was not significantly lowered 0.28 kg (95% CI −1.13, 1.69, three studies, 1980 participants, $I^2 = 43\%$).

## 3.6 | Strength of evidence

The strength of the evidence for each outcome was summarized using the GRADE approach. The overall certainty of evidence for each outcome, alongside reasons for downgrading the evidence, is recorded in Table 3. The strength of the evidence was judged to be low for pre-eclampsia, cesarean section and birthweight and very low for all other outcomes.

# 4 | DISCUSSION

A small reduction in GWG of between 0.3 and 2.4 kg with lifestyle interventions compared with standard care was noted within the included systematic reviews. However, overall certainty of this evidence is very low. This was due to concerns over risk of bias within both the included trials and the included systematic reviews, substantial heterogeneity within the included reviews, and potential small study effects within two reviews that were among those incorporating the largest number of trials. The small reduction in GWG is in line with the findings of a meta-analysis from a consortium of seven centers that undertook collaborative randomized trials of lifestyle interventions in women with overweight or obesity[46] and with a previous overview that found GWG was reduced with diet and physical activity interventions by between 0.7 and 1.8 kg for women of all BMI classes and by between 0.63 and 0.91 kg in a subgroup of women with overweight or obesity.[47] Our finding also agrees with the results of a recent RCT that was not within the included systematic reviews, which showed a small reduction in GWG but no impact on pregnancy and infant outcomes with partial meal replacement and encouragement to achieve 10,000 steps per day.[48] Due to the lack of reporting within the current systematic reviews, it was not possible to determine if this small reduction in gestational weight gain had any impact on the proportion of women with GWG within IOM recommendations. Further research is also required around the impact of this reduced GWG on weight retention postpartum, as weight gain during pregnancy is a well-recognized contributor to increasing maternal BMI over the childbearing years.[49]

Excess GWG has been associated with increased adverse pregnancy outcomes in observational studies.[50,51] Although GWG was significantly different in the meta-analyses undertaken within the majority of reviews, the small nature of the reduction did not appear to have a clear impact upon maternal and infant outcomes for women with overweight or obesity. For some outcomes, such as low birthweight, preterm birth, and pre-eclampsia with low incidences, this may be due to a lack of power within the current evidence; however, for other outcomes such as GDM, macrosomia, SGA, LGA, and cesarean section, at least some of the trials included within the meta-analyses were adequately powered to detect reductions in these outcomes. The lack of benefit on pregnancy or infant outcomes from lifestyle interventions noted within this overview of reviews was in line with a previous meta-analysis of intervention trials undertaken across a consortium.[46] Within this overview, only for the outcome of GDM was there evidence that dietary only interventions or physical activity only interventions may reduce the odds of GDM with the intervention compared with control. The lack of reduction in the incidence of macrosomia with lifestyle interventions within this overview contrasts with a previous overview of reviews that found a reduced incidence of macrosomia within a subgroup of women with overweight or obesity[47]; however, this current overview contains more systematic reviews incorporating a wider range of trials that the previous overview.

While no clear positive clinical outcomes have been demonstrated from undertaking lifestyle interventions during pregnancy within the subgroup of women with overweight or obesity, there was also no evidence of any adverse outcomes from restricting diet or undertaking physical activity, with SGA, low birthweight, and preterm delivery all showing no differences between those in the intervention and control groups.

A recent systematic review of six studies that incorporated cost estimates found lifestyle interventions aimed at limiting GWG were mainly not cost effective.[52] This was largely due to the lack of benefit across a range of clinical outcomes, which some studies may have been underpowered to detect. The analysis was also limited by the lack of studies reporting cost-effectiveness.[52] Furthermore, neither this overview of reviews nor the cost effective analysis could consider the impact of reduced GWG or improved maternal nutrient intake and exercise participation on important longer term benefits such as postpartum weight retention, maternal BMI at the start of a subsequent pregnancy, maternal psychosocial well-being, and long-term infant health due to lack of current evidence.

The impact of maternal diet during pregnancy on the long-term well-being of the infant is increasingly recognized, as the role of fetal-programming through epigenetics is increasingly understood.[53,54] The Mediterranean diet is considered one of the healthiest dietary patterns within the general population.[54] Limited studies within pregnant populations suggest that adherence to a Mediterranean style diet may reduce long term metabolic ill health in the offspring.[54] Furthermore, a recent trial of a low glycemic diet in women of all BMIs showed differential methylation in infants within the intervention and control groups.[55] Our understanding of the impact of maternal diet on human

**TABLE 3** Summary of findings table for lifestyle interventions compared with standard care in pregnancy for women with overweight or obesity

| Certainty assessment | | | | | | | Summary of findings |
|---|---|---|---|---|---|---|---|
| Systematic reviews reporting outcome | Risk of bias | Inconsistency | Indirectness | Imprecision | Publication bias | Overall certainty of evidence | Impact |
| Gestational weight gain | | | | | | | |
| 9 | Serious[a] | Serious[b] | Not serious | Not serious | Strongly suspected[c] | ⊕◯◯◯ VERY LOW | Small reduction in gestational weight gain suggested, of between 0.3 and 2.4 kg with lifestyle interventions compared with standard care |
| Gestational diabetes (GDM) | | | | | | | |
| 7 | Serious[a] | Serious[d] | Not serious | Serious[e] | None | ⊕◯◯◯ VERY LOW | Reduced odds of GDM were suggested in one systematic review of dietary only interventions and one systematic review of physical activity only interventions. There was no consistent reduction in GDM observed in women undertaking any lifestyle interventions (diet and/or physical activity) compared to standard care |
| Pre-eclampsia | | | | | | | |
| 4 | Serious[a] | Not serious | Not serious | Serious[e] | None | ⊕⊕◯◯ LOW | No clear effect on the odds of pre-eclampsia in women undertaking lifestyle interventions compared to standard care |
| Cesarean section | | | | | | | |
| 6 | Serious[a] | Not serious | Not serious | Serious[e] | None | ⊕⊕◯◯ LOW | No clear effect on the odds of cesarean delivery in women undertaking lifestyle interventions compared with standard care |
| Preterm delivery | | | | | | | |
| 3 | Serious[a] | Not serious | Not serious | Serious[e] | Other bias[f] | ⊕◯◯◯ VERY LOW | No clear effect on the odds of preterm delivery in women undertaking lifestyle interventions compared with standard care |
| Birthweight | | | | | | | |
| 4 | Serious[a] | Not serious | Not serious | Serious[e] | None | ⊕⊕◯◯ LOW | No clear effect on birthweight in infants of women undertaking lifestyle interventions compared with standard care |
| Macrosomia | | | | | | | |
| 4 | Serious[a] | Not serious | Not serious | Serious[e] | Other bias[f] | ⊕◯◯◯ VERY LOW | No clear effect on the odds of macrosomia in infants of women undertaking lifestyle interventions compared with standard care |
| Low birthweight | | | | | | | |
| 1 | Serious[g] | Not serious | Not serious | Very serious[h] | Other bias[f] | ⊕◯◯◯ VERY LOW | No clear effect on the odds of low birthweight infants in women undertaking lifestyle interventions compared with standard care |

(Continues)

**TABLE 3** (Continued)

| Certainty assessment | | | | | | | Summary of findings |
|---|---|---|---|---|---|---|---|
| **Systematic reviews reporting outcome** | **Risk of bias** | **Inconsistency** | **Indirectness** | **Imprecision** | **Publication bias** | **Overall certainty of evidence** | **Impact** |
| Large for gestational age | | | | | | | |
| 4 | Serious[a] | Serious[d] | Not serious | Serious[e] | Other bias[f] | ⨁◯◯◯ VERY LOW | No clear effect on the odds of infants large for gestational age in women undertaking lifestyle interventions compared with standard care |
| Small for gestational age | | | | | | | |
| 3 | Serious[a] | Not serious | Not serious | Serious[e] | Other bias[f] | ⨁◯◯◯ VERY LOW | No clear effect on the odds of infants small for gestational age in women undertaking lifestyle interventions compared with standard care |

[a]Downgraded (−1) for risk of bias due to concerns over bias within the included randomized controlled trials with less than half being judged to be low risk of bias across all three areas of random sequence generation, allocation concealment and attrition bias and due to low or critically low confidence in the findings of the majority of included systematic reviews.
[b]Downgraded (−1) for inconsistency due to substantial unexplained statistical and procedural heterogeneity within many included systematic reviews.
[c]Downgraded (−1) for publication bias due to small study effects noted within several systematic reviews with the highest number of included randomized controlled trials.
[d]Downgraded (−1) for inconsistency due to statistical and procedural heterogeneity between studies within some included reviews.
[e]Downgraded (−1) for imprecision due to uncertainty over the true effect size within the different included systematic reviews.
[f]Downgraded (−1) due to suspected poor reporting of outcome within included systematic reviews despite the outcome itself being reported in many included randomized controlled trials.
[g]Downgraded (−1) for risk of bias due to concerns over bias within the included randomized controlled trial and within the included systematic review.
[h]Downgraded (−2) for very serious concerns around imprecision due to single study, small sample size, with few events.

fetal development and on the long-term health outcomes for infants are only just beginning to develop. Further exploration is required to increase our understanding of the specific nutritional components that are important in pregnancy, to both maximize pregnancy outcomes and long-term infant health.

Historically, pregnancy has been viewed as a "teachable moment" for women due to their motivation, related to the developing fetus's health, and the frequent contact with health professionals providing an opportune time to deliver health promotion.[56] However, this overview of reviews has been unable to demonstrate a clear clinical benefit of lifestyle interventions during pregnancy for women with a raised BMI. This may in part be due to the short time scale of pregnancy in which to change habits and also due to competing demands on a woman's attention including financial, emotional, and other health promotional activities.[57] It is suggested that targeting interventions to the pre-conception period could have more impact, as women have more time to be exposed to healthy lifestyle advice and to assimilate positive behavior change.[57,58] There are currently very limited lifestyle intervention studies during the preconceptual period around nutrition.[59] This is despite NICE guidance highlighting the importance of the pre-conceptual period for informing women with a raised BMI about losing weight prior to pregnancy.[14] In part, this may be due to the perception that undertaking pre-conception studies is difficult due to the number of unplanned pregnancies. A recent survey of women at antenatal clinics in a region within England has however suggested that just 5.5% of pregnancies not ending in induced abortion were unplanned.[60] Given the importance of the preconceptual and early pregnancy periods and their impact on fetal-programming, it is an urgent area of further investigation.

There was insufficient evidence to confirm the most effective type of lifestyle intervention in women with overweight or obesity during pregnancy, with all types of intervention: dietary only, physical activity only, and combined interventions having an impact on GWG within some of the included reviews. It was also difficult to identify the characteristics of interventions that have the potential to impact most upon GWG and clinical outcomes, due to the pronounced methodological and statistical heterogeneity between interventions within each review. Interventions could vary from providing women with additional information to in-depth dietary and physical activity support. A previous meta-analysis of lifestyle interventions for women across all BMI categories found that physical activity interventions that combined both individual and group elements were more effective at reducing GWG than individual or group interventions in isolation.[61] However, none of the other study characteristics investigated including gestation at which the intervention commenced, intensity of the intervention in terms of length of time, frequency, or duration of the intervention or the type of diet advised predicted the success of the lifestyle intervention.[61] This current lack of clarity regarding effective interventions during pregnancy appears to carry over into practice, with a recent study of providers and commissioners[62] highlighting provider's desire for clearer guidance on which to base their practice. This current overview illustrates how much our understanding of effective interventions still needs to advance. Michie et al.[63] have developed a taxonomy of behavior change techniques that allows the active behavior change components of interventions to be more clearly identified. Determining which behavior change techniques are effective, as well as the required frequency of an intervention requires further investigation within the subpopulation of pregnant women with overweight or obesity. Indeed, the identification of effective components of lifestyle interventions that promote dietary improvements during pregnancy and optimize gestational weight gain has been identified as a key research priority by the Health in Preconception, Pregnancy, and Postpartum Global Alliance.[64]

### 4.1 | Limitations of the review

A strength of this review was limiting the evidence base to RCTs to minimize heterogeneity in study design and to ensure comparability. The review searched multiple databases with no date restrictions to provide a comprehensive overview of current evidence. Rigorous quality appraisal by two reviewers was also undertaken using the AMSTAR-2 tool.

The limitations within this review were the diverse nature of the included lifestyle interventions preventing understanding of effective components of interventions. There is also inconsistency in end points for GWG within included trials and therefore within the systematic reviews. GWG from pre-pregnancy to delivery is used to assess IOM adherence; however, multiple other time points were used within the included trials. One review[40] describes these clearly with "initial" weight taken as pre-pregnancy, early pregnancy, or trial entry, which extended up to 28 weeks within one study. "End" weights were from 24 weeks' gestation up to delivery. The inclusion of few studies undertaken within low income countries within the included systematic reviews is recognized as a further limitation, despite the increased incidence of obesity globally.

It is recognized that there was an updated version of one included review.[26] However, the more recent update[65] no longer included an overweight/obese subgroup for the outcome of GWG, so was not eligible for inclusion. The decision was therefore made to retain the older review[26] within this overview.

This overview is also limited by the limitations within the included reviews including the quality of their searches, extraction, and reporting. Areas of weakness identified included, for example, combining LGA and macrosomia outcomes, including studies within their overweight and/or obese subgroups that were not exclusively women with a raised BMI, for example, including women of normal weight,[66–68] those with previous GDM as well as those with a raised BMI[69] and women with raised blood glucose levels.[70] Others too have noted the inclusion of apparently ineligible trials within systematic reviews.[71] Furthermore, several errors in data extraction within included reviews were noted such as extracting standard error rather than standard deviation. It is felt that going back to the original study results within this overview and correcting or highlighting the areas of inconsistency has mitigated these limitations in part.

### 4.2 | Implications for research

Further trials are required to identify the most effective components of interventions, as well as the required frequency and level of supervision within an intervention. Exploration of the impact of specific nutrients in pregnancy also need further exploration in both pregnant women as a whole and within the subgroup of women with overweight or obesity. To reduce some heterogeneity between studies, a universal definition for the measurement of GWG would be beneficial. Consideration should also be given to exploring lifestyle interventions in the prenatal period given the current lack of benefit on maternal and infant outcomes from lifestyle interventions during pregnancy.

Care is required when compiling an overview of reviews to prevent perpetuation of errors that are present within included systematic reviews.

## 5 | CONCLUSION

Lifestyle interventions appear to have a small effect in reducing GWG in women with overweight or obesity. Heterogeneity between studies within most of the included reviews meant it was not possible to identify the most effective interventions within this group of women. Current evidence does not show a clear benefit on maternal and infant outcomes from the small nature of the reduction in GWG produced by lifestyle interventions in women with overweight or obesity.

### ETHICAL APPROVAL

Ethical approvals were not required to undertake this overview of reviews.

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### CONFLICT OF INTEREST

No known conflicts of interests to declare.

### AUTHOR CONTRIBUTIONS

F.F. was primary responsible for the development of the research question, study design and protocol, assessing articles for inclusion, undertaking quality appraisal and extraction of data of included studies, analysis, and writing the main body of the manuscript and also agreed final manuscript for submission. H.S. was responsible for advisory role in research question and protocol development, assessed full text articles for inclusion, undertaking quality appraisal of included studies, cross-checked all extracted data, and revised manuscript, also agreed final manuscript for submission.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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## 3.5 Summary and implication for thesis

The overview was undertaken in a robust and rigorous manner. A protocol was published a priori, as considered best practice, to enhance the transparency and reproducibility of the overview of reviews. Further strengths of the overview are that it searched multiple databases with no date restrictions to provide a comprehensive overview of evidence. Rigorous quality appraisal was undertaken by two reviewers using the AMSTAR-2 tool to establish the level of confidence in the quality of each included systematic review(285). Additionally, the strength of the evidence for each outcome was considered using the GRADE approach(286).

The key finding of the overview of systematic reviews was that lifestyle interventions had a small effect in reducing GWG in women with overweight or obesity. However, the clinical significance of the reduction in GWG in women with overweight or obesity was questioned given the small nature of the reduction in GWG and the lack of clear impact upon clinical outcomes for the mother or her infant. Overall certainty in the evidence, assessed using the GRADE approach, was low for pre-eclampsia and birthweight and very low for all other outcomes. Additionally, heterogeneity between the studies included within the systematic reviews meant the most effective lifestyle interventions for this group of women could not be identified from the current evidence base, including the required intensity of an intervention.

The work provided an overall body of evidence regarding lifestyle interventions for women with overweight or obesity to avoid excessive GWG by summarising previously published works. This overview therefore added clarity within this area.

The research gaps identified within the background literature in Chapter 2 and within this overview of systematic reviews are explored throughout the rest of the thesis in the programme of research undertaken.

The next chapter sets out the detailed methodology of the programme of research to address the gaps identified.

# Chapter 4: Methodology

## 4.1 Introduction

This chapter provides an overview of the theoretical frameworks influencing this programme of research and the chosen methods. It discusses mixed methods research designs and the research paradigms generally associated with mixed methods approaches. A rationale for the use of an explanatory sequential mixed methods design and the paradigmatic stances taken within the research are subsequently given, alongside an overview of the programme of research. Finally, a brief description of the methods used, and the ethical considerations is presented, with full details of the methods provided within each related article.

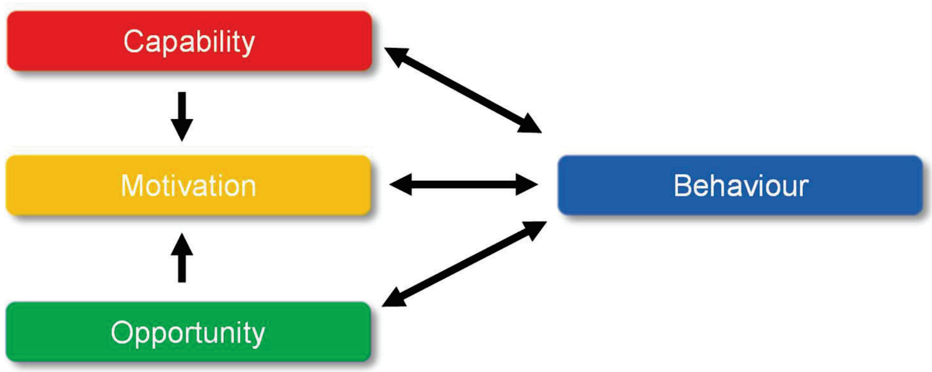
## 4.2 Theoretical framework

A theoretical framework is the structure, scaffolding and frame of a study(287). This theory provides the worldview lens from which the problem is analysed(288) and therefore determines how the research question is framed, what data is gathered and what is looked for when interpreting the data(289). Multiple competing theories exist, which allows phenomena to be viewed from multiple perspectives, with each perspective providing a reasonable explanation of a phenomenon(289). It is therefore considered essential to explicitly state the theoretical framework when undertaking any research(288).

This current research was influenced by two theoretical frameworks. They provided the lens through which the study occurred and was interpreted. The first of the theoretical frameworks was the Capability, Opportunity, Motivation, Behaviour (COM-B) model(290). This views human behaviour to be generated by three essential components: capability, motivation and opportunity, with these three entities in turn also influenced by behaviour(290). The COM-B model is shown in Figure 4.1.

Capability has both physical and psychological components and includes the knowledge and skills that an individual requires to undertake the given behaviour(291). Motivation is the brain processes involved in producing a behaviour and includes both autonomic (instinctive or habitual processes) as well as a reflective component which involves conscious thought processes such as making plans and evaluating(291). Finally, opportunity includes both physical opportunities for example having the material resources to undertake a behaviour, as well as social opportunities with other people and cultural norms impacting upon behaviour(291).

**Figure 4.1. The COM-B model** (Based on Michie et al., 2011(290))




Within the NICE guidance on individual approaches to behaviour change, the use of the COM-B model is recommended to tailor interventions to both assess and address participants individual needs(273). This framework has been used extensively by other researchers within the field of maternal obesity and/or gestational weight management(292-295).

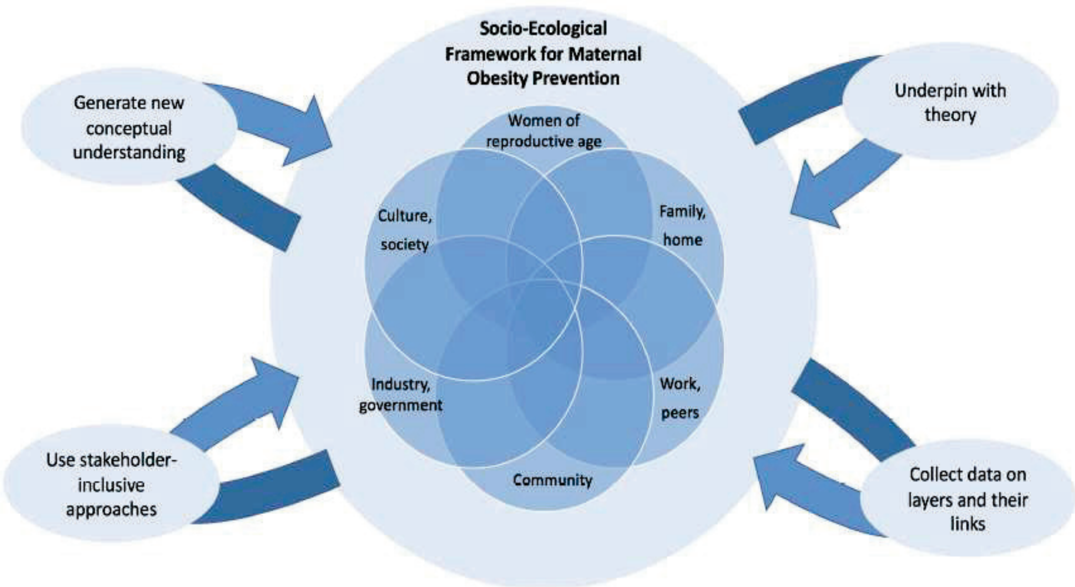
The second theoretical framework influencing this current research was the socio-ecological model(296). Behaviour is viewed as being determined by the five major factors listed in Table 4.1. Intra-personal factors, incorporate individual characteristics such as knowledge, attitude, self-concept, intentions and skills. These are impacted by the developmental history of the individual(296). Inter-personal factors include the social groups or support systems surrounding the individual such as family and friends(296). Rather than just considering how these social influences could be used to support the individual to change, the socio-ecological model also places an emphasis on changing social norms that may influence an individual's undesirable behaviour(296). This was not the case in models developed prior to the socio-ecological, when even if aspects of social support were incorporated the focus remained on changing the individual behaviour, not on modifying the social environment[296]. The third major factor within the model is institutional factors. These include organisational characteristics or rules and regulations within social institutions[296]. While interventions at this level may support change in the individual such as increasing food nutritional information labelling, the model also highlights the importance of changing organisational culture to become more supportive of health issues[296]. Community factors incorporate the relationship between organisations, institutions and networks[296]. Interventions that promote interagency working for health promotion activities would fall under this level. The final factor within the model is public policy factors which contain local as well as national policies and laws[296].

**Table 4.1. The five major factors viewed as determinants of behaviour within the socio-ecological model** (McLeroy et al., 1988)[296]

| **Behaviour is determined by:** |
|---|
| • Intra-personal factors<br>• Inter-personal factors<br>• Institutional factors<br>• Community factors<br>• Public policy |

This model has been used by other researchers to conceptualise or analyse barriers to healthy lifestyles among pregnant women[297,298]. Recently a new socioecological model has also been developed specifically for the prevention of maternal obesity[299]. This removed the individual from being the centre of focus which can lead to stigmatisation and blame for the woman[299]. Instead, the focus has been placed on the interaction between all layers within the socio-ecological model including the woman herself, her family, work or peers, wider community, industry or government and overall culture and society. The link between the multiple factors is represented in Figure 4.2.

**Figure 4.2. The socio-ecological framework for maternal obesity prevention** (From Hill, 2021: Publisher John Wiley and Sons)[299]




## 4.3 Mixed methods research

Mixed methods research methodology began to develop from the mid 1980's when authors were moving from viewing qualitative and quantitative studies as separate entities and to consider how the two could be combined and complement each other[300]. Textbooks were published around mixed methods from the late 1990's, for example Tashakkori & Teddie (1998)[301]. Subsequently, the first peer-reviewed journal dedicated to mixed methods the 'Journal of Mixed Methods Research' was established in 2007[302]. Mixed methods research grew out of the recognition that all methods of gaining knowledge are fallible, therefore using multiple diverse methods can be beneficial[303]. This is especially important for social phenomena that are complex in nature[303].

There are several advantages of mixed methods research. They combine the different perspectives of qualitative and quantitative methodology, while at the same time compensating for the inherent weakness of only using one method[300]. The qualitative aspect can add context and participants voices, while the quantitative aspect allows generalisability of results. Mixed methods studies can therefore answer research questions that could not be asked with one approach, for example qualitative interviews can be used to explain quantitative results(300). It is increasingly recognised that complex questions within research are best answered by integrating both quantitative and qualitative evidence – as each lead to a distinct, but important, understanding and explanation of complex problems(302). By combining the two approaches new insights can be made. Mixed methods research also provides enhanced opportunities for triangulation(302).

The disadvantages of mixed methods research are that the researcher requires expertise in both qualitative and quantitative research methodology and to understand how to ensure rigour within the quantitative aspect as well as credibility within the qualitative aspect(300). Additionally, given the multiple data collection methods and the requirement for data integration, more resources are required for mixed methods studies.

Mixed methods research has been defined in multiple ways by different researchers over the years(300). Four core characteristics of mixed methods research have been proposed(300):

1. It collects both qualitative (open-ended) and quantitative (closed ended) data in a rigorous way in response to a specific research question.
2. These are combined into a specific research design that provides the procedure for undertaking the study.
3. The procedures are framed within theory and philosophy.
4. The findings from the two forms of data collection are combined.

Many different mixed methods classifications have been advanced, however most recently three core types of mixed methods design have been described. These are the convergent design, the explanatory sequential design and the exploratory sequential design(300). The process, weighting and timing corresponding to each of these mixed methods research designs are shown in Table 4.2.

**Table 4.2. Core mixed methods research designs**

| Design type | Notation | Weighting | Process | Timing |
|---|---|---|---|---|
| **Convergent** | QUAN + QUAL | Equal | Qualitative and quantitative methods implemented simultaneously | Concurrent |
| **Explanatory sequential** | QUAN → qual | Quantitative | Qualitative results used to explain the quantitative ones. | Sequential |
| **Exploratory sequential** | QUAL → quan | Qualitative | Qualitative methods used to explore the phenomena, which are then tested for generalisability with quantitative methods | Sequential |

Table developed from Creswell & Plano Clark (2017)[300, p63]

In addition to the core methods described above, numerous complex mixed method designs have been identified. One of these is the mixed methods experimental (or intervention) design. Within this the quantitative component is the dominant aspect and is used to assess the impact of an intervention compared to a comparison group. A supplemental qualitative component can occur either before the intervention (exploratory sequential design), in parallel with the intervention (the convergent design) or after the intervention (explanatory sequential design)[300].

## 4.4 Research paradigms

Paradigms have been described as the beliefs, values, and assumptions held by the members of a specific community about knowledge and how it is formed[304]. Since the original work by Kuhn (1970)[304], the concept of paradigms has subsequently been used by researchers in four distinct ways.

This includes as all-encompassing worldviews, differences in epistemological stance, shared beliefs within a research field and as model exemplars for how research should be done(305). Each of these definitions are not mutually exclusive and range from the most general to the more specific(305).

When the concept of paradigms is used to portray specific worldviews, they differ in their ontology (the nature of reality); epistemology (how we gain understanding of what we know) and methodology(300). There is ongoing debate about the potential different worldviews that researchers can hold(306), especially with regard to mixed methods research. The conceptual stances for the use of paradigms within mixed methods are shown in Table 4.3. They include incompatibility, a-paradigmatic, the single paradigm stance, the dialectical perspective and the multiple paradigms stance(307,308). Each of these will be discussed in brief below.

**Table 4.3. The main conceptual stances within mixed methods research**

| **Conceptual stance** | **Definition** |
| --- | --- |
| Incompatibility | Quantitative and qualitative research are based on fundamentally different philosophies so it is not possible to integrate them |
| A-paradigmatic | Research paradigms are unimportant, especially for studies undertaken in real world settings |
| Single paradigm stance | Mixed methods research can be underpinned by a single paradigm such as the pragmatic, critical realist or transformative paradigms |
| Dialectical perspective | Using multiple paradigms contributes to greater understanding of a phenomena |
| Multiple paradigms stance | The researcher decides which paradigm is most appropriate as a single paradigm does not always apply to all research designs |

Adapted from Teddie & Tashakkori, 2009(307); Teddie & Tashakkori, 2010(308).

Some have argued that due to quantitative and qualitative research having fundamentally different underpinning philosophical epistemologies and assumptions that they are incompatible and cannot be combined[287,309]. Others however view research paradigms as providing a general philosophical orientation, but do not consider them as completely standalone compartments[305,310], with paradigms increasingly seen as a continuum[307,308]. The legitimacy of standalone paradigms and the imposed order they try to establish has particularly been questioned given the arbitrariness of how each paradigm is defined and concerns over who establishes the legitimacy of any given paradigm[305]. Many researchers have therefore moved beyond the stance that integration of qualitative and quantitative methodologies is incompatible and have offered various ways in which the different paradigms can be combined within mixed methods research[307,308].

The a-paradigmatic stance takes the viewpoint that paradigms are unimportant within mixed methods research, especially for studies undertaken in real world settings[307,308].

The single paradigm stance asserts that mixed methods research can be underpinned by just one paradigm[307,308]. The four main paradigms in mixed methods research are the postpositivist, constructivist, transformative and pragmatic paradigms[302]. The differences between these different philosophies are shown in Table 4.4. Each paradigm is associated with specific research approaches, although these approaches are not discrete, but acknowledged to more fit on a continuum[306,311].

Traditionally the paradigm associated with quantitative research was the positivist paradigm. The positivist paradigm viewed there to be one single reality that researchers aim to discover[312]. However, as it was recognised that we can never be truly certain about our claims of knowledge, post positivism has increasingly replaced positivism[306]. This acknowledges that all observations we make are influenced by the observer's background knowledge and assumptions – the observer can never be truly neutral[312].

In contrast the constructivist paradigm is largely associated with qualitative methods. Much work was done on this by Guba and Lincoln (1994)[313] and Guba and Lincoln (2005)[314]. In contrast to the positivist paradigm that viewed there to be one single reality, the constructivist paradigm recognised the multiple realities of participants within any given situation and the crucial impact of social and historical influences on the meanings participants generate[306].

**Table 4.4. Research paradigms and their associated ontology, epistemology and methodologies***

| **Paradigm** | **Ontology** (what is the nature of reality) | **Epistemology** (relationship between the researcher and what is researched) | **Aim** | **Inquiry process** | **Associated research designs** |
|---|---|---|---|---|---|
| **Postpositivist** | Critical realism - Single reality that can only ever be imperfectly understood | Objectivist, neutrality, distance and impartiality | Reductionism (focus on a narrow set of variables)<br>Deterministic – (identification of the causes that influence the outcomes of interest)<br>Prediction and control | Theory verification (deductive) | Mainly quantitative: e.g. RCT; Quasi-experimental; Longitudinal designs; Survey |
| **Constructivist** | Relativism - Multiple realities that are socially constructed | Subjectivist - Interactive and interpretive as researchers recognise their own role within the interpretation | Construction of the meaning of a situation | Theory generation - inductive | Qualitative: e.g. Ethnography; Grounded theory; Phenomenology |
| **Pragmatic** | Pluralistic - Singular and multiple realities, continually created through interaction and transaction with the 'world' | Practicality - what works to address the research question | Problem centred | Abductive – real world practice orientated | Mixed methods: e.g. Convergent; Explanatory sequential; Exploratory sequential; Complex mixed methods designs |
| **Transformative** | Multifaceted - consequence of inequalities shaped by different positions in society e.g. ethnicity, gender, social, political, cultural, disability | Interactive, trust, collaborative | Social justice/ Change orientated; research agenda intertwined with politics to confront social oppression | Abductive - change orientated | Mixed methods; e.g. Dialogic, Emancipatory; Participatory action research; Critical theory; Narrative designs |

*Information within the table is based on information contained within: Creswell & Plano Clark (2017)[300,Ch 2]; Creswell & Creswell (2018)[306,Ch 1]; Lincoln et al., (2018)[311,Ch 5]; Mertens & Tarsilla, (2015)[302,Ch 24]; Teddie & Tashakkori (2009)[307,Ch 5].

The pragmatic paradigm encourages researchers to use their research question to determine their research methods, not just to base their methods on a specific paradigm[305]. The pragmatic approach therefore considers the workability of any approach and is guided by which methods are most appropriate for answering the research question[301,305,315]. This has led to the traditional concept of paradigms which advocate specific ontological, epistemological and methodological viewpoints, being challenged[305]. The pragmatic paradigm abandons the choice between positivism and constructivism[300] and places an emphasis on shared meaning[305] and on qualitative and quantitative methods complimenting each other[315]. It mixes multiple sources of evidence to identify potential solutions or actions to the problem studied[316].

The transformative paradigm places emphasis on those who are marginalised and the impact of inequalities[315]. This perspective intentionally collaborates with minorities to give them a voice, for example not just through participation within the research but also in research question development, recruitment, sensitive data collection and analysis[315]. It frames the research within the social and historical context and is oriented towards effecting social change.

As well as the use of these single paradigm stances within mixed methods research, a further conceptual stance is the dialectical perspective (Table 4.3). Rather than using a single worldview such as pragmatism, the dialectical stance acknowledges that multiple paradigms can exist within mixed methods research[300,303,315,316]. It is recognised that different paradigms consider that there are different ways of knowing and understanding the social world, which can add new insights[302,303,316]. The differences and contradictions that occur are respectfully acknowledged[316], but they are not reconciled, with the divergent results bringing a fuller picture of the complex phenomenon being studied[302,303,316]. The different paradigms bring their unique perspective, thus allowing for divergence within the results from the different methodological aspects[315]. The research design is intentionally interactive between the different data sets at multiple timepoints within the study[316].

A final stance, the multiple paradigms stance, has been proposed[300]. This again acknowledges that more than one worldview may exist, with different worldviews used within different phases of the mixed methods study, with the worldview informed by the type of mixed methods design and the study context[300]. When paradigms were first described by Kuhn (1970)[304], he himself noted that while most researchers work within a single paradigm, there was nothing that prevented the followers of one paradigm understanding the claims of those from a different paradigm. Indeed, Greene and Carcelli (1997)[303] acknowledged that there are different philosophical stances but suggested that mixed methods research should move beyond the pre-occupation with philosophy and instead view mixed methods research as allowing plurality of perspectives. The multiple paradigms stance is viewed to be of particular benefit within explanatory sequential mixed methods designs, with researchers encouraged to use different philosophical positions within the quantitative and qualitative aspects[300]. For example, using a postpositivist stance is suggested for the quantitative phase of an explanatory sequential mixed methods research design, which would be guided by an overall theory and hypotheses. When moving into the qualitative phase which attempts to explore the multiple realities experienced by participants, it is suggested that the worldview shifts to align with constructivist philosophical assumptions[300]. Within the multiple paradigms' stance, the importance of the researcher being explicit about the paradigms utilised has been emphasised[300].

## 4.5 Use of theory

Two main uses of theory have been identified within research; the deductive approach and the inductive approach[306]. Figure 4.3 and Figure 4.4 illustrate these different approaches to theory.

**Figure 4.3. The deductive approach** (adapted from Trochim et al., 2006[317])


**Figure 4.4. The inductive approach** (adapted from Trochim et al., 2006[317])

The deductive approach is traditionally linked to quantitative approaches, where a hypothesis is formed from an initial theory. The researcher then sets out to gather data to either confirm or refute the initial hypothesis(306). In contrast the inductive approach is used within some qualitative research, where the researcher gathers data, followed by looking for patterns within the data. From this a tentative hypothesis or theory can be postulated. Theory development is therefore the end point of the study(306).

Within mixed methods research both inductive and deductive approaches can be used(318). However, it is acknowledged that research is very rarely either inductive or deductive. A further category of abductive reasoning has therefore been added, where researchers move backwards and forwards between theory driven and data-driven approaches(305). This values both inductive and deductive aspects and is most suited to mixed methods research which incorporates both quantitative and qualitative aspects to provide a more complete understanding of the research problem(318).

## 4.6 Methodology within this thesis

### 4.6.1 Background

This thesis explored the impact of an antenatal healthy lifestyle service for women with obesity. This innovative midwife-led service was known locally as 'Monday clinic'. It was led by midwives who provided support and advice on lifestyle change while working alongside other professions such as obstetricians, dieticians, anaesthetists and exercise programme providers. The approach in Monday Clinic to weight management encouraged four things: healthy eating, not gaining excessive weight during pregnancy, increasing activity levels and breastfeeding. It encouraged women to set their own goals such as to swap one unhealthy food for a healthy one.

The service was established in July 2009 offering support to all pregnant women with a BMI ≥35kg/m² who booked for care within an NHS Trust in the Yorkshire and Humber region of England. Women were offered a visit at 16 weeks of gestation and a further optional visit at 36 weeks. In 2012 the service was intensified with women offered three appointments at 16, 28 and 36 gestational weeks. At this point, due to service demands, service provision became for women with a BMI ≥40kg/m² at their booking appointment. Due to resource limitations the service was discontinued in 2017.

The service was recognised by the Nursing Times in 2009 for its support in the management of maternal obesity, with the midwives running the service receiving the British Journal of Midwifery "Innovator of the year award" in 2010. Audit data suggested the service was effective at reducing GWG. However local midwives called for a robust and external evaluation to allow national credibility and the potential for further national implementation of the service. This thesis therefore presents results from this external evaluation.

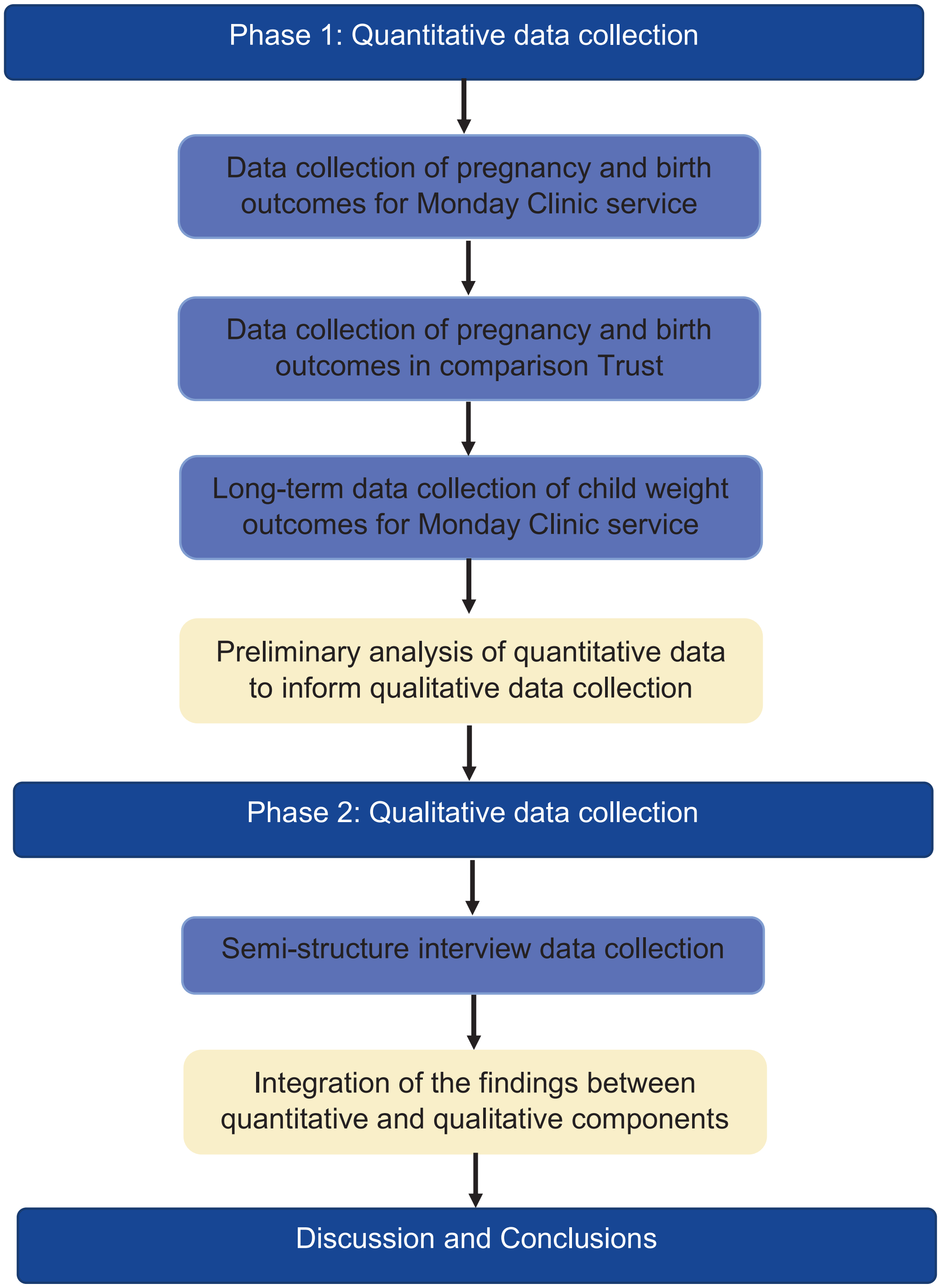
### 4.6.2 Overall research plan

A mixed methods design was planned, utilising an explanatory sequential design. This incorporated both quantitative and qualitative components, with greater emphasis placed on the quantitative aspect to determine the impact of the antenatal healthy lifestyle service. This quantitative data was gathered first. Supplemental qualitative interviews to elicit participants' experiences were then undertaken to complement the interpretation of the quantitative results. Figure 4.5 provides a flow chart of the individual components of the research study. This approach was planned due to the complexity of the problem of weight management in women with obesity during pregnancy. While the discontinuation of the antenatal healthy lifestyle service meant that it was not directly possible to talk to those attending the service, a qualitative phase was still undertaken to explore women's experiences of maternal weight management to assist with the interpretation of the quantitative results. Findings from both stages have been used in the interpretation phase.

An abductive approach, which valued both inductive and deductive aspects was utilised as this was most suited to the mixed methodology approach undertaken. Using an abductive approach allowed a more extensive conceptualisation of the topic.

An article-based format to present each aspect of the study has been used within this thesis. Therefore, the methods for each aspect are largely reported within each of the articles. However, this chapter provides an overview of incorporated components of the study.

**Figure 4.5. Flow chart of research phases**



### 4.6.3 Quantitative components

Within the quantitative phase of this programme of research, a postpositivist research paradigm was adopted which was guided by overall hypotheses. This stance was taken when developing the quantitative research questions and to identify the variables that would need collecting[300].

Three research questions were developed within the quantitative component to determine the impact of the healthy lifestyle service.

<u>Research question 1:</u>

> What is the impact on GWG and other maternal and neonatal health outcomes of an enhanced antenatal healthy lifestyle service (where women were routinely offered three visits) compared to a lower intensity service (where women were routinely offered one visit but could chose to attend a further optional visit)?

Hypothesis 1:

> There is no difference in GWG or other maternal or neonatal health outcomes between the lower intensity antenatal healthy lifestyle service provision and the more intense service provision.

The changing intensity of the antenatal healthy lifestyle service from one appointment (July 2009-Dec 2011) to three appointments (July 2012-2015) provided a unique opportunity to compare the impact of the differing levels of provision. While the service was continuous, data was not analysed during the six-month period while the service was transitioning between the different levels of service intensity to minimise contamination.

<u>Research question 2:</u>

> What is the impact of an enhanced antenatal healthy lifestyle service on GWG and other maternal and neonatal health outcomes compared to an NHS Trust with no routine antenatal healthy lifestyle service provision?

Hypothesis 2:

There is no difference in GWG or other maternal or neonatal health outcomes between the NHS Trust with antenatal healthy lifestyle service provision and a comparison NHS Trust without routine provision.

A comparison group from a neighbouring NHS Trust was included within the study. The comparison Trust was chosen as both NHS Trusts were located in the Yorkshire and the Humber region. Both Trusts had similar health and demographic profiles including for deprivation (% of households living in the most deprived 20% of England), adult overweight or obesity, smoking at birth, the number of adults reporting eating '5 a day', physically active adults[(319)] and ethnicity[(320)].

In the comparison NHS Trust, no services were available until a dietician led service was established in 2012. However, referral and uptake figures to the service were low. The few women with obesity who had opted to use the dietician services for maternal weight management in the comparison Trust were excluded from the analysis.

Research question 3:

What is the association between providing an antenatal healthy lifestyle service to women with obesity during pregnancy and the prevalence of childhood obesity at school entry?

Hypothesis 3:

There is no difference in prevalence of obesity at school entry between children of mothers who attended the antenatal healthy lifestyle service and those who did not.

Given the age of the intervention, it was possible to evaluate the feasibility of linking maternal data to childhood obesity data. This was done through linkage with the IT system, SystmOne, utilised by health visitors and school nurses. Since 2010, SystmOne had been used to electronically record infants' weight and height at 6-8 weeks, 9-12 months and school entry (4-5.5 years of age). This provided an excellent opportunity to use data linkage for long-term follow up of the healthy lifestyle service on child anthropometric data.

#### 4.6.3.1 Statistical analysis

The primary interest of this research was to determine the effect of the enhanced healthy lifestyle service (three visits) on maternal and infant outcomes compared to either the lower intensity healthy lifestyle service or the comparison Trust. Binary logistic regression was used for binary outcomes, multinomial regression for categorical outcomes with more than two categories and independent t-test for continuous outcomes. Analysis was restricted to women with a BMI ≥40kg/m² and a singleton pregnancy to mediate the impact on outcomes due to BMI or higher order pregnancy.

Given the retrospective nature of the data, it was impossible to ensure conditions remained the same over time between the different levels of service intensity. Nor could it be assumed that women in the comparison Trust would be similar to those in the Trust with the healthy lifestyle service. It was therefore essential to consider baseline imbalances between the groups to allow for adjustment of confounding factors within the analysis. Potential confounding baseline variables were identified from the academic literature, as well as being determined by availability within the retrospective dataset. Multiple logistic and linear regression were used to adjust for baseline differences in these potentially confounding factors. For the analyses comparing the different intensities of the healthy lifestyle service, baseline differences in index of multiple deprivation quintile and smoking status when booking for antenatal care were adjusted for within the analyses. For the analyses comparing the healthy lifestyle service to the comparison Trust baseline differences in index of multiple deprivation quintile, highest household occupation and smoking status when booking for antenatal care were adjusted for within the analyses. Additionally, we found the prevalence of GDM was substantially higher in the Trust with the healthy lifestyle service than the comparison Trust. Given the impact that this could have on outcomes such as birthweight, gestation at birth, mode of birth and other adverse maternal outcomes, results were also adjusted for GDM. Results were presented as crude and adjusted odds ratios or crude and adjusted mean differences.

A power calculation was undertaken in Stata 15.1 for the primary outcome of GWG. A minimum of 58 women would be required in each group to have 95% power to detect with 95% confidence, a decrease in GWG of 4.1kg with the enhanced intervention. This GWG decrease had been achieved in a previous maternal obesity management intervention undertaken by the research team[321], and would be of clinical relevance[322]. Given the biases that could be introduced depending on the sampling method used as well as the infrequency of some secondary research outcomes, it was however decided to include all eligible women within the analyses.

For childhood measurement data the child weight centiles and z scores were calculated at 6-8 weeks, 9-12 months and at school entry, and BMI centile and z scores at school entry for infants of women with a BMI ≥35kg/m² when booking for antenatal care. Children with a weight /BMI ≥85$^{th}$ centile were classified as a child with overweight, those with a weight /BMI ≥95$^{th}$ centile as a child with obesity and those with a BMI ≥99.6$^{th}$ centile as a child with severe obesity in accordance with Office for Health Improvement and Disparities classifications[323]. Univariate logistic regression was used to determine the odds ratios and 95% confidence intervals of childhood overweight or obesity according to uptake of the antenatal healthy lifestyle service, GWG and other maternal sociodemographic characteristics. Multiple logistic regression was undertaken on factors that were significant within the univariate analysis to determine the significance of these variables once controlling for other factors.

### 4.6.4 Qualitative component

The qualitative component of the research used semi-structured interviews to explore the experiences of antenatal healthy lifestyle provision and the barriers and facilitators to weight management during pregnancy among women with a BMI ≥40kg/m². In addition, qualitative interviews explored the type of service provision the women would have liked. The interview data was used to help to explain the quantitative healthy lifestyle service evaluation. The qualitative phase was aligned with constructivist philosophical assumptions. The use of different philosophical positions within the quantitative and qualitative aspects within this project is encouraged in explanatory sequential mixed methods designs[300]. The constructivist philosophical position was used as the aim of the interviews was to understand the meanings the women created and attributed to their experiences[324]. A relativist ontological stance was taken as the researchers acknowledged that there were multiple realities shaped through individual lived experiences(324,325). A transactional epistemological position was adopted(324). This recognized that the researchers did not come into the research process as blank slates but brought with them their own previous histories and perspectives of weight management. As one cannot separate oneself from one's prior knowledge and experiences, these understandings influence the interpretation of the topic under question(326). Reflexivity was undertaken, where the researchers critically reflected on how their social background, assumptions, and behaviour may impact on the research process and the subsequent interpretation(327,328).

### 4.6.5 Maternity service user involvement

Public and patient involvement (in this case maternity service user involvement) is known to improve the quality of research, as well as enhance the impact and relevance(329). It ensures that research focusses on the areas considered as priorities by the public and enhances the researcher's understanding of the participant's experience(329) which in turn can lead to more effective interventions.

This research evaluated an already established service. When the service was developed maternity service users were approached to assist with the design of the service. The feedback that was received ensured acceptable naming of the service to avoid inappropriate language and stigmatisation. In line with maternity service users wishes, the service was also designed as face-to-face and incorporated into routine care for all women with a BMI ≥35kg/m².

This project directly collaborated with maternity service users to develop and review the interview schedule and participant information sheet for the qualitative data collection component. This was to ensure the schedule was clear and would be acceptable to a diverse audience.

### 4.6.6 Ethics and consent

Four key ethical principles should be considered when undertaking research; autonomy, beneficence, non-maleficence and justice(330).

Autonomy ensures individuals are treated as capable of making their own decisions or protects them if they are not capable[331]. To achieve this, obtaining informed consent and voluntariness of participation are essential components of research.

Beneficence (maximising the possible benefits) and non-maleficence (doing no harm) ensures that the possible benefits of the research are maximised and any potential harms are minimised, with the researcher taking the participant's wellbeing into consideration at all times within the research[331].

Justice ensures fair treatment of all participants, including aspects such as fair distribution of any benefits or burdens from the research as well as inclusivity[331].

One of the recognised challenges of an explanatory sequential design is that the qualitative design cannot be specified in advance, making ethical approvals difficult to obtain[300]. For this reason, ethical approvals for the different aspects of this project were obtained independently. Furthermore, approvals were obtained from the governance departments within both NHS Trusts to undertake the project. Ethical considerations specific to each aspect of the study are discussed separately below, followed by a discussion of the ethical considerations applicable to the study overall.

#### 4.6.6.1 Quantitative components

Ethical approval was obtained from East of England: Cambridge East Research Ethics Committee (IRAS 207998) (see Appendix D), as well as relevant Health Research Authority (HRA) approvals.

Given the retrospective nature of the research there were concerns that individuals who responded to any request for consent would be likely to differ significantly from non-responders, particularly in areas such as motivation and social demographic status. This would therefore introduce bias to the research. Anonymised data was therefore obtained from the routine data collected within the NHS Trusts to determine the impact of the healthy lifestyle service. Furthermore, postcode data was converted to Index of Multiple Deprivation (IMD) scores.

Those extracting the data from medical records were either healthcare professionals or those under the same duty of confidentiality.

To allow matching of maternity records with infant height and weight records pseudo-anonymised data was obtained. The child's NHS numbers were encoded into a 32-character long string using the MD5 hash system. It was not possible to convert this string back to the original NHS number, but because the same NHS number produces the same string, matching across the data sets was possible.

Both significant and non-significant results were published to avoid selective reporting and publication bias.

#### 4.6.6.2 Qualitative component

Ethical approval was obtained from East of England: Essex Research Ethics Committee (IRAS 231105) (see Appendix E), as well as relevant HRA approvals.

Participants were provided with written information about the study. Appendix F includes a copy of the Participant Information Sheet. Anyone expressing an interest in further contact about the study was asked to provide contact details (their preferred method of contact of either telephone or email). This was no longer stored after making contact or attempting to contact the woman on two occasions. Participants were provided with opportunities to ask any questions they may have about the study with written, voluntary consent obtained prior to commencing the interview (Appendix G contains an example consent form). Both the written information and the consent form reinforced that the study was voluntary, and that participation or non-participation would not influence their current or future care in any way. A £10 high street shopping voucher was provided to participants to recompense them for the time taken to participate in the interview.

Participants were also provided with an opportunity to comment on the initial analysis of the results should they wish. Additionally, they were provided with an opportunity to receive a copy of the results once published. Either an email or postal address was collected from participants who showed an interest in either aspect, according to their preference. This data was kept in a secure location which only the researchers had access to. Contact details were destroyed once no longer required.

Participants were provided with pseudonyms within the written report to prevent identification and ensure confidentiality. Transcripts were anonymised to remove anything that could identify participants including any reference to places of work, place of residence or names of family members. Audio recordings were stored for the duration of the project, with only anonymised transcripts stored beyond this point. Participants were informed within the Participant Information Sheet however that confidentiality could not be guaranteed if any safeguarding incidents were disclosed within the interviews.

Within the analysis multiple perspectives were described where diversity was apparent within the data, with contradictory cases identified and discussed. This is considered essential to maintain ethical integrity(306).

#### 4.6.6.3 Both components

All members of the research team had undertaken relevant Good Clinical Practice (GCP) training.

A data management plan was established. Storage and use of data was undertaken in accordance with the Data Protection Act(332) at the beginning of the project. General Data Protection Regulation (GDPR) guidance came into law part way through the project in May 2018, with Participant Information Sheets updated to reflect this. All electronic data was stored on password protected computers within a project specific folder on the secure drive at Sheffield Hallam University, which is a drive specifically for storing research data. Only the research team had access to this data. Physical data such as signed consent forms were stored in a locked filing cabinet, which again only members of the research team had access to. Transcripts were stored electronically and consent forms physically to prevent identification.

Funding sources were fully disclosed within all publications.

## 4.7 Summary

This chapter has sought to justify the reasoning behind the explanatory sequential mixed methods approach that was utilised within this research. It has outlined the theoretical frameworks and philosophical underpinnings of the research. A brief background to the antenatal healthy lifestyle service being evaluated within the research has been provided and the methodological approaches for the quantitative and qualitative components outlined. Full details of the methodological approach for each aspect are given within the associated article manuscripts. The ethical considerations within the research project have also been presented.

The following four chapters present the articles which were derived from the different components of this programme of research.

# Chapter 5: Evaluation of differing intensities of an antenatal healthy lifestyle service

## 5.1 Introduction

This chapter presents Article B. This is the first article from the quantitative component of this programme of research. A comparison of the maternal and neonatal outcomes among women with a BMI of 40kg/m² or above who were offered one antenatal healthy lifestyle service appointment compared to three appointments is presented. The aim of the study is provided below. The full article as submitted for peer review is then presented. The chapter concludes by summarising the key findings of this component.

## 5.2 Study aim

Changes to antenatal healthy lifestyle service provision over time allowed the ideal opportunity to compare different service intensities. The study aim was to compare pregnancy and birth outcomes in women with a BMI ≥40kg/m² who received a midwife-led low intensity antenatal healthy lifestyle service intervention (one visit) with those who received an enhanced intervention (three visits). This addressed the second aim of this programme of research: *"To explore the impact of a service supporting women with the highest class of obesity to achieve adequate GWG and improve maternal and infant outcomes."*

## 5.3 Article B

The manuscript is entitled *"Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study."* It is reproduced in full in the format in which it has been submitted for review. The supplementary data associated with this article are provided in Appendix H.

## 5.4 Publication and impact

This manuscript has been submitted and is under peer review in the journal Midwifery.

# Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study


## ABSTRACT

**Introduction:** Maternal obesity and excessive gestational weight gain are associated with adverse maternal and neonatal outcomes. There is uncertainty over the most effective antenatal healthy lifestyle service, with little research determining the impact of different lifestyle intervention intensities on pregnancy outcomes.

**Method:** This retrospective cohort study compared pregnancy and birth outcomes in women with a body mass index of 40 or above who were offered a low intensity midwife-led antenatal healthy lifestyle service (one visit) with women who were offered an enhanced service (three visits). The primary outcome was gestational weight gain.

**Results:** There were no differences between the two healthy lifestyle service intensities (N=682) in the primary outcome of mean gestational weight gain [aMD -1.1kg (95% CI -2.3 to 0.1)]. Women offered the enhanced service were less likely to gain weight in excess of Institute of Medicine recommendations [aOR 0.63 (95% CI 0.40-0.98)] with this reduction mainly evident in multiparous women. Multiparous women also gained less weight per week [aMD -0.06kg/week (95% CI -0.11 to -0.01)]. No beneficial effects were seen in maternal or neonatal outcomes measured such as birth weight [aMD 25g (95% CI -71 to 121)], rate of vaginal birth [aOR 0.87 (95% CI 0.64-1.19)] or gestational diabetes mellitus [aOR 1.42 (95% CI 0.93-2.17)]. However, multiparous women receiving the enhanced service experienced a reduction in SGA [aOR 0.52 (95% CI 0.31-0.87)]. This study was however underpowered to detect differences in some outcomes with low incidences.

**Discussion:** Uncertainty remains over the best management of women with severe obesity regarding effective interventions in terms of intensity. It is suggested that further research needs to consider the different classes of obesity separately and have a particular focus on the needs of nulliparous women given the lack of effectiveness of this service among these women.

**Key words:** Maternal obesity, gestational weight gain, healthy lifestyle, pregnancy outcome, prenatal care, weight management

## INTRODUCTION

Over half of the adult population in the United Kingdom (UK) are now classified as overweight (body mass index (BMI) 25-29.9) or obese (BMI 30 or more) (Health and Social Care Information Centre, 2015). Obesity alone during pregnancy in England has almost tripled over the last three decades from 7.6% in 1989 (Heslehurst et al. 2010) to 22.2% in 2018-2019 (National Health Service Digital, 2019). Furthermore, childbearing itself is acknowledged to contribute to the rise of women with overweight or obesity (Bello et al. 2016).

Obesity during pregnancy is associated with increased risk of adverse outcomes for both the childbearing woman and neonate. Adverse outcomes for the woman include increased risk of gestational diabetes mellitus (Najafi et al. 2019; Santos et al. 2019), pre-eclampsia (He et al. 2020; Santos et al. 2019), preterm birth (Santos et al. 2019) and caesarean section (Kim et al. 2016; D'Souza et al. 2019). Adverse outcomes for the neonate include increased risk of being large for gestational age (LGA) (Santos et al. 2019; D'Souza et al. 2019), admission to a neonatal intensive care unit (Kim et al., 2016), and poorer breastfeeding outcomes (Huang et al. 2019). It has been estimated that 23.9% of pregnancy complications are attributable to maternal overweight or obesity prior to pregnancy, with the highest risk of pregnancy complications occurring in women with a BMI of 40 or more (Santos et al. 2019). Additionally, women with overweight or obesity prior to pregnancy are at increased risk of excessive gestational weight gain (GWG) (Samura et al. 2016). Increased GWG has also been associated with many adverse outcomes such as increased risk of LGA (Goldstein et al. 2017; Santos et al. 2019), caesarean section (Goldstein et al. 2017), induction of labour (Xu et al. 2021), long term maternal weight retention (Samura et al. 2016) and childhood obesity (Voerman et al. 2019). To maximise the health of both the woman and the neonate, the Institute of Medicine (IOM) has proposed guidelines for GWG based on maternal pre-pregnancy BMI category (Institute of Medicine, 2009). For women with obesity a total GWG of 5-9kg is recommended, with a rate of weight gain in the second and third trimesters of 0.17-0.27kg/week (Institute of Medicine, 2009). A recent meta-analysis of individual patient data has however found 44% of women with obesity to gain weight above these recommendations (Rogozińska et al. 2017).

The National Institute for Health and Clinical Excellence (NICE) (NICE, 2010) weight management before, during and after pregnancy guidelines identified limited UK based research into the efficacy of weight management interventions in pregnancy and therefore recommended more research into ways of managing maternal obesity and GWG to optimise pregnancy outcomes. Interviews with health care providers and commissioners have also identified uncertainty among professionals about what constitutes the most suitable service to tackle maternal obesity, despite pregnancy being recognised as a good opportunity to influence behaviour change for women and families (Fair et al. 2020). As a result of professional uncertainty, a UK based survey undertaken at the same time as the interviews, found maternal healthy lifestyle service provision for women with obesity to be variable across the country and identified a need for more antenatal weight management services for women with obesity (Fair et al. 2020). Furthermore, systematic reviews evaluating the impact of antenatal lifestyle interventions on maternal and neonatal outcomes (Thangaratinam et al. 2012; Yeo et al. 2017; Fair & Soltani 2021) have noted current studies to be heterogenous in the format and intensity of the lifestyle advice given, for example simply providing women with training on how to use a treadmill (Kong et al. 2014) or delivering 10 individual one hour sessions with a dietician (Wolff et al. 2008). Little research to date has been undertaken to determine the impact of different intensities of lifestyle interventions on pregnancy outcomes. A recent meta-regression of lifestyle interventions in all pregnant women did not find any optimal frequency of contact for intervention delivery, with some low intensity, low-cost interventions found to be effective (Walker et al. 2018). Determining the frequency of an intervention that could improve clinical outcomes is an important consideration, particularly for those that commission services. Furthermore, pragmatic trials are increasingly recognised as an ideal way to determine the impact of interventions under real-world conditions (Battaglia & Glasgow 2018).

The objective of this study was therefore to compare pregnancy and birth outcomes in women with a BMI of 40 or more who received a midwife-led low intensity antenatal healthy lifestyle service intervention (one visit) with those who received an enhanced intervention (three visits).

## METHOD

### Study setting

In July 2009 a midwife-led antenatal healthy lifestyle service was established in a National Health Service (NHS) Trust in the Yorkshire and Humber region of England. Further details around the service set up, including perinatal user involvement and training for professionals initiating conversations with the women is discussed elsewhere (West 2010; Garland 2011). When established, the service offered a low intensity intervention to pregnant women with a booking BMI of 35 or more, with pre-existing diabetes, excessive GWG or previous bariatric surgery. This incorporated a visit at 16 weeks' gestation and an optional follow up visit. In July 2012 service provision intensified, offering women routine appointments at 16, 28 and 36 gestational weeks. Due to service demands the provision at this point became for women with a BMI of 40 or more. Women with pre-existing diabetes, excessive GWG or previous bariatric surgery also continued to be referred to the service. At both time points women could also seek out the service for additional appointments if they wished. The main service input was from midwives due to practical consideration (West 2010), but also to redress the imbalance many women with obesity feel during pregnancy as their pregnancies have become increasingly medicalised (McGlone and Davies 2012). Midwives ran the service alongside other professionals such as dieticians and exercise programme providers, with specialised input from obstetricians and anaesthetists as required. Women were provided with support and advice around weight management; particularly minimising GWG, healthy eating, undertaking physical activity and breastfeeding. The aim of the clinic was to encourage and support women to make lifestyle choices and behavioural changes during pregnancy, which could also be sustained after the birth. At the 16 week appointment awareness was raised about the potential risks for women and their baby of a raised BMI in pregnancy. Individualised care planning, including the offer of a dietician consultation was initiated, with women informed of healthy eating principles and healthy activity during pregnancy. Women were encouraged to identify personal goals such as swapping an unhealthy food for a healthier one. The additional appointments with the enhanced service provided opportunities to follow up progress and reassess the personal goals as required. The 36 week appointment also offered an opportunity to discuss breastfeeding and weight loss in the postpartum period, as well as to assess moving and handling and tissue viability prior to admission in labour. The changing intensity of the service provided a unique opportunity to compare the effectiveness of the differing levels of provision.

## Study participants

A retrospective comparative cohort study was undertaken. All pregnant women in the Trust with a booking BMI of 40 or more who were referred to the low intensity service from 2009-2011 and to the enhanced service from July 2012 to July 2015 were included within the study. While the service was continuous, data was not analysed during the six-month period while the service was transitioning between the different levels of service intensity to minimise potential contamination. Although women with a BMI of 35 or more were referred to the service from 2009-2011, and women with pre-existing diabetes, excessive GWG or previous bariatric surgery were referred in both periods, to ensure comparability only women with a BMI of 40 or more were included within the analysis. Women with a twin pregnancy were excluded from the analysis.

## Data collection

Maternal and neonatal pregnancy and birth data were obtained from routinely collected data. Where available, data was collected electronically, with the remainder being obtained directly from paper-based maternal health records. Individuals extracting data from health records were health professionals or others under the same duty of confidentiality as health professionals.

The primary outcome for this study was GWG. Secondary outcomes included the antenatal outcomes (weight gain in accordance with IOM guidance (Institute of Medicine, 2009), gestational diabetes mellitus, anaemia, additional monitoring for pregnancy induced hypertension); intrapartum outcomes (mode of birth, labour induction, requirement of epidural analgesia or general anaesthesia, perineal laceration, postpartum haemorrhage);

and neonatal outcomes (birth weight, gestation, Apgar scores, breastfeeding initiation and adverse outcomes).

### Variable definitions

BMI was calculated using the standard equation weight/height squared using weight at booking. In a small minority of cases (n=9) BMI was obtained from the health records as weight or height at booking were not recorded to calculate BMI independently. The last weight recorded in pregnancy from the middle of the third trimester (34+0 weeks') gestation onwards was taken as the final weight. GWG was measured by subtracting weight at booking from final weight. Women were classified as gaining weight below, in accordance with or above IOM recommendations of 5-9kg. Birth weight less than 2500g was classified as low birth weight and birth weight more than 4000g as macrosomia. Birth weight centiles were calculated using GROW charts (UK version 8.0.6.1) (Gardosi et al. 2011; Gardosi et al. 2020), which customise centiles according to maternal height, maternal weight, ethnicity, parity, gestation and neonatal sex, as these have been shown to be more accurate in populations with overweight or obesity (Pritchard et al. 2020). Birth weight less than the $10^{th}$ centile for gestational age was classified as small for gestational age (SGA) and above the $90^{th}$ centile as LGA. Anaemia was classified according to the NICE antenatal care definitions (NICE, 2008 (updated 2019)) as a haemoglobin level less than 110g/l at the booking appointment or less than 105g/l at 28 weeks' and 36 weeks' gestation. Requiring raised blood pressure monitoring was taken as the need for any appointment to assess blood pressure above routine antenatal care, for example day care unit assessment. Throughout the study period local protocols defined gestational diabetes mellitus as a blood glucose level of 5.3mmol/l or more after fasting or 8.5mmol/l or more two hours after a 75g glucose challenge. The official measure of relative deprivation in England, the Index of Multiple Deprivation (IMD) was used to measure deprivation. This combines information from seven domains of deprivation (income, employment, education, health, crime, housing and living environment) to give an overall deprivation score for each area from 1 (most deprived) to 32844 (least deprived) (Smith et al. 2015). These scores were then designated into the appropriate quintiles. The highest occupation category for each household (either the woman or her partner) was calculated using the three category National Statistics Socioeconomic Classification (NS-SEC) system (Office for National Statistics, 2010).

## Data analysis

Logical checks and data cleaning were carried out and inconsistencies returned to the field for clarification. An initial comparison at baseline for the differing service intensities was undertaken to identify potential confounding variables such as maternal age, ethnicity, marital status, socioeconomic status and parity. Differences in antenatal, intrapartum and neonatal outcomes between the two service intensities were then analysed both with and without adjusting for baseline differences. For binary outcomes, logistic regression analyses were used and for categorical data with more than two categories multinomial regression was used to compare groups with the appropriate referent group identified. Outcomes on a continuous scale were compared using independent samples *t*-tests. Multiple logistic and linear regression were used to adjust for baseline differences in potentially confounding factors. Model assumptions were checked using standard regression diagnostics for linearity, normality, leverage and influence. Where any outliers or points of potentially high leverage were identified, the data analysis was rerun after removal of these points to determine if they had an impact on the effect size significance or direction. Where differences in the magnitude or direction of the effect size were noted, both effect sizes have been presented. For categorical outcomes, crude and adjusted odds ratios have been reported (OR and aOR) and for continuous outcomes, crude and adjusted mean difference (MD and aMD) have been reported, all along with their 95% Confidence intervals (CI). Statistical significance was taken as a p value less than 0.05. All analyses were undertaken in SPSS 24.0. Given evidence within the literature that nulliparous women gain more GWG than multiparous women (Rogozińska et al. 2017) secondary analysis according to parity was also undertaken.

An important element for any service is acceptability, therefore maternal characteristics were compared between women who attended the antenatal healthy lifestyle service and those who declined to attend their provided appointment.

## RESULTS

### Demographic data

Figure 1 provides a flowchart of participant selection. Of the 330 childbearing women with a BMI of 40 or more who were referred to the service between July 2009 and December 2011, 315 were eligible for inclusion. Of the 377 women with a BMI of 40 or more referred to the service from July 2012 to July 2015, 367 were eligible for inclusion within the analysis.

**Figure 1. STROBE flowchart of participant selection**

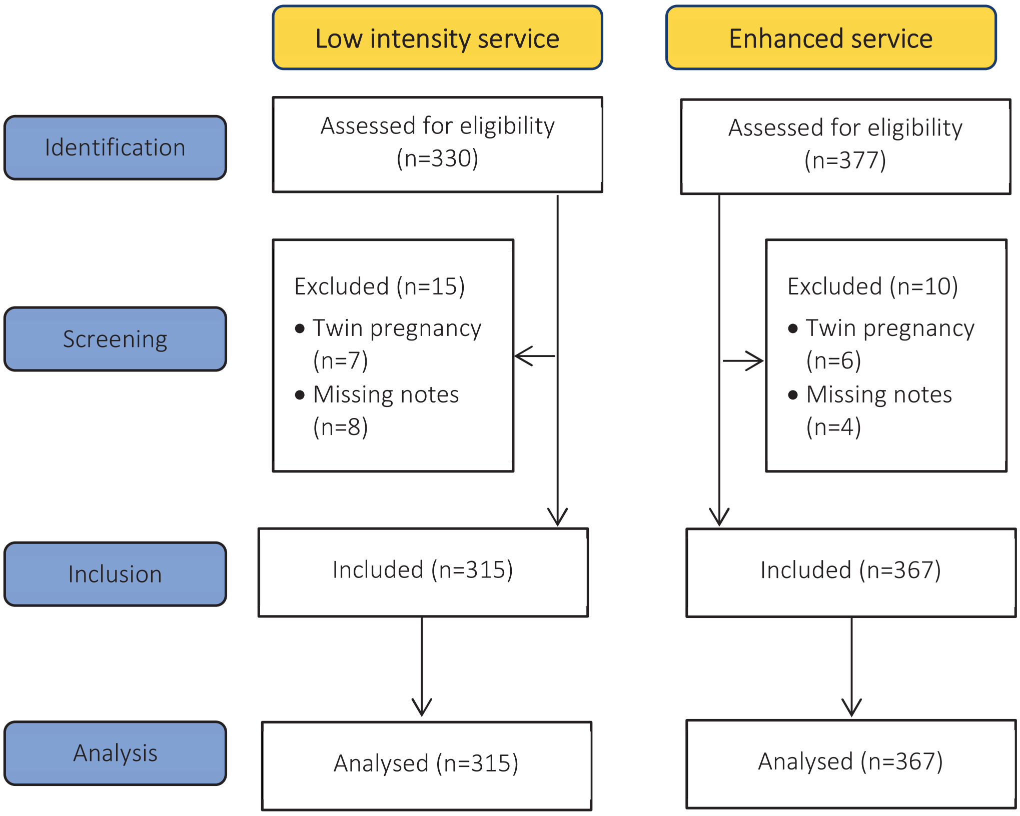



Table 1 provides demographic data for the two different service intensities. There were significant differences in baseline deprivation quintile and smoking status when booking for antenatal care. Compared to women referred to the low intensity service, women referred to the enhanced service were less likely to be in the most deprived quintile or to smoke. There was a trend for women referred to the enhanced service to be more likely to be nulliparous than those referred to the service from 2009-2011, however this was not significant.

**Table 1. Baseline demographics of women referred to the different service intensities**

| Characteristic | Low intensity 2009-2011 (n=315) | Enhanced service 2012-2015 (n=367) | *P* Value |
|---|---|---|---|
| **Maternal age, mean (SD), y** | 28.5 (5.5) | 28.5 (5.4) | 0.93 |
| **Deprivation quintile, n (%)** | | | 0.032 |
| Quintile 1: Most deprived IMD score 1-6568 | 198 (62.8%) | 190 (51.8%) | |
| Quintile 2: IMD score 6569-13137 | 58 (18.4%) | 80 (21.8%) | |
| Quintile 3: IMD score 13138-19706 | 27 (8.6%) | 50 (13.6%) | |
| Quintile 4: IMD score 19707-26275 | 21 (6.7%) | 36 (9.8%) | |
| Quintile 5: Least deprived IMD score 26276-32844 | 11 (3.5%) | 11 (3.0%) | |
| **Smoking status at booking, n (%)** | | | 0.023 |
| Smoker | 82 (26.1%) | 69 (18.9%) | |
| Non-smoker | 232 (73.9%) | 297 (81.1%) | |
| **Parity, n (%)** | | | 0.065 |
| 0 | 81 (25.8%) | 125 (34.1%) | |
| 1 | 114 (36.3%) | 119 (32.4%) | |
| 2+ | 119 (37.9%) | 123 (33.5%) | |
| **Ethnicity, n (%)** | | | 0.79 |
| White British | 297 (95.2%) | 349 (95.6%) | |
| Other | 15 (4.8%) | 16 (4.4%) | |
| **Highest household Occupation, n (%)[a]** | | | 0.65 |
| Higher managerial, administrative and professional occupations | 45 (15.0%) | 67 (18.5%) | |
| Intermediate occupations | 69 (22.9%) | 75 (20.7%) | |
| Routine and manual occupations | 107 (35.5%) | 125 (34.4%) | |
| Housewife/ Long-term no income or never worked/ student | 80 (26.6%) | 96 (26.4%) | |
| **Education, n (%)** | | | 0.27 |
| GCSE/ equivalent or lower | 32 (43.8%) | 78 (43.3%) | |
| AS/A level or equivalent | 16 (21.9%) | 55 (30.6%) | |
| Degree, postgraduate or equivalent | 25 (34.3%) | 47 (26.1%) | |
| **Marital status, n (%)** | | | 0.77 |
| Married/civil partnership | 113 (36.0%) | 121 (33.3%) | |
| Partner | 165 (52.5%) | 199 (54.8%) | |
| Single[b] | 36 (11.5%) | 43 (11.9%) | |
| **Booking body mass index, mean (SD), kg/m²** | 43.98 (3.75) | 43.98 (3.64) | 0.96[c] |
| **Maternal height, mean (SD), m** | 1.64 (0.07) (n=310) | 1.64 (0.07) (n=365) | 0.86 |
| **Gestation at booking, mean (SD), wk** | 9.2 (3.5) (n=314) | 9.2 (3.2) (n=366) | 0.86 |
| **Alcohol intake at booking, n (%)** | | | 0.74[d] |
| None | 300 (98.1%) | 359 (98.9%) | |
| 1-3 units | 5 (1.6%) | 3 (0.8%) | |
| 4-8 units | 1 (0.3%) | 1 (0.3%) | |

IMD – Index of Multiple Deprivation (Smith et al. 2015)

[a] Occupations coded using the 3 category National Statistics Socioeconomic Classification (NS-SEC) system (ONS 2010)

[b] The single category included 4 women in 2009-2011 and 5 women in 2012-2015 who were divorced/ separated/widowed

[c] Mann Whitney test used when the Shapiro-Wilk test showed data were not normally distributed

[d] Fisher exact test used due to small cell counts

**Maternal and neonatal outcomes**

Table 2 presents maternal outcomes according to service intensity. The number of sessions attended was significantly different, with the mean number of clinic sessions attended being 1.2 (standard deviation (SD) 1.3) and mode one session (45.5%) for the low intensity service versus mean of 2.2 (SD 1.2) and mode three sessions (45.5%) for the enhanced service. There was no difference in the primary outcome, mean GWG, between the two clinic intensities. However, a significant difference in gestation at final weight was noted between the different service intensities therefore, GWG was additionally adjusted for gestation at which the final weight was measured and remained non-significant (aMD -0.52 (95% CI -1.78 to 0.75). Furthermore, to eliminate the impact of gestation at which the final weight was recorded, further analysis of mean weight gain per week was also undertaken where total weight gain was divided by the length of time from booking weight to the final recorded weight. There was no significant difference in mean weight gain per week between the two different service intensities. When adjusting for baseline differences in deprivation and smoking the odds of gaining weight above IOM recommendations was lower for those receiving the enhanced intervention [aOR 0.63 (95% CI 0.40-0.98)]. The only other differences after adjusting for baseline imbalances were the higher odds of being discharged on day one after birth [aOR 2.14 (95% CI 1.27-3.60)] and of labour induction [aOR 1.70 (95% CI 1.19-2.45)] in women referred to the enhanced service.

**Table 2. Maternal outcomes according to service intensity** (see end of manuscript)

Table 3 presents neonatal outcomes according to service intensity. No differences were noted between the different service intensities for any outcomes including birth weight, gestation at birth, breastfeeding rates or adverse outcomes. The number of women who experienced a termination or miscarriage prior to 24 weeks gestation was similar for both clinic intensities [low intensity (n=8, 2.6%) versus enhanced service (n=8, 2.5%)], as were the number of intrauterine fetal deaths [n=2 (0.6%) low intensity intervention versus n=4 (1.1%) enhanced service]. The numbers were too small for any statistical comparison but appeared even between the groups.

**Table 3. Neonatal outcomes according to service intensity**

| Outcome | Low intensity 2009-2011 (n=315) | Enhanced service 2012-2015 (n=367) | Crude Mean difference (MD) or Odds ratio (OR) (95% CI) | Adjusted MD/OR (95% CI) [a] |
|---|---|---|---|---|
| **Birth weight. mean (SD), g** | 3466 (628) (n=301) | 3498 (609) (n=347) | MD 32 (-64 to 127) | aMD 25 (-71 to 121) |
| **Gestation at birth, mean (SD), wk** | 39.4 (2.0) (n=302) | 39.2 (2.0) (n=348) | MD -0.1 (-0.4 to 0.2) | aMD -0.1 (-0.4 to 0.2) |
| **Low birth weight (<2500g), n (%)** | 15/301 (5.0%) | 15/347 (4.3%) | OR 0.86 (0.41-1.79) | aOR 0.94 (0.45-1.98) |
| **Macrosomia (>4000g), n (%)** | 45/301 (15.0%) | 65/347 (18.7%) | OR 1.31 (0.87-1.99) | aOR 1.26 (0.83-1.93) |
| **Small for gestational age (<$10^{th}$ centile), n (%)** | 65/301 (21.6%) | 54/347 (15.6%) | OR 0.67 (0.45-1.00*) | aOR 0.68 (0.45-1.02) |
| **Large for gestational age (>$90^{th}$ centile), n (%)** | 29/301 (9.6%) | 38/347 (11.0%) | OR 1.15 (0.69-1.92) | aOR 1.12 (0.67-1.88) |
| **Preterm (<37+0 weeks), n (%)** | 30/302 (9.9%) | 31/348 (8.9%) | OR 0.89 (0.52-1.50) | aOR 0.85 (0.50-1.46) |
| **Postdates (>41+6 weeks), n (%)** | 3/302 (1.0%) | 10/348 (2.9%) | OR 2.95 (0.80-10.82) | aOR 2.95 (0.80-10.93) |
| **Apgar score at 1 minute <7, n (%)** | 42/299 (14.0%) | 40/331 (12.1%) | OR 0.84 (0.53-1.34) | aOR 0.83 (0.52-1.34) |
| **Apgar score at 5 minutes <7, n (%)** | 5/299 (1.7%) | 5/330 (1.5%) | OR 0.91 (0.26-3.16) | aOR 0.97 (0.27-3.46) |
| **Neonatal unit admission, n (%)** | 20/299 (6.7%) | 25/338 (7.4%) | OR 1.11 (0.61-2.05) | aOR 1.13 (0.61-2.10) |
| **Breastfeeding initiation, n (%)** | 159/295 (53.9%) | 181/337 (53.7%) | OR 0.99 (0.73-1.36) | aOR 0.93 (0.67-1.28) |
| **Breastfeeding at discharge from hospital, n (%)** | 131/292 (44.9%) | 135/328 (41.2%) | OR 0.86 (0.63-1.18) | aOR 0.79 (0.57-1.09) |
| **Sex of neonate, n (%)** | | | | |
| Male | 141 (46.4%) | 180 (51.7%) | OR 1.24 (0.91-1.69) | aOR 1.23 (0.90-1.69) |
| Female | 163 (53.6%) | 168 (48.3%) | REF | REF |

[a] Adjusted for deprivation (REF= most deprived quintile) and smoking (REF=non smoker) as these were the only significant differences in baseline characteristics

* significant at *P*<0.05 level, ** significant at *P*<0.01 level, *** significant at *P*<0.01 level

The impact of changing service intensity on women of different parities was explored (maternal and neonatal outcomes for primiparous women are given in Supplementary Material: Appendix S1 and for multiparous women are given in Supplementary Material: Appendix S2). A reduction in those gaining above IOM recommendations with the enhanced service was noted in multiparous women but not nulliparous women, with the weekly weight gain also significantly less in multiparous women after adjusting for baseline differences [aMD -0.06kg/week (95% CI -0.11 to -0.01)]. With the enhanced service, multiparous women were noted to have a reduction in SGA [aOR 0.52 (95% CI 0.31-0.87)].

The number of women declining attendance at the clinic after referral was significantly lower with the enhanced service (8.5% versus 27.4% for the low intensity service, $P<0.001$). Table 4 compares the characteristics of women who chose to attend their antenatal healthy lifestyle service appointment with those who declined attendance. Women who declined attendance were significantly more likely to be from the most deprived quintile, to have two or more children, to smoke and to belong to a household where the highest occupation was classified as 'housewife /no income /student'.

## DISCUSSION

The primary outcome GWG was not significantly different between the different intensities of an antenatal healthy lifestyle service. Within this study much lower proportions of women gained more weight than IOM recommendations within both the low intensity service (37.5%) and the enhanced service (27.4%), than seen within a recent meta-analysis of individual patient data which suggested that 44% of women with obesity had a GWG above IOM recommendations (Rogozińska et al., 2017). This may be because this study only included women with a BMI of 40 or more rather than all women with obesity. It however specifically highlights the need for further exploration of GWG patterns in women with different classes of obesity, particularly those with a BMI of 40 or more, to better understand the proportion of women in each obesity class who gain above IOM recommendations.

Overall fewer women gained weight above IOM recommendations when offered the enhanced service compared to those offered the low intensity intervention. However, a significant difference in gestation at which the final weight had been recorded was noted between the two different service intensities, with those attending the enhanced service having their final weight recorded at a significantly earlier gestation. An additional analysis

**Table 4. Comparison of maternal characteristics in those who attended versus those who declined attendance at the healthy lifestyle service**

| Characteristic | Attended service (n=560) | Service attendance declined (n=117) | *P* Value |
|---|---|---|---|
| **Maternal age, mean (SD), y** | 28.6 (5.5) | 27.8 (5.1) | 0.12 |
| **Deprivation quintile, n (%)** | | | 0.006 |
| Quintile 1: Most deprived - IMD score 1-6568 | 306 (54.6%) | 82 (70.1%) | |
| Quintile 2: IMD score 6569-13137 | 114 (20.4%) | 23 (19.7%) | |
| Quintile 3: IMD score 13138-19706 | 71 (12.7%) | 4 (3.4%) | |
| Quintile 4: IMD score 19707-26275 | 50 (8.9%) | 5 (4.3%) | |
| Quintile 5: Least deprived IMD score 26276-32844 | 19 (3.4%) | 3 (2.6%) | |
| **Smoking status at booking, n (%)** | | | 0.001 |
| Smoker | 101 (18.1%) | 49 (41.9%) | |
| Non-smoker | 458 (81.9%) | 68 (58.1%) | |
| **Parity, n (%)** | | | <0.001 |
| 0 | 195 (34.8%) | 9 (7.7%) | |
| 1 | 187 (33.4%) | 45 (38.5%) | |
| 2+ | 178 (31.8%) | 63 (53.8%) | |
| **Ethnicity, n (%)** | | | 0.10 |
| White British | 528 (94.8%) | 114 (98.3%) | |
| Other | 29 (5.2%) | 2 (1.7%) | |
| **Highest household Occupation, n (%)**[a] | | | <0.001 |
| Higher managerial, administrative and professional occupations | 100 (18.3%) | 12 (10.4%) | |
| Intermediate occupations | 129 (23.7%) | 13 (11.3%) | |
| Routine and manual occupations | 190 (34.9%) | 41 (35.7%) | |
| Housewife/ Long-term no income or never worked/ student | 126 (23.1%) | 49 (42.6%) | |
| **Education, n (%)** | | | 0.73 |
| GCSE/ equivalent or lower | 97 (44.1%) | 11 (37.9%) | |
| AS/A level or equivalent | 62 (28.2%) | 8 (27.6%) | |
| Degree, postgraduate or equivalent | 61 (27.7%) | 10 (34.5%) | |
| **Marital status, n (%)** | | | 0.10 |
| Married/civil partnership | 200 (35.9%) | 33 (28.4%) | |
| Partner | 290 (52.1%) | 73 (62.9%) | |
| Single[b] | 67 (12.0%) | 10 (8.6%) | |
| **Booking body mass index, mean (SD), kg/m²** | 44.0 (3.8) | 43.8 (3.2) | 0.52 |
| **Gestation at booking, mean (SD), wk** | 9.1 (3.4) (n=559) | 9.4 (3.1) | 0.46 |

IMD – Index of Multiple Deprivation (Smith et al. 2015)

[a] Occupations coded using the 3 category National Statistics Socioeconomic Classification (NS-SEC) system (ONS 2010)

[b] The single category included 4 women in 2009-2011 and 5 women in 2012-2015 who were divorced/ separated/widowed

of rate of weight gain was therefore incorporated as this controlled for the different length of time over which weight gain was measured during pregnancy for different women. This rate of weight gain was no different between the different service intensities. This emphasises the importance of considering the gestation at final weight when assessing and reporting GWG within the literature.

When considering the service impact on women of different parities, a significant reduction in those gaining above IOM recommendations was only evident among multiparous women. Additionally multiparous women attending the enhanced service also achieved a lower rate of weight gain. This larger impact of the enhanced service in multiparous women is of interest, given that primiparous women are known to gain more weight in pregnancy. One potential explanation may be that qualitative studies have found multiparous women to voice regret over gaining excessive weight within their first pregnancy (Fair et al. 2022). This may make multiparous women more conscious of implementing any advice provided in a subsequent pregnancy and appreciative of the additional support received from the enhanced service.

As would be expected women receiving the lower intensity service attended fewer dietary service appointments than women in the enhanced clinic intervention. Increased attendance with the increasing number of appointments available to women suggests a general acceptability of the appointments. However, to evaluate service acceptability it is also important to consider those who declined attendance at the antenatal healthy lifestyle service. These women were significantly more likely to be of lower socioeconomic status, to already have children, and to smoke. Others have found similar factors to influence engagement, for example in one service women with obesity who smoked were less likely to attend individual weight management appointments during pregnancy (Porteous et al 2020). In a separate study, women from low income households or who lived in larger households engaged less with a text based health education intervention during pregnancy and the postpartum (Gazmararian et al. 2014). To ensure equitable access for all groups, when developing future services additional attention is needed on structural barriers women may face, for example through offering childcare or covering the cost of transportation to appointments. There was a lower proportion of women not attending any appointments with the enhanced service (8.5%) compared to the low intensity service

(27.4%). The slightly higher number of nulliparous women referred to the enhanced service could not account for all of this difference. It may therefore reflect that the established service had increased awareness of obesity during pregnancy within the Trust which had given community midwives more confidence to raise the issue of a woman's BMI when referring them into the service. This is important as midwives have previously been shown to avoid challenging discussions around weight with women during pregnancy (Atkinson and McNamara 2017), with women getting inadequate information about services they had been referred to as a result (Heslehurst et al. 2017).

The only other differences in outcomes between the two differing intensities of service after adjusting for baseline differences, were day of discharge from hospital and labour induction. It is believed that these differences more likely reflected changes in practice and policy over time rather than being a direct impact of the antenatal healthy lifestyle service. Nationally, over the period of this study, there was a reduction in the length of postpartum hospital stay (Bowers & Cheyne 2015) and an increasing proportion of births being induced (National Health Service Digital, 2019). Although not significant, there was an increased rate of gestational diabetes mellitus in women attending the enhanced service. This could not be explained by any changes to diagnostic criteria during the study period. While the proportion of women with a blood glucose measurement increased over time, from 84.4% versus 87.7% this alone could not explain the increased rate of gestational diabetes mellitus. Women with gestational diabetes mellitus are more likely to have an induced labour (Koivunen et al. 2020), therefore the increased proportion of women with gestational diabetes mellitus in those attending the enhance service could also have impacted on the higher rates of labour induction. No other differences were noted in outcomes between the two service intensities, except for a reduction in SGA for multiparous women. It is however acknowledged that this study was underpowered to detect changes in some outcomes with low incidences and did not look at longer term maternal outcomes, such as postpartum weight retention or weight upon entering any subsequent pregnancies.

The findings within this study are in line with a recent overview of systematic reviews of randomised controlled trial evidence that showed that while lifestyle interventions during pregnancy could result in small reductions in GWG among women with overweight or obesity, this corresponded with limited or no improvements in other pregnancy outcomes such as gestational diabetes mellitus, pre-eclampsia, mode of birth or birth weight outcomes (Fair & Soltani 2021). This therefore may indicate that rigorous service evaluations, with appropriate controlling for confounding factors, could perhaps be a good alternative for RCTs, which are often costly and less relevant to real-life situations for such complex public health challenges.

No optimal intervention frequency was found in a previous systematic review of randomised controlled trial evidence among women from all pre-pregnancy BMI categories (Walker et al 2018). Within that review, subgroup analysis showed no difference in excessive GWG between lifestyle interventions delivered 1-3 times and those delivered 4-7 or eight or more times. This suggested clear consistent advice from professionals trained to initiate conversations around GWG had the potential to reduce excessive GWG as much as intense interventions. The systematic review grouped together interventions where the frequency of contact was between one and three times. This current study has however suggested that especially in multiparous women that rate of weight gain during pregnancy could be reduced by increasing intervention intensity, therefore further exploration of the differential impact of antenatal healthy lifestyle service for nulliparous and multiparous women is recommended, particularly for women with a BMI of 40 or more.

**Strengths and limitations of the study**

This cohort study explored the impact of an antenatal healthy lifestyle service within a large number of women with a BMI of 40 or more, a category often lacking in studies of lifestyle interventions in pregnancy. Despite the increasing national prevalence of obesity, the proportion of women with a BMI of 40 or more within the Trust remained at 3.5%, with the mean BMI also being the same in both study periods. The study took advantage of changing practices in antenatal healthy lifestyle service provision to enable a pragmatic exploration of differing service intensities within a real-life situation. Some limitations however need to be acknowledged. Retrospective data collection is well known for its limitations around data completeness (Song and Chung 2010). Poor documentation of maternal education within the health records was particularly evident within this study. The antenatal healthy lifestyle service was provided by the same midwives throughout the whole time-period offering consistency. However, due to the retrospective nature of the study it was not possible to fully adjust for changes in midwifery practice or policy over time to ensure that all other care received by women in the low intensity service was identical in every way to women offered the enhanced service.

## CONCLUSIONS

Among women with a BMI of 40 or more there were no overall differences on the outcome of mean GWG between women provided with three sessions at an antenatal healthy lifestyle service compared to those provided with one session. However multiparous women offered the enhanced serviced were less likely to gain weight in excess of IOM recommendations and gained weight at a slower rate after adjusting for baseline differences. No improvements in any maternal or neonatal outcomes were seen with additional antenatal healthy lifestyle service visits except for reduced odds of SGA in multiparous women. However, this study was underpowered to detect changes in some outcomes with low incidences. Uncertainty remains over the best management of GWG in women with a BMI of 40 or more. Further research is required to establish the most effective intervention types and intensities for women of different classes of obesity. A specific focus on nulliparous women could be suggested given the lack of impact of this current antenatal healthy lifestyle service on nulliparous women.

**Supplementary Material: Appendix S1. Maternal and neonatal outcomes according to service intensity for primiparous women**

**Supplementary Material: Appendix S2. Maternal and neonatal outcomes according to service intensity for multiparous women**

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**Table 2. Maternal outcomes according to service intensity**

| Outcome | Low intensity 2009-2011 (n=315) | Enhanced service 2012-2015 (n=367) | Crude Mean difference (MD) or Odds ratio (OR) (95% CI) | Adjusted MD/OR (95% CI) [a] |
|---|---|---|---|---|
| **Number of antenatal healthy lifestyle service appointments attended, mean (SD)** | 1.2 (1.3) (n=314) | 2.2 (1.2) (n=363) | MD 1.1 (0.9-1.2)*** | aMD 1.00 (0.8-1.2)*** |
| **Number of antenatal healthy lifestyle service appointments, n (%)** | | | | |
| 0 | 86 (27.4%) | 31 (8.5%) | REF | REF |
| 1 | 143 (45.5%) | 69 (19.0%) | OR 1.34 (0.81-2.21) | aOR 1.27 (0.76-2.12) |
| 2 | 58 (18.5%) | 98 (27.0%) | OR 4.69 (2.78-7.91)*** | aOR 4.48 (2.62-7.65)*** |
| 3 or more | 27 (8.6%) | 165 (45.5%) | OR 16.95 (9.51-30.22)*** | aOR 16.08 (8.89-29.08)*** |
| **Gestation at first antenatal healthy lifestyle appointment, mean (SD), wk** [b] | 17.3 (5.4) (n=228) | 17.3 (4.8) (n=331) | MD -0.0 (-0.9 to 0.8) | aMD -0.1 (-0.9 to 0.8) |
| **Gestational weight gain, mean (SD), kg** | 6.6 (7.4) (n=264) | 5.7 (6.9) (n=296) | MD -1.0 (-2.2 to 0.2) | aMD -1.1 (-2.3 to 0.1) |
| **Gestation at final weight, mean (SD),wk** | 38.1 (1.9) (n=264) | 36.9 (1.6) (n=296) | MD -1.2 (-1.5 to -0.9)*** | aMD -1.2 (-1.5 to -0.9)*** |
| **Weekly weight gain, mean (SD), kg/wk** | 0.24 (0.28) (n=264) | 0.21 (0.25) (n=296) | MD -0.04 (-0.08 to 0.01) | aMD -0.04 (-0.09 to 0.001)[c] |
| **Weight gain according to Institute of Medicine recommendations, n (%)** | | | | |
| Too little | 104 (39.4%) | 133 (44.9%) | OR 0.95 (0.63-1.45) | aOR 1.00 (0.65-1.52) |
| Recommended | 61 (23.1%) | 82 (27.7%) | REF | REF |
| Too much | 99 (37.5%) | 81 (27.4%) | OR 0.61 (0.39-0.95)* | aOR 0.63 (0.40-0.98)* |
| **Vaginal birth, n (%)** | 166/302 (55.5%) | 180/347 (51.9%) | OR 0.88 (0.65-1.20) | aOR 0.87 (0.64-1.19) |
| **Caesarean birth, n (%)** | 126/302 (41.7%) | 150/347 (43.2%) | OR 1.06 (0.78-1.45) | aOR 1.09 (0.79-1.49) |
| **Induction of labour (excluding Caesarean birth prior to labour), n (%)** | 112/229 (48.9%) | 170/273 (62.3%) | OR 1.72 (1.21-2.46)** | aOR 1.70 (1.19-2.45)** |
| **Postpartum haemorrhage (estimated blood loss ≥500ml), n (%)** | 126/301 (41.9%) | 137/302 (45.4%) [d] | OR 1.15 (0.84-1.59) | aOR 1.19 (0.86-1.65) |

| | | | | |
|---|---|---|---|---|
| **Perineal laceration sustained (excluding women with a Caesarean birth), n (%)** | 106/176 (60.2%) | 123/192 (64.1%) | OR 1.18 (0.77-1.80) | aOR 1.14 (0.74-1.76) |
| **Epidural analgesia (attempted or achieved), n (%)** | 141/301 (46.8%) | 170/331 (51.4%) | OR 1.20 (0.88-1.64) | aOR 1.17 (0.85-1.62) |
| **General anaesthetic, n (%)** | 29/303 (9.6%) | 23/332 (6.9%) | OR 0.70 (0.40-1.25) | aOR 0.72 (0.40-1.29) |
| **Shoulder dystocia (excluding women with a Caesarean birth), n (%)** | 8/174 (4.6%) | 3/193 (1.6%) | OR 0.33 (0.09-1.26) | aOR 0.29 (0.07-1.14) |
| **Day of discharge from hospital, n (%)** | | | | |
| Day of birth | 46 (15.1%) | 35 (10.2%) | REF | REF |
| Day 1 | 88 (29.0%) | 146 (42.7%) | OR 2.18 (1.31-3.64)** | aOR 2.14 (1.27-3.60)** |
| Day 2 | 114 (37.5%) | 99 (29.0%) | OR 1.14 (0.68-1.91) | aOR 1.31 (0.67-1.91) |
| Day 3+ | 56 (18.4%) | 62 (18.1%) | OR 1.46 (0.82-2.57) | aOR 1.37 (0.77-2.43) |
| **Haemoglobin <110g/l at booking, n (%)** | 6/303 (2.0%) | 6/349 (1.7%) | OR 0.87 (0.28-2.71) | aOR 0.99 (0.31-3.15) |
| **Haemoglobin<105 g/l at 28 weeks' gestation, n (%)** | 18/289 (6.2%) | 14/326 (4.3%) | OR 0.68 (0.33-1.38) | aOR 0.77 (0.37-1.60) |
| **Haemoglobin<105g/l at 36 weeks gestation, n (%)** | 16/195 (8.2%) | 23/241 (9.5%) | OR 1.18 (0.61-2.30) | aOR 1.33 (0.67-2.63) |
| **Gestational diabetes mellitus (excluding those with gastric surgery), n (%)** | 45/262 (17.2%) | 75/314 (23.9%) | OR 1.51 (1.00-2.29)* | aOR 1.49 (0.98-2.26) |
| **Additional monitoring for raised blood pressure, n (%)**[e] | 54/282 (19.1%) | 59/305 (19.3%) | OR 1.01 (0.67-1.53) | aOR 1.00 (0.66-1.52) |

* significant at $P$<0.05 level, ** significant at $P$<0.01 level, *** significant at $P$<0.01 level

[a] Adjusted for deprivation (REF= most deprived quintile) and smoking (REF=non smoker) as these were the only significant differences in baseline characteristics

[b] Gestation at first antenatal healthy lifestyle appointment only available for those who attended the clinic

[c] This was further away from reaching significance once removing the outlier aMD -0.04 (-0.08, 0.01)

[d] The new electronic health notes for recording intrapartum care from 2015 made it difficult to obtain estimated blood loss for many women who gave birth in 2015

[e] Additional monitoring for raised blood pressure - women receiving monitoring over and above routine care due to raised blood pressure, including those who went on to be diagnosed with pregnancy Induced hypertension, pre-eclampsia or HELLP syndrome

## 5.5 Summary and implications for thesis

Robust, comparative analysis of one antenatal healthy lifestyle service appointment versus an enhanced service offering three appointments on maternal and infant health outcomes was provided within this study.

The results of this study showed no overall difference in gestational weight gain, although multiparous women showed a small reduction in weight gain in excess of Institute of Medicine recommendations. No beneficial effects of the enhanced service were noted on clinical outcomes except for a reduction in SGA infants among multiparous women.

A comparison of maternal and infant outcomes with the enhanced service compared to no service within a neighbouring NHS Trust is presented in the following chapter.

# Chapter 6: Evaluation of an antenatal healthy lifestyle service versus a comparison cohort

## 6.1 Introduction

This chapter presents Article C, the second article from the quantitative component of this programme of research. This is a comparison of the maternal and neonatal outcomes among women with a BMI of 40kg/m² or above who attended an antenatal healthy lifestyle service to a cohort of women in the neighbouring Trust who did not have access to such as service. The aims of the study are provided below, alongside the details of publication and impact of the article. The full published article is then presented. The chapter concludes by summarising the key findings of this component.

## 6.2 Study aim

The study aim was to compare pregnancy and birth outcomes for mothers with a BMI ≥40kg/m² who experienced an antenatal healthy lifestyle service with a cohort of mothers from a neighbouring comparison NHS Trust without this service. The neighbouring NHS Trust was chosen as the comparison cohort due to the similar health and demographic profile to the Trust with the antenatal healthy lifestyle service. This component of the quantitative research also addressed the second aim of the overall programme of research: *"To explore the impact of a service supporting women with the highest class of obesity to achieve adequate GWG and improve maternal and infant outcomes."*

## 6.3 Published article: Article C

The manuscript is entitled "*A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index.*" It is reproduced in full in the format in which it has been published[333].

## 6.4 Publication and impact

The article was accepted for publication in Women and Birth on 29th August 2023. It was published online as an 'Article in Press' on 9th September 2023, before being published in the February 2024 edition of Women and Birth.

Women and Birth is a midwifery journal publishing papers that contribute to the relevant contemporary research, policy and/or theoretical literature on topics around pregnancy, childbirth and the first six weeks postpartum. It is the official publication of the Australian College of Midwives. In 2022 Women and Birth had an impact factor of 3.8.

Since publication this article has been self-cited once (as of 31st January 2024). The publisher does not track online views, however it has an Altmetric score of 1 which is average compared to outputs of the same age.

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# A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index

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ABSTRACT

*Background:* Women with obesity are more likely to gain excessive gestational weight; with both obesity and excessive weight gain linked to adverse outcomes for mothers and their infant. Provision of antenatal healthy lifestyle services is currently variable, with uncertainty over the most effective gestational healthy lifestyle interventions.
*Aim:* To compare pregnancy and birth outcomes among women who experienced an antenatal health lifestyle service with a cohort who did not receive this service.
*Methods:* A retrospective comparative cohort study was undertaken in women with a BMI $\geq$ 40 kg/m$^2$ attending maternity care in two NHS Trusts. One Trust provided an antenatal healthy lifestyle service, while the comparison Trust provided routine maternity care. Data was collected from medical records.
*Findings:* No differences were observed between the antenatal healthy lifestyle service and comparison cohorts for average gestational weight gain [adjusted mean difference (aMD) − 0.70 kg (95%CI −2.33, 0.93)], rate of weight gain [aMD − 0.02 kg/week (95%CI −0.08, 0.04)] or weight gain in accordance with recommendations. The proportion of women breastfeeding at discharge was higher for the antenatal healthy lifestyle service than the comparison cohort (42.4% vs 29.8%). No other clinical outcomes were enhanced with the antenatal healthy lifestyle service.
*Conclusion:* Internal audit had suggested the antenatal healthy lifestyle service was successful at managing gestational weight gain in women with a BMI $\geq$ 40 kg/m$^2$. However, no benefit on gestational weight gain was evident once the service was evaluated against a comparison cohort with adequate adjustment for confounders. It is essential that future services are evaluated against a relevant comparison group.

**Statement of significance**

**Issue**

Rising obesity rates place women and their infants at risk, especially of excessive gestational weight gain (GWG), which is also associated with adverse outcomes.

**What is already known**

The best management to reduce GWG in women with obesity is uncertain.

**What this paper adds**

The interventional service was not superior in reducing GWG in women with a BMI $\geq$ 40 kg/m$^2$ compared to the comparison Trust. Even without an intervention service the average GWG was within the recommended IOM range. There were no observed improvements in other outcomes for the intervention group. Clear effective GWG management strategies are required.

## Introduction

The proportion of women with obesity at the start of their pregnancy has risen significantly over recent decades, with the rate more than doubling from 7.6% in 1989 to 15.6% in 2007 across 37 maternity units in England [1]. Since then, the proportion has continued to increase, being 22.2% in 2018–2019 [2]. Furthermore, childbearing is acknowledged to contribute to the rise in women with overweight and obesity [3]. Socio-demographic disparities in maternal obesity are well known with women who are older, of a higher parity and from deprived areas

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being more likely to be obese at the start of pregnancy [1,2].

Obesity during pregnancy has been associated with a wide range of adverse outcomes including gestational diabetes, pre-eclampsia, preterm birth [4], poorer induction outcomes [5], caesarean section [6], maternal mortality [7], shoulder dystocia [8], large for gestational age (LGA) infants [4], and poorer rates of breastfeeding initiation and continuation [9]. An individual patient meta-analysis from 39 cohort studies undertaken in Europe, Australia and North America including 265,270 births estimated that of all pregnancy complications 23.9% were attributable to maternal overweight or obesity prior to pregnancy, with the highest risk of pregnancy complications for mothers with a BMI $\geq$ 40 kg/m$^2$ [4]. Furthermore, children born to women with obesity during pregnancy have been shown to have an increased risk of obesity themselves [10]. In addition to health risks, these complications can lead to a longer length of hospital stay which has significant implications on health service resource utilisation as well as cost, with an estimated additional cost of £ 1172 to the National Health Service in the United Kingdom (UK) for every maternity in a woman with obesity [11].

Women with obesity prior to pregnancy are also at high risk of excessive gestational weight gain [12]. Increased gestational weight gain (GWG) is itself associated with adverse maternal and neonatal outcomes such as increased risk of LGA infants [4], caesarean section [13], induction [14], maternal weight retention [3] and childhood obesity [10], as well as reduced incidence of breastfeeding [9]. In view of the many adverse effects of excessive GWG, the Institute of Medicine (IOM) [15] has proposed guidelines for GWG based on maternal pre-pregnancy BMI category. A GWG between 5 and 9 kg is recommended for women with obesity [15], however evidence suggests about 60% of women with obesity gain more weight during pregnancy than recommended [16].

Provision of maternity services for women with obesity is variable within the UK, with a need for more equitable antenatal maternal obesity services identified [17]. Despite pregnancy being recognised as a good opportunity to influence behaviour change for mothers and families [18], there is uncertainty among professionals about what constitutes the most suitable service to tackle maternal obesity [17]. The lack of certainty about the best interventions to control weight gain during pregnancy is further reinforced by numerous international studies [19–22] that have given mixed results. A recent overview of systematic reviews has suggested that while lifestyle interventions may cause a small reduction in GWG, the current data found no clear benefit on maternal and infant clinical outcomes [23]. Optimization of gestational weight gain management has recently been identified as a top research priority by the international Health in Preconception, Pregnancy and Postpartum Global Alliance [24]. Furthermore, the National Institute for Health and Clinical Excellence (NICE) has recommended more research - particularly UK based investigations into ways of managing maternal obesity and GWG to optimise pregnancy outcomes as UK based research into the efficacy of weight management interventions in pregnancy is limited [25]. Establishing the optimal management of obesity and weight gain during pregnancy is also essential given the weight stigma many women describe during pregnancy and in the postnatal period [26]. Women report healthcare providers assuming that they are lazy, lack will power and are unintelligent [26]. This stigma itself has been shown to lead to weight gain, exercise avoidance and increased nutritional intake [26]. This study therefore investigates the outcomes for women and their neonates of an antenatal healthy lifestyle service in a real-life practice setting to further inform the debate as to the most suitable service for women at this key period in their life.

### Aim

To compare pregnancy and birth outcomes for mothers with a BMI $\geq$ 40 kg/m$^2$ who experienced an antenatal healthy lifestyle service with a cohort of mothers from a neighbouring comparison NHS Trust without this service.

## Method

A retrospective comparative study from two neighbouring Trusts was undertaken.

### Setting

#### Antenatal healthy lifestyle service

A midwife-led antenatal healthy lifestyle service was initially established in an NHS Trust in the Yorkshire and Humber region of England in 2009. As the service was established community midwives were trained in initiating conversations with women when referring them to the clinic [27,28]. From July 2012 women with a BMI $\geq$ 40 kg/m$^2$ were offered appointments at 16, 28 and 36 gestational weeks, with an opportunity to further access the service for additional appointments if they wished. Women's attendance or non-attendance at the antenatal healthy lifestyle service was documented. Midwives led the service and provided support and advice on lifestyle change while working alongside other professions such as obstetricians, dieticians, anaesthetists and exercise programme providers. The overall aim of the clinic was to encourage women to make lifestyle choices and behavioural changes during pregnancy, which could be sustained in the postpartum period. The approach to weight management encouraged four healthy lifestyle facets. The first of these was around healthy eating with women informed of healthy eating principles for pregnancy and individual support provided where required for example around managing pregnancy related cravings. The second facet was around being physically active during pregnancy which included advice around what exercise could safely be undertaken during pregnancy and referral to relevant local services such as aquanatal classes. The third component was around not gaining excessive gestational weight during pregnancy, with the women's current weight gain discussed within each appointment. The final element was around breast feeding. Individualised care planning was undertaken, which encouraged women to set goals such as to swap one unhealthy food for a healthy one. These goals were followed up and reassessed at subsequent appointments. Additionally, women were offered a dietician consultation [27]. Local audit data suggested this service to be effective at reducing GWG. However local midwives called for a robust and external evaluation to allow national credibility and the potential for rolling out the service.

#### Comparison cohort

Women attending for antenatal care in the neighbouring Trust were chosen as the comparison cohort. This neighbouring Trust was chosen due to the similar health, lifestyle and demographic profile in 2015 to that of the Trust that provided the antenatal healthy lifestyle service as seen in Table 1. No specific antenatal healthy lifestyle services were available in the neighbouring NHS Trust until a dietician provided service was established in 2012. Women could opt to use this dietician

**Table 1**
Health, lifestyle and demographic profiles of the two NHS Trusts.

| Characteristic | Comparison Trust | Trust providing the antenatal healthy lifestyle service |
|---|---|---|
| Deprivation (proportion living in the most deprived 20% in England) | 29.6% | 29.1% |
| Proportion of adults with overweight or obesity | 71.0% | 73.4% |
| Smoking at birth of infant | 20.5% | 20.7% |
| Healthy eating (adults reporting eating '5 a day' on a usual day | 52.4% | 49.6% |
| Physically active adults | 59.7% | 58.6% |
| Ethnicity | 97.9% | 95.3% |

Data from Public Health England 2015 [43] and Office for National Statistics 2011 [52] service for antenatal weight management if they wished to do so. Referral and uptake figures for this service were however very low for the time period of this study, 2012–2015, due to poor staff training around referral to the service and high staff turnover within the service [29]. Due to the very low numbers involved, women who attended the dietician services were not included within the comparison group. The women in the comparison cohort therefore received no targeted healthy eating or physical activity support or advice.

### Data collection

Maternal and neonatal pregnancy and birth data were obtained from routinely collected data for all women with a BMI $\geq$ 40 kg/m$^2$ booking for maternity care with a singleton pregnancy in either Trust from 2012–2015. Data was collected electronically where this was available, with the rest being obtained directly from maternal medical records.

The primary outcome for this study was maternal gestational weight gain. Secondary outcomes included maternal weight gain in accordance with IOM guidance, gestational diabetes, pregnancy induced hypertension, anaemia, mode of birth, induction, requirement of epidural or general anaesthetic for labour or birth, perineal tear, postpartum haemorrhage, birthweight, gestational age at birth, APGAR scores, breastfeeding initiation and adverse outcomes of shoulder dystocia and admission to the neonatal special care unit.

BMI was calculated from the standard formula weight/height squared (kg/m$^2$) using weight at booking. In a small minority of cases (n = 6) BMI was taken as recorded in the medical records as weight or height at booking was not recorded to calculate BMI independently. Weighing was routine at 36 weeks gestation within both Trusts, therefore GWG was measured by subtracting weight at booking from the final weight measured during pregnancy from the middle of the third trimester (34 +0 weeks gestation) onwards. The recommended range for weight gain for women with obesity prior to pregnancy is 5–9 kg [15]. According to IOM recommendations, women were classified as gaining too little weight, in accordance with recommendations or above recommendations (excessive weight gain). Birthweight less than 2500 g was classified as low birth weight and birthweight more than 4000 g as macrosomia. Infant birthweight centiles were calculated using GROW charts (UK version 8.0.6.1) [30,31]. This customized the centiles according to maternal height, maternal weight, ethnicity, parity, gestation and infant gender, which have been shown to be more accurate in populations with overweight and obesity [32]. Birthweight less than the 10th centile for gestational age was classified as small for gestational age (SGA) and above the 90th centile as LGA. Anaemia was classified as a haemoglobin level < 110 g/l at the booking appointment or < 105 g/l at 28 weeks and 36 weeks [33]. Pregnancy induced hypertension was taken as the need for any appointment to assess blood pressure above routine antenatal care, for example day care unit assessment. Definitions for gestational diabetes between the 2 units varied slightly, therefore for the purposes of this study gestational diabetes was defined as fasting blood glucose $\geq$ 5.3mmmol/l or 2 h post 75 g glucose challenge blood glucose $\geq$ 8.5 mmol/l, rather than gestational diabetes as diagnosed within the medical notes. Postpartum haemorrhage was defined as a blood loss of 500 ml or more at a vaginal birth and 1000 ml or more for a Caesarean birth. Occupations of the women and their partners were coded using the 3 category National Statistics Socio-economic Classification (NS-SEC) system [34]. The highest occupation category for each household (either for the woman or her partner) was utilised within the analysis. The Index of Multiple Deprivation (IMD) was used to measure deprivation, as this is the official measure of relative deprivation in England. The score for each area combines information from seven domains of deprivation (income, employment, education, health, crime, housing and living environment) to give one overall deprivation score from 1 (most deprived) to 32844 (least deprived) [35]. These scores were designated into the appropriate quintiles.

### Data analysis

Logical checks and data cleaning were carried out and inconsistencies were returned to the field for clarification. An initial comparison between the Trusts for baseline characteristics was undertaken using SPSS 24.0 to identify potential confounding variables. The outcomes from women attending the antenatal healthy lifestyle service were then compared to the outcomes in the cohort of women from the neighbouring Trust. To compare differences in outcomes logistic regression analyses were used for binary outcomes, and multinomial regression analyses for categorical data with more than 2 categories with the appropriate referent group identified. Outcomes on a continuous scale were compared using independent samples t test. Multivariate logistic or multivariate linear regression were used to adjust comparisons for confounding factors. For categorical outcomes, crude and adjusted odds ratios are reported (OR and aOR) and for continuous outcomes, crude and adjusted mean difference (MD and aMD) are reported, all along with their 95% confidence interval (CI). $p < 0.05$ was regarded as statistically significant. Linear regression model assumptions were checked using standard regression diagnostics for linearity, normality, leverage, and influence. However, no cases were noted where assumptions were violated or where removal of outliers had an impact on the significance or direction of the effect size.

## Findings

### Demographic data

In the comparison NHS Trust, 417 women with a BMI $\geq$ 40 kg/m$^2$ booked for care with a singleton pregnancy between 2012 and 2015. Of these 16 records could not be found and 30 women had attended a dietician appointment, data was also missing regarding dietician appointments for 6 women, 3 of whom had an early miscarriage. After excluding these women from the analysis, 365 women were left within this cohort.

In the intervention NHS Trust within the same time period, 371 women with a BMI $\geq$ 40 kg/m$^2$ with a singleton pregnancy were referred to the antenatal healthy lifestyle service. Of these, four records could not be found, 31 women did not attend for an antenatal healthy lifestyle service appointment and four women miscarried prior to their expected first appointment. These women were excluded from the analysis, leaving a total of 332 women.

Baseline demographic and lifestyle data for the intervention and comparison cohorts can be seen in Table 2. Women in the comparison cohort were significantly more likely to smoke at booking (p = 0.005). Highest household occupation also significantly differed between the comparison cohort and those attending the antenatal healthy lifestyle service (p = 0.016). Women in the comparison cohort were less likely to be in a household where the highest occupation was classified as higher managerial, administrative or professional occupation or have a routine or manual occupation and they were more likely to be in a household with an intermediate occupation. Women attending the comparison Trust were also less likely to be in the most deprived quintile, but more likely to be in the second most deprived quintile. Other baseline characteristics were not significantly different between the two groups.

### Maternal and Infant outcomes

Table 3 presents the maternal outcomes for the antenatal healthy lifestyle service cohort versus the comparison cohort. Odds ratios and mean differences were adjusted for smoking at booking, highest household occupation and deprivation as these were significantly different between the two Trusts. Additionally, due to the observed differences in prevalence of gestational diabetes between the two Trusts, this was adjusted for within the analysis given the potential impact of gestational diabetes on multiple outcomes.

**Table 2**
Baseline demographic and lifestyle data.

| Characteristic | Comparison cohort 2012–2015 (n = 365) | Antenatal healthy lifestyle service 2012–2015 (n = 332) | P value |
|---|---|---|---|
| **Maternal age** | 28.3 ( ± 5.5) (n = 364) | 28.5 ( ± 5.4) | 0.632 |
| **Deprivation quintile** | | | |
| Quintile 1: Most deprived - IMD score 1–6568 | 173 (47.4%) | 170 (51.2%) | 0.001 * * |
| Quintile 2: IMD score 6569–13137 | 129 (35.3%) | 72 (21.7%) | |
| Quintile 3: IMD score 13138–19706 | 32 (8.8%) | 46 (13.9%) | |
| Quintile 4: IMD score 19707–26275 | 24 (6.6%) | 33 (9.9%) | |
| Quintile 5: Least deprived IMD score 26276–32844 | 7 (1.9%) | 11 (3.3%) | |
| **Smoking status at booking** | | | |
| Smoker | 92 (25.4%) | 55 (16.6%) | 0.005 * * |
| Non-smoker | 270 (74.6%) | 276 (83.4%) | |
| **Parity** | | | |
| 0 | 127 (34.8%) | 122 (36.8%) | 0.244 |
| 1 | 138 (37.8%) | 106 (31.9%) | |
| 2 + | 100 (27.4%) | 104 (31.3%) | |
| **Ethnicity** | | | |
| White British | 355 (97.5%) | 314 (95.2%) | 0.093 |
| Non White British | 9 (2.5%) | 16 (4.8%) | |
| **Highest household Occupation ϒ** | | | |
| 1. Higher managerial, administrative and professional occupations | 62 (17.7%) | 63 (19.2%) | 0.016 * |
| 2. Intermediate occupations | 111 (31.7%) | 71 (21.6%) | |
| 3. Routine and manual occupations | 94 (26.9%) | 115 (35.1%) | |
| 4. Housewife/ Long-term unemployed or never worked/ student | 83 (23.7%) | 79 (24.1%) | |
| **Education** | | | |
| GCSE/ equivalent or lower | 114 (52.5%) | 74 (44.8%) | 0.193 |
| AS/A level or equivalent | 63 (29.0%) | 49 (29.7%) | |
| Degree, postgraduate or equivalent | 40 (18.4%) | 42 (25.5%) | |
| **Marital status** | | | |
| Married/civil partnership | 112 (30.9%) | 116 (35.3%) | 0.096 |
| Partner | 221 (60.9%) | 175 (53.2%) | |
| Single ϛ | 30 (8.3%) | 38 (11.5%) | |
| **Booking body mass index** (in kg/m$^2$) | 44.2 ( ± 3.5) Range 40.01–60.3 | 44.0 ( ± 3.7) Range 40.01–67.1 | 0.091† |
| **Maternal height** (in m) | 1.65 ( ± 0.06) | 1.64 ( ± 0.07) | 0.174 |
| **Gestation at booking** | 9.5 ( ± 3.6) | 9.1 ( ± 3.1) | 0.171† |
| **Alcohol intake at booking** | | | |
| None | 362 (99.5%) | 327 (99.4%) | 0.794$^{\Theta}$ |
| 1–3 units | 1 (0.3%) | 2 (0.6%) | |
| 4–8 units | 1 (0.3%) | 0 (0.0%) | |

ϒ - Occupations coded using the 3 category National Statistics Socio-economic Classification (NS-SEC) system.
ϛ - The single category included 1 woman in the comparison cohort and 5 women from the antenatal healthy lifestyle service who were divorced/ separated/ widowed
† - Mann Whitney test used as data not normally distributed when assessed using the Shapiro-Wilk test
Θ - Fisher exact test used due to small cell counts
* $p < 0.05$, * * $p < 0.01$, * **$p < 0.001$

A total of 49.7% of women attended for at least three antenatal healthy lifestyle appointments, 29.5% of women attended two appointments and 20.8% of women chose to only attend one appointment. The primary outcome of average gestational weight gain was not significantly different in women attending the antenatal healthy lifestyle service versus those in the comparison cohort before or after adjusting for baseline differences [aMD − 0.70 kg (95% CI −2.33, 0.93)]. No difference between the cohorts was noted for weight gain according to IOM recommendations. Rate of weight gain was calculated as total weight gain divided by length of time from the weighing at booking to the final weight. No differences in the crude or adjusted rate of weight gain were noted between the antenatal healthy lifestyle service and comparison cohorts. Women attending the antenatal healthy lifestyle service had higher odds of breastfeeding at discharge from hospital [aOR 1.72 (95% CI 1.18, 2.51)]. No other maternal outcomes favoured antenatal healthy lifestyle service provision. Gestational diabetes was noted to be lower in the comparison group (11.8%) than in the antenatal healthy lifestyle service group (24.1%). The proportion of women tested for gestational diabetes was 85.9% in the comparison Trust compared to 93.4% of those attending the antenatal healthy lifestyle service. Of the 30 women who were excluded from the comparison cohort for attending a dietician appointment, 15 of them had gestational diabetes. If these women had been included within the analysis, the rate of gestational diabetes would have been 15.5% in the comparison Trust. This was still significantly lower than the 24.1% of women attending the antenatal healthy lifestyle service who had gestational diabetes.

Infant outcomes for the antenatal healthy lifestyle service versus the comparison group are presented in Table 4. The adjusted odds of macrosomia were reduced in women attending the antenatal healthy lifestyle service [aOR 0.65 (95% CI 0.43, 0.99)]. Gestational age at birth was however significantly lower in the cohort receiving the antenatal healthy lifestyle service. Once adjusted for this difference in gestation at birth, as well as the baseline differences in deprivation, occupation and smoking there was no difference in the odds of macrosomia between the comparison and antenatal healthy lifestyle service cohorts [aOR 0.76 (95% CI 0.49, 1.18)]. No other infant outcomes were favourable to antenatal healthy lifestyle service provision.

There were two intrauterine fetal deaths (0.5%) in women in the comparison cohort and three (0.9%) in women referred to the antenatal healthy lifestyle service. The numbers were too small for any meaningful statistical comparison.

## Discussion

Through this independent evaluation, after adjusting for baseline variations, no differences were found in the primary outcome of GWG or any other maternal or infant secondary outcomes that favoured the antenatal healthy lifestyle service except for increased breastfeeding rates at discharge from hospital.

No differences were found for the primary outcome of GWG in those who attended the antenatal healthy lifestyle service compared to the cohort from the neighbouring Trust. Although women in the comparison cohort were slightly more likely to have gained weight over the IOM recommendations (31.4%) compared to those receiving the antenatal healthy lifestyle intervention (27.2%), this was not significant. Unexpectedly poor recording of weight from 34 weeks onwards was noted within the comparison cohort, being recorded in just 25% of women, compared to 79% of women who attended the antenatal healthy lifestyle service. This lack of universal weighing near to the end of pregnancy in the comparison cohort meant that women who were weighed may have been more likely to be those who were motivated to keep track of their own gestational weight gain or who had a midwife who was more proactive about promoting appropriate gestational weight gain. This could have reduced the mean gestational weight gain within this comparison cohort and therefore impacted upon the significance.

The antenatal healthy lifestyle service had been found through

**Table 3**
Maternal outcomes for the antenatal healthy lifestyle service versus the comparison cohort.

| Outcome | Comparison cohort 2012–2015 (n = 365) | Antenatal healthy lifestyle service 2012–2015 (n = 332) | p value | Crude mean difference or odds ratio (95%CI) | Adjusted mean difference or odds ratio (95% CI) ‡ |
|---|---|---|---|---|---|
| **Number of antenatal healthy lifestyle service appointments** | | | | - | - |
| 0 | 365 (100.0%) | 0 | | | |
| 1 | 0 | 69 (20.8%) | | | |
| 2 | 0 | 98 (29.5%) | | | |
| 3 + | 0 | 165 (49.7%) | | | |
| **Gestational weight gain** (in kg) | 6.54 ( ± 6.05) (n = 105) | 5.66 ( ± 7.00) (n = 276) | 0.254 | MD − 0.88 (−2.41, 0.64) | aMD − 0.70 (−2.33, 0.93) |
| **Gestation of final weight** (in weeks) | 36.9 ( ± 1.2) (n = 105) | 36.9 ( ± 1.6) (n = 276) | 0.864 | MD − 0.02 (−0.37, 0.31) | aMD 0.12 (−0.25, 0.50) |
| **Rate of weight gain** (in kg/week) | 0.23 ( ± 0.21) (n = 105) | 0.21 ( ± 0.25) (n = 276) | 0.326 | MD − 0.03 (−0.08, 0.03) | aMD − 0.02 (−0.08, 0.04) |
| **GWG according to Institute of Medicine recommendations** | | | | | |
| Too little | 38 (36.2%) | 124 (44.9%) | 0.305 | OR 1.44 (0.84, 2.48) | aOR 1.52 (0.85, 2.75) |
| Recommended | 34 (32.4%) | 77 (27.9%) | | REF | REF |
| Excessive | 33 (31.4%) | 75 (27.2%) | | OR 1.00 (0.57, 1.78) | aOR 1.23 (0.66, 2.31) |
| **Vaginal birth** | 200/331 (60.4%) | 166/319 (52.0%) | 0.031 * | OR 0.71 (0.52, 0.97)* | aOR 0.75 (0.54, 1.06) |
| **Caesarean Section** | 106/331 (32.0%) | 136/319 (42.6%) | 0.005 * * | OR 1.58 (1.15, 2.17)* * | aOR 1.46 (1.03, 2.08)* |
| **Induction of labour** (excluding women who has a CS prior to labour) | 164/311 (52.7%) | 156/254 (61.4%) | 0.038 * | OR 1.43 (1.02, 2.00)* | aOR 1.31 (0.90, 1.90) |
| **Postpartum haemorrhage** (EBL ≥500 ml at vaginal birth, ≥1000 ml at CS birth) | 43/329 (13.1%) | 46/270 (17.0%) | 0.174 | OR 1.37 (0.87, 2.14) | aOR 1.20 (0.73, 1.96) |
| **Perineal trauma sustained** (excluding women giving birth by CS) | 152/227 (67.0%) | 114/177 (64.4%) | 0.591 | OR 0.89 (0.59, 1.35) | aOR 0.80 (0.51, 1.28) |
| **Epidural** (attempted or achieved) | 135/330 (40.9%) | 160/303 (52.8%) | 0.003 * * | OR 1.62 (1.18, 2.21)* * | aOR 1.63 (1.16, 2.30)* * aOR 1.43 (0.91, 2.24) when adjust for differences in rate of CS |
| **General anaesthetic** | 26/331 (7.9%) | 18/304 (5.9%) | 0.338 | OR 0.74 (0.40, 1.38) | aOR 0.65 (0.33, 1.28) |
| **Breastfeeding initiation** | 166/324 (51.2%) | 173/310 (55.8%) | 0.249 | OR 1.20 (0.88, 1.64) | aOR 1.15 (0.81, 1.63) |
| **Breastfeeding at discharge from hospital** | 94/315 (29.8%) | 129/304 (42.4%) | 0.001 * * | OR 1.73 (1.24, 2.42)* * | aOR 1.72 (1.18, 2.51)* * |
| **Day of discharge from hospital** | | | | | |
| * day | 51 (15.3%) | 32 (10.1%) | | REF | REF |
| day 1 | 138 (41.6%) | 136 (43.1%) | 0.173 | OR 1.57 (0.95, 2.59) | aOR 1.40 (0.81, 2.42) |
| day 2 | 80 (24.1%) | 91 (28.8%) | | OR 1.81 (1.06, 3.09)* | aOR 1.62 (0.90, 2.93) |
| day 3 + | 63 (19.0%) | 57 (18.0%) | | OR 1.44 (0.82, 2.55) | aOR 1.22 (0.65, 2.29) |
| **Haemoglobin < 110 g/l at booking** | 9/363 (2.5%) | 4/320 (1.3%) | 0.241 | OR 0.50 (0.15, 1.63) | aOR 0.48 (0.13, 1.79) |
| **Haemoglobin< 105 g/l at 28 weeks** | 17/338 (5.0%) | 12/303 (4.0%) | 0.516 | OR 0.78 (0.37, 1.66) | aOR 0.52 (0.20, 1.33) |
| **Haemoglobin< 105 g/l at 36 weeks** | 30/331 (9.1%) | 20/224 (8.9%) | 0.957 | OR 0.98 (0.54, 1.78) | aOR 0.93 (0.48, 1.81) |
| **Gestational diabetes** (excluding those with gastric surgery) | 38/322 (11.8%) | 71/294 (24.1%) | 0.000 * ** | OR 2.38 (1.55, 3.66)* ** | aOR 2.19 (1.40, 3.42)* *ø |
| **Additional monitoring for raised blood pressure ϒ** | 83/350 (23.7%) | 58/281 (20.6%) | 0.357 | OR 0.84 (0.57, 1.22) | aOR 0.76 (0.50, 1.15) |

‡ - Adjusted for smoking at booking (non smoker = REF), highest occupation (housewife = REF), deprivation (most deprived quintile =REF) and gestational diabetes (no gestational diabetes = REF).
ϒ - Additional monitoring for raised blood pressure - women receiving monitoring over and above routine care due to raised BP, including those who went on to be diagnosed with Pregnancy Induced hypertension, pre-eclampsia or HELLP syndrome
ø not adjusted for GDM
* $p < 0.05$, * * $p < 0.01$, * **$p < 0.001$
CI – confidence interval
CS – Caesarean section
MD – mean difference
OR – odds ratio

internal audit to keep GWG among women with obesity to within the recommended range of 5–9 kg. The service was therefore seen as a success. As a result, the service was promoted on the shared learning database by the National Institute of Health and Care Excellence (NICE) within the UK [28]. However, within this study the average weight gain of women within the comparison cohort of 6.54 kg ( ± 6.05) was also noted to be within the IOM recommended range and to be lower than the weight gain of 8.2 kg found in women with a BMI between 40 and 49 kg/m$^2$ in previous UK based literature [36]. Similarly, the proportion of women gaining in excess of IOM weight gain recommendations of 31.5% in the comparison cohort varied markedly with the current literature in this area. Previous studies have noted much higher proportions of women with a BMI ≥ 30 kg/m$^2$ gaining above IOM recommendations including 60% [18] to 68% [37] in cohorts of Canadian women, 55% [38] to 84.6% in cohorts from the USA [39] and 44% reported in a meta-analysis of intervention trials in women with obesity prior to or at the start of pregnancy [40]. While weight gain is known to decrease with increasing BMI, even among women with a BMI ≥ 40 kg/m$^2$ it has been

**Table 4**
Infant outcomes for antenatal healthy lifestyle service versus the comparison cohort.

| Outcome | Comparison cohort 2012–2015 (n = 365) | Antenatal healthy lifestyle service 2012–2015 (n = 332) | p value | Crude MD or OR (95% CI) | Adjusted MD/ OR (95% CI) ǂ |
|---|---|---|---|---|---|
| **Birthweight** (in gram) | 3580 ( ± 640) (n = 332) | 3505 ( ± 584) (n = 319) | 0.122 | MD − 74 (−169, 20) | aMD − 69 (−172, 35) |
| **Gestation at birth** (in weeks) | 39.8 ( ± 1.8) (n = 332) | 39.3 ( ± 1.9) (n = 320) | 0.000 * ** † | MD − 0.57 (−0.86, −0.28)* ** | aMD − 0.32 (−0.63, −0.02)* |
| **Gender of infant** Male | 175 (52.7%) | 165 (51.6%) | 0.769 | OR 0.96 (0.70, 1.30) | aOR 1.01 (0.72, 1.41) |
| Female | 157 (47.3%) | 155 (48.4%) | | | |
| **Low birthweight** (<2500 g) | 19/332 (5.7%) | 12/319 (3.8%) | 0.240 | OR 0.64 (0.31, 1.35) | aOR 0.71 (0.32, 1.56) |
| **Macrosomia** (>4000 g) | 84/332 (25.3%) | 60/319 (18.8%) | 0.046 * | OR 0.68 (0.47, 0.99)* | aOR 0.65 (0.43, 0.99)* |
| **Small for gestational age** (<10th GROW centile) | 53/331 (16.0%) | 50/319 (15.7%) | 0.906 | OR 0.98 (0.64, 1.49) | aOR 0.98 (0.61, 1.57) |
| **Large for gestational age** (>90th GROW centile) | 25/331 (7.6%) | 35/319 (11.0%) | 0.132 | OR 1.51 (0.88, 2.58) | aOR 1.09 (0.60, 1.98) |
| **Preterm** (<37 +0 weeks) | 22/332 (6.6%) | 26/320 (8.1%) | 0.464 | OR 1.25 (0.69, 2.25) | aOR 1.06 (0.55, 2.05) |
| **Postdates** (>41 +6 weeks) | 15/332 (4.5%) | 9/320 (2.8%) | 0.248 | OR 0.61 (0.26, 1.42) | aOR 0.86 (0.36, 2.08) |
| **Shoulder dystocia (in women with a vaginal birth)** | 7/226 (3.1%) | 2/180 (1.1%) | 0.309 ϴ | OR 0.35 (0.07, 1.71) | aOR 0.21 (0.03, 1.79) |
| **Apgar < 7 at 1 min** | 30/330 (9.1%) | 37/305 (12.1%) | 0.213 | OR 1.38 (0.83, 2.30) | aOR 1.24 (0.71, 2.18) |
| **Apgar < 7 at 5 min** | 5/330 (0.8%) | 4/304 (1.3%) | 1.000 ϴ | OR 0.87 (0.23, 3.26) | aOR 1.03 (0.24, 4.41) |
| **Neonatal unit admission** | 17/328 (5.2%) | 21/311 (6.8%) | 0.402 | OR 1.33 (0.69, 2.56) | aOR 1.10 (0.54, 2.22) |

ǂ - Adjusted for smoking at booking (non smoker = REF), highest occupation (housewife = REF), deprivation (most deprived quintile =REF) and gestational diabetes (no gestational diabetes = REF).
† - Mann Whitney test used when data not normally distributed when assessed using the Shapiro-Wilk tests
ϴ - Fisher exact test used due to small cell counts
* p < 0.05, * * p < 0.01, * **p < 0.001
CI – confidence interval
MD – mean difference
OR – odds ratio

found that 45.8% exceeded IOM recommendations in the USA [41]. Only one previous individual participant data analysis had similarly shown women with a BMI ≥ 40 kg/m$^2$ to gain within IOM recommendations, with the median weight gain being 6.27 kg at 40 weeks [42]. However, it should be noted that by reporting median weight gain, the influence of those with extreme weight gains would be reduced within that study. These marked differences in the proportion of women exceeding IOM recommendations within different populations highlight the essential requirement of including a comparison group when evaluating any maternal obesity service interventions, as comparing service figures to previous literature could lead to unfounded conclusions about the impact of the service. The necessity to focus on the different classes of obesity separately is also highlighted.

After adjusting for confounding factors, the odds of breastfeeding at discharge were noted to be higher among women who attended the antenatal healthy lifestyle service than among women in the comparison Trust. This was despite the comparison hospital Trust having full UNICEF Baby Friendly Initiative Accreditation from October 2012, whereas the hospital Trust running the antenatal healthy lifestyle service did not achieve full accreditation until December 2013. In both Trusts the proportion of women initiating breastfeeding were far lower than the figures reported overall within the Trusts during this time period, being 63.2–65.9% in the antenatal healthy lifestyle service intervention Trust and 61.7–64% in the comparison Trust [43]. This reflects the well-known poorer breastfeeding outcomes for women with a raised BMI. However, given that the rate of breastfeeding at discharge was markedly lower than the 52.3% of women with a BMI ≥ 40 kg/m$^2$ noted to breastfeed at discharge in a previous national cohort [36]; it is also likely to reflect local demographics with higher rates of deprivation than the average for England [43].

The comparison cohort had much lower rates of gestational diabetes. Some of this difference is due to the inclusion criteria of this study that excluded women in the comparison cohort who had attended any dietician appointments and excluded women who had not attended the antenatal healthy lifestyle service. Given that women who have gestational diabetes would be more likely to access dietary support services this disproportionately excluded women with gestational diabetes from the comparison cohort. However, even if women who had attended a dietician appointment in the comparison cohort had been included the rate of gestational diabetes remained significantly lower in the comparison cohort compared to those attending the antenatal healthy lifestyle service. The difference in the proportion of women being tested for gestational diabetes, being 7.5% higher among those who attended the antenatal healthy lifestyle service may additionally explain some, but not all, of the difference in rate of gestational diabetes. Interestingly, the rate of macrosomia was lower in women attending the lifestyle service, despite the higher rates of gestational diabetes, although this was not significant once adjusting for the differences in gestational age at birth. The comparison cohort had favourable outcomes for Caesarean Section which remained after adjusting for confounding factors including the differences in gestational diabetes. The reason for this difference was unclear. It may represent a difference in policy implementation and practices within the different maternity units. However, it may also be an unintentional consequence of the antenatal healthy lifestyle service. The presence of the service may have raised awareness of the risks of maternal obesity within the Trust. Some have noted that labelling women with obesity as 'high risk' can lead to an unintended cascade of interventions [44] which may have resulted in more medicalised management of women within the Trust with the antenatal healthy lifestyle service and therefore raised the proportion of births by Caesarean.

Previous lifestyle interventions for women with overweight or obesity during pregnancy have had mixed effects. A recent overview of systematic reviews of randomised controlled trial evidence has shown that women with overweight or obesity who received an intervention had a small reduction in gestational weight gain compared to women in the control groups [23]. However, this small reduction in weight gain had no impact upon other pregnancy outcomes such as gestational diabetes, pre-eclampsia or birthweight outcomes [23]. Many of the included trials within these systematic reviews had limited numbers of women with a BMI ≥ 40 kg/m$^2$; however within our cohort of women exclusively with a BMI ≥ 40 kg/m$^2$ a similar limited impact of an antenatal healthy lifestyle service on maternal and infant outcomes compared to the comparison cohort was seen. Several reasons for this lack of effect have been suggested including that there is limited time within pregnancy for a demonstrable effect to occur upon outcomes, that increases in physical activity are difficult to achieve during pregnancy and that women with obesity are less responsive to lifestyle changes to enhance metabolic function due to their different metabolic profile to that of women with a BMI in the normal range [45]. Traditionally pregnancy has been viewed as a time when women may be particularly receptive to public health messages, especially around healthy eating and physical activity [18]. However little research has focused on women's capability or opportunity to change behaviours during pregnancy or considered the complex interplay between the numerous health messages provided to women at this time such as diet, folic acid supplementation, smoking, exercise and alcohol consumption [46]. The idea of pregnancy in and of itself not necessarily being a 'teachable moment' is supported by women's experiences themselves [47].

There is also a lack of clarity regarding what food types can improve maternal and infant outcome. During pregnancy it is suggested that diets high in fruit, vegetables and seafood and low in red meat and fried foods reduce the risk of preterm birth, however uncertainty remains over dietary links during pregnancy and birthweight outcomes [48]. More research is required to establish the best diet to maximise maternal outcomes, especially in women with overweight or obesity.

The effective components of interventions to maximise behaviour change are also poorly understood, highlighting the need for better identification of which components and specific behaviour change techniques are most effective. Michie et al. (2013) developed a structured taxonomy of behaviour change techniques which provides a framework for a more precise reporting of complex interventions [49]. A recent review of behaviour change techniques used within gestational weight management trials has found these techniques to be poorly implemented and reported [50]. Future services need to develop dietary and physical activity interventions with clarity around which behaviour change techniques are incorporated. This will allow for interventions to be more readily reproduced, better comparisons between interventions and for the active components of successful interventions to be more reliably and robustly identified. There is also a need to think of obesity and gestational weight management at societal, not just an individual level using systems approaches due to the multifaceted contributory factors including societal, environmental, social, individual and genetical factors [51] as all of these factors influence an individual's weight management during pregnancy.

In summary, the findings from this comparative study, derived from an existing practice setting, are in line with many large randomised controlled trials [19,20,22]. This provides pragmatic evidence on the ongoing debate regarding effective solutions for this growing public health challenge. Pragmatic evaluation derived from real-life practical settings with adequate controlling for confounders may provide more pertinent evidence for such ongoing public health debates as opposed to high resource demanding study designs with limited applicability outside of the trial setting. Furthermore, robust and independent evaluation of intervention effectiveness in this time of austerity is imperative before wider implementation and resource investment.

### *Strengths and limitations*

This is one of the few studies that independently and rigorously evaluates the impact of an antenatal healthy lifestyle service within a large number of women with a BMI $\geq$ 40 kg/m$^2$. However, some limitations need to be acknowledged particularly over the well-known concerns over data completeness with retrospective data collection. It was particularly evident within this study that GWG in the comparison cohort was poorly documented within the maternity notes, as was maternal education level within both Trusts. Additionally, just under half of women attended all three of the offered antenatal healthy lifestyle service appointments, which may in part explain the limited impact of the service on significantly improving clinical outcomes. It was also not possible to ensure that the intervention and comparison cohorts were identical in every way except for the antenatal healthy lifestyle service. To reduce the number of potential confounders, only women with a BMI $\geq$ 40 kg/m$^2$ were compared within both Trusts during the same time period, from 2012 to 2105 and adjustments were made to account for baseline differences. Selection bias was minimised by collecting data on the whole cohort within both Trusts. It was not possible within this study to quantify the relationship between the provider and the client in the antenatal healthy lifestyle service which may have an impact on intervention effectiveness. Finally, generalizability of the study is limited by the higher rate of social deprivation within the cohort than across the UK as a whole [43].

## Conclusion

No significant benefits were observed of an antenatal healthy lifestyle intervention in a real-life practice setting over a comparison cohort, which is in line with evidence from existing large randomised controlled trials. There is uncertainty over the best management of GWG in populations with a BMI of 40 or more. Further research is required with a particular focus on system wide approaches not just focussing at an individual level. Additionally, more focus is required on the behaviour change techniques associated with effective GWG management interventions. Independent and rigorous evaluation of maternal obesity management services are recommended prior to widespread implementation to ensure time, resource and cost efficiency.

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## Ethical statement

Ethical approval was obtained for this project through East of England - Cambridge East Research Ethics Committee (IRAS project number 207998). Research Governance approvals were also obtained from both NHS Trusts. Individuals extracting data from medical records were health professionals or others under the same duty of confidentiality as a health professional. Postcode data was converted to Index of Multiple Deprivation score and all NHS numbers were pseudo-anonymised using a MD5 hash string. This ensured women's confidentiality was protected.

## Author contributions

FF – conceptualization and funding acquisition, data curation, formal analysis and interpretation of the data, Writing – original draft, Writing – approval of final manuscript. HS – conceptualization and funding acquisition, specialist input regarding methodology, supervision of data analysis and interpretation of the data, Writing – review of the manuscript, Writing – approval of final manuscript.

## Conflicts of interest

None declared.

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## 6.5 Summary and implications for thesis

This article provided a comparative analysis of antenatal healthy lifestyle service attendance compared to no service on maternal and infant health outcomes.

The study identified that even without any intervention the GWG of women with a BMI ≥40kg/m² was within Institute of Medicine recommendations and lower than previously reported within the literature for women with obesity. This is important as it demonstrates the potential importance of considering different classes of obesity separately. The service was not superior at reducing GWG and no maternal or infant clinical outcomes studied were improved with antenatal healthy lifestyle service attendance except for a higher rate of breastfeeding at discharge from hospital.

An evaluation of the association between antenatal healthy lifestyle service attendance and child weight outcomes up to the age of 5 is presented in the following chapter.

# Chapter 7: Association of long term child weight outcomes with attendance at an antenatal healthy lifestyle service

## 7.1 Introduction

This chapter presents Article D, the third article from the quantitative component of this programme of research. This is an evaluation of the association between providing weight management advice to women with a high BMI during pregnancy and long-term child weight status. The aims of the study are provided below, alongside the details of publication and impact of the article. The full published article is then presented. The chapter concludes by summarising the key findings of this component.

## 7.2 Study aim

Given the duration since the start of the antenatal healthy lifestyle service, it was possible to evaluate the association between service attendance and child weight outcomes. This enabled an exploration of any association between the provision of healthy lifestyle advice during pregnancy and any long-term changes to dietary or exercise patterns within the family that could impact child weight. This was done by matching data on antenatal healthy lifestyle service attendance with data collected by health visitors, as well as at school entry as part of the National Child Measurement Programme. The study aim was to explore the association between infant weight outcomes and antenatal healthy lifestyle service intervention provision within a hospital Trust for women booking for care with a BMI ≥35kg/m². This addressed the third aim within this programme of research: *"To investigate the association between providing a weight management service to women with a high BMI during pregnancy and long-term child weight outcomes.*"

## 7.3 Published article: Article D

The manuscript is entitled “Association of child weight with attendance at a healthy lifestyle service among women with obesity during pregnancy”. It is reproduced in full in the format in which it has been published[(334)].

## 7.4 Publication and impact

The article was accepted for publication in Maternal and Child Nutrition on 8th January 2024 before being published fully open access in “Early View” on 4th February 2024. Maternal and Child Nutrition is a maternal and child health journal which addresses nutrition and its outcomes for women and their children across the globe. In 2022 Maternal and Child Nutrition had an impact factor of 3.4.

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ORIGINAL ARTICLE

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# Association of child weight with attendance at a healthy lifestyle service among women with obesity during pregnancy

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## Abstract

Women with obesity during pregnancy are at increased risk of excessive gestational weight gain (GWG) and other maternal and infant adverse outcomes, which all potentially increase childhood obesity. This study explored infant weight outcomes for women with a body mass index (BMI) ≥ 35 kg/m² who were offered an antenatal healthy lifestyle service. A retrospective cohort study, including linking data from two separate health care Trusts, was undertaken. Data were collected from maternity records for women with a BMI ≥ 35 kg/m² referred to an antenatal healthy lifestyle service from 2009 to 2015. The respective child's weight outcome data was additionally collected from health and National Child Measurement Programme records. Univariate logistic regression determined the odds of childhood overweight, obesity and severe obesity according to attendance at the antenatal healthy lifestyle service, GWG and sociodemographic characteristics. Factors significant ($p < 0.05$) within the univariate analysis were entered into multiple logistic regression models. Among women with a BMI ≥ 35 kg/m², 30.4% of their children were obese at school entry and 13.3% severely obese. Healthy lifestyle service attendance was not associated with childhood overweight or obesity at any point within the univariate analysis. At school age multiple regression analysis showed the odds of overweight and obesity increased with excessive GWG and the odds of obesity decreased with a parent in a professional occupation, additionally having a mother who smoked in pregnancy increased severe obesity. Women should be supported to optimise their BMI before pregnancy. Additionally, rather than exclusively focusing on changing an individual's behaviour, future interventions should consider external influences such as the woman's family, friends and sociodemographic background.

**KEYWORDS**
childhood obesity, developmental origins of disease, gestational weight gain, healthy lifestyle, maternal obesity

## 1 | INTRODUCTION

In the United Kingdom, 32.5% of women are classified as overweight (body mass index [BMI]: 25–29.9 kg/m²) and a further 26.4% as obese (BMI ≥ 30 kg/m²) (Baker, 2023). Women affected by overweight or obesity account for over 50% of maternities, and 22.2% of pregnancies in the UK were in women with obesity in 2018–2019 (National Health Service National Health Service [NHS] Digital, 2019a).

Women with overweight or obesity before pregnancy are at high risk of excessive gestational weight gain (GWG) (Samura et al., 2016). Obesity during pregnancy and excessive GWG are both associated with an increased risk of adverse outcomes for both the mother and the infant. Adverse outcomes for the mother include increased risk of gestational diabetes (Najafi et al., 2019; Santos et al., 2019), pre-eclampsia (He et al., 2020; Santos et al., 2019), preterm birth (Santos et al., 2019) and caesarean birth (Goldstein et al., 2017; Kim et al., 2016). The adverse outcomes for the infant include an increased risk of being large for gestational age (LGA) (Goldstein et al., 2017; Santos et al., 2019; Shin & Song, 2015), and poorer breastfeeding outcomes (Huang et al., 2019). Additionally, maternal obesity and excessive GWG have been associated with increased childhood obesity (Voerman et al., 2019), as have many of their associated adverse outcomes such as gestational diabetes, hypertension, reduced breastfeeding (Skrypnik et al., 2019) and caesarean birth (Masukume et al., 2019). Overall, the proportion of overweight or obesity in early childhood (2–5 years) estimated to be attributable to maternal prepregnant obesity and excessive GWG is 10.2% and 11.4%, respectively (Voerman et al., 2019). Rates of childhood obesity by age 7 have been shown to vary across Europe, with the lowest prevalence in Denmark (5.7%) and the highest in Greece (17.1%) (WHO European Region, 2022). In England, the prevalence of obesity in children when starting school (age 4–5 years) was 10.1% in 2021–2022 (NHS Digital, 2022).

Pregnancy has been suggested as a good opportunity to influence behaviour change in mothers and their families through adaptations to lifestyle such as healthy eating, physical activity and weight management (Phelan, 2010). However, a recent UK survey found maternal healthy lifestyle service provision for women with obesity to be inconsistent in availability, BMI eligibility criteria and content (Fair et al., 2020). Additionally, interviews with providers and commissioners alongside the above survey also identified uncertainty among professionals about what constitutes the most suitable service to tackle maternal obesity (Fair et al., 2020). Antenatal lifestyle interventions, mainly focussed on healthy eating and physical activity, have been evaluated within numerous studies and systematic reviews for their impact on maternal outcomes such as GWG and mode of birth, as well as neonatal outcomes such as birthweight and gestational age at birth (Dodd et al., 2014; Fair & Soltani, 2021; Hill et al., 2013; Thangaratinam et al., 2012). However, little has been done to date to evaluate pregnancy lifestyle interventions on longer term infant health. This is despite the impact of maternal health and diet before and during pregnancy being increasingly understood on long-term offspring health and development, through the role of epigenetics (Aldhous et al., 2018; Lorite Mingot et al., 2017). Within two systematic reviews of lifestyle interventions during pregnancy (Dalrymple et al., 2018; Raab et al., 2021) few studies were found that evaluated childhood anthropometric outcomes up to school entry. Evidence around the effect of antenatal lifestyle interventions on long-term child obesity is especially limited among women with obesity. This is despite these infants being recognised to be at increased risk of childhood obesity (Voerman et al., 2019). The need for studies which explore longer term health outcomes for mothers and infants of interventions in pregnancy has been recognised (Goldstein et al., 2016).

Socioeconomic inequalities are known to be strongly associated with the prevalence of obesity (Nguyen et al., 2023). Obesity is higher among those with the highest levels of deprivation, and food insecurity, those from an ethnic minority (Nguyen et al., 2023), as well as those with lower educational attainment (Devlieger et al., 2016). These factors therefore need careful consideration when exploring child's weight status. This study therefore aimed to explore the association between child overweight and obesity and attendance at an antenatal healthy lifestyle service intervention, along with other sociodemographic characteristics, for women with a BMI ≥ 35 kg/m² when booking for pregnancy care within one hospital Trust.

**Key messages**

- Among children born to women with a body mass index (BMI) ≥ 35 kg/m$^2$ almost 50% were classified as overweight or obese at age 5. Of these, only 15.6% had been born large for gestational age.
- This brief antenatal healthy lifestyle intervention provided to mothers with obesity did not significantly reduce child's overweight or obesity.
- Demographic factors such as household occupation and maternal smoking during pregnancy were associated with long-term childhood obesity.
- More emphasis is required on interventions that support women to optimise their BMI before pregnancy.
- Future interventions should consider external influences on the woman for example through a socioecological framework.

## 2 | METHODS

### 2.1 | Setting

In England, the NHS provides routine care to all pregnant women. Non-NHS care is rare, with only 0.5% of all births in England and Wales in 2021 taking place in non-NHS establishments or 'elsewhere' (Office for National Statistics [ONS], 2023). In July 2009, a midwife-led antenatal healthy lifestyle service was established at Doncaster and Bassetlaw Teaching Hospitals NHS Foundation Trust which is within the Yorkshire and Humber region of England. This service was established in response to the recognition of high rates of maternal obesity within the local area. When established, the service offered a low-intensity intervention to pregnant women with a BMI ≥ 35 kg/m$^2$ at their first antenatal appointment which incorporated a visit at 16 weeks of gestation, with additional follow-up visits available if the woman wanted them. In July 2012 service provision intensified, offering women routine appointments at 16, 28 and 36 gestational weeks. Due to service demands the provision at this point became exclusively for women with a BMI ≥ 40 kg/m$^2$. Midwives ran the service alongside other professionals such as dieticians and exercise programme providers, with specialised input from obstetricians and anaesthetists. Women were provided with support and advice around weight management; particularly minimising GWG, healthy eating, undertaking physical activity and breastfeeding. The aim of the clinic was to encourage and support women to make positive lifestyle choices and behavioural changes during pregnancy to optimise GWG and improve birth outcomes. The intention was that these changes could also be sustained after the birth. For example, women were encouraged to identify personal goals such as swapping an unhealthy food for a healthier one. Given that the healthy lifestyle service intervention commenced in 2009 it was possible to evaluate whether it was feasible to determine the association between pregnancy weight gain and antenatal healthy lifestyle service attendance on the rate of childhood obesity up to school age (4–5.5 years). This was done through the linkage of maternity records with health visitors' and National Child Measurement Programme records of infants' weight at 6–8 weeks, 9–12 months and school entry (4–5.5 years of age).

## 2.2 | Data collection

Data were collected from hospital records for all women with a BMI ≥ 35 kg/m$^2$ who were offered the antenatal healthy lifestyle service between 2009 and 2015. Data extracted from these records included attendance at the antenatal healthy lifestyle service, maternal sociodemographic data and GWG, as well as pregnancy data including complications such as gestational diabetes, mode of birth and post-natal data around infant feeding methods. Within the UK basic neonatal data, as well as the child's NHS number, are also stored within the maternity hospital records.

Within England, children are routinely weighed by health visitors at 6–8 weeks and 9–12 months. They are also weighed and measured by school nurses when starting school (age 4–5.5 years) as part of the National Child Measurement Programme. Health visitor and school nurse data are entered into the IT system; SystmOne. Data were collected from this database for infants born to women within the above cohort of women (attending antenatal care at the NHS Trust with the antenatal healthy lifestyle service between 2009 and 2015 with a BMI ≥ 35 kg/m$^2$). Within both the hospital records and the SystmOne data, the child NHS number was pseudoanonymised to allow for data linkage. The MD5 hash system was used to pseudonymise the data. This takes a string of any length and encodes it into a 32-character long 'hash'. Upon entering the same string, the MD5 hash produced will always be the same. However, it is not possible to take the MD5 hash and convert it back to the original string. The NHS Trust data was therefore matched to data from SystmOne by pairng the MD5 hash code for the child's NHS number within the two datasets.

### 2.2.1 | Standard measures

BMI was calculated from weight at the first antenatal appointment using the formula weight/height squared (kg/m$^2$). GWG was measured by subtracting weight at the first antenatal appointment from the final weight measured during pregnancy from the middle of the third trimester (34 + 0 weeks') gestation onwards. According to Institute of Medicine (IOM, 2009) guidance, the recommended weight gain for women with obesity is between 5 and 9 kg. In accordance with this recommendation, women were classified as gaining too little weight if they gained less than 5 kg, or as gaining excessive weight if their GWG was above the 9 kg recommended. Infant birthweight centiles were calculated using GROW charts (UK version 8.0.6.1) (Gardosi et al., 2011, 2020). These centiles are customised according to maternal height, maternal weight, ethnicity, parity, gestation and infant gender. This has been shown to be more accurate in populations with overweight and obesity (Pritchard et al., 2020). Birthweight above the 90th centile for gestational age was classified as LGA. Gestational diabetes was defined as fasting blood glucose ≥ 5.3 mmmol/L or blood glucose 2 h post 75 g glucose challenge ≥ 8.5 mmol/L.

Child weight percentiles at 6–8 weeks, 9–12 months and at school entry, as well as BMI percentiles at school entry, were calculated using the World Health Organization (WHO) Anthro (WHO, 2010) and AntroPlus (WHO, 2009) software. Children were classified as 'overweight' if their weight or BMI centile was between the 85th and 94.9th centile or as 'obese' if their weight or BMI centile was ≥95th centile. Additionally, children with severe obesity at school entry were identified as those with a BMI ≥ 99.6th centile. These classifications were in accordance with those used by the Office for Health Improvement and Disparities (OHID) (OHID, 2022a).

Occupation data was collected from women when first attending for pregnancy care. The woman and their partners' occupations were coded using the three-category National Statistics Socio-economic Classification system (ONS, 2010). The highest occupation category for each household (either for the woman or her partner) was utilised within the analysis. The Index of Multiple Deprivation (IMD) was used to measure deprivation, as this is the official measure of relative deprivation in England. The score for each area combines information from seven domains of deprivation (income, employment, education, health, crime, housing and living environment) to give one overall deprivation score from one (most deprived) to 32844 (least deprived) (Smith et al., 2015). These scores were designated into evenly sized quintiles. Quintile 1 included IMD scores 1–6568 and was the most deprived, quintile 2 included IMD scores 6569–13,137, quintile 3 included IMD scores 13,138–19,706, quintile 4 included IMD scores 19,707–26,275 and quintile 5 included IMD scores 26,276–32,844 which was the least deprived quintile. Due to the limited number of cases, the least deprived quintiles (quintiles 4 and 5) were then combined within the analysis.

## 2.3 | Data analysis

Analysis was undertaken using SPSS 26.0. Univariate logistic regression was used to assess the association between childhood overweight, obesity and severe obesity according to uptake of the antenatal healthy lifestyle service and sociodemographic characteristics. GWG was the primary intended outcome of the antenatal healthy lifestyle service, it was therefore also assessed. Given their links with child obesity within the literature, gestational diabetes, hypertension, breastfeeding and caesarean birth were additionally evaluated to determine if they would require adjustment within the multiple logistic regression models. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated.

Any factors that were significant ($p < 0.05$) within the univariate analysis at any timepoint were included in the multiple logistic regression main effects model to determine the significance of each variable once controlling for other factors. Separate models were developed for childhood overweight or obesity at each of the timepoints 6–8 weeks, 9–12 months and at school entry, as well as severe obesity at school entry. These models were adjusted for anthropometric measures including maternal weight when booking for antenatal care, maternal height, maternal age, birthweight, gestation at birth and infant gender. Variance inflation factors were used to assess for multicollinearity within all multiple logistic regression models. The results indicated potential multicollinearity of marital status and other measures of deprivation due to moderately high variance inflation factors at all timepoints. Marital status was therefore omitted from all of the final multiple logistic regression models. Variance inflation factors were low (<2) between all other independent variables. Additionally, each model was assessed for a linear relationship between the continuous independent variables and the logit transformation of the dependent variable using the Box–Tidwell test for linearity. Where the assumption for linearity was not met, higher ordinal terms were included within the model.

The multiple logistic regression model for each separate timepoint was assessed using the Hosmer–Lemeshow goodness of fit test to determine how well the data fit the model. The presence of outliers or points of leverage was explored using Cook's distance and the studentized residuals.

## 2.4 | Ethical statement

Ethical approval was obtained for this project (IRAS project number 207998).

# 3 | RESULTS

Of the 1301 women with a BMI ≥ 35 kg/m² attending for antenatal care and giving birth to a live infant within the Trust from 2009 to 2015, 1146 (88.1%) had at least one child measurement available. Measurements were available for 91.6% of those attending their first antenatal appointment from 2009 to summer 2012. However, measurements were only available for 81.2% of those attending their first antenatal appointment from summer 2012 to 2015 as only 17 of these children had reached school age when the data was obtained from SystmOne. The average age of weight was 47.7 (±11.9) days at 6–8 weeks, 9.4 (±1.3) months at 9–12 months and 4.7 (±0.31) years at school entry.

Height was poorly recorded before school age, therefore overweight and obesity were classified using weight centiles only at 6–8 weeks and 9–12 months. Figure 1 shows the proportion of children at each age who were classified as overweight or obese. The proportion of children with weight ≥ 95th centile increased with age, being just 2.7% of children at 6–8 weeks, but 22.0% of children by school entry. When height was also taken into account to calculate child BMI at school entry, the proportion of children with obesity was 30.4%, with 13.3% of school-age children having a BMI ≥ 99.6th centile. Of those with a weight ≥85th centile at 6–8 weeks and 9–12 months 33.0% and 19.5%, respectively, had been born LGA. By school age, only 15.6% of those with overweight or obesity had been born LGA.

## 3.1 | Univariate analysis

Of the 1146 women with at least one child weight available, 79.7% had attended the antenatal healthy lifestyle service and 20.3% of women had not attended. Table 1 provides the crude odds of weight ≥ 95th centile at 6–8 weeks and 9–12 months and of childhood BMI ≥95th centile and ≥99.6th centile at school entry and Table 2 the crude odds of weight ≥85th centile at 6–8 weeks and 9–12 months and of childhood BMI ≥85th centile at school entry according to uptake of the antenatal healthy lifestyle service, GWG and other sociodemographic characteristics.

There was no difference in the odds of childhood overweight or obesity at any of the timepoints with healthy lifestyle attendance compared to no attendance at the service. Infants of women with excessive GWG according to IOM recommendations had higher odds of overweight at 6–8 weeks and of overweight or obesity at school entry. There was also a trend for increased childhood obesity at 9–12 months and severe obesity at school entry with excessive GWG. However, at 6–8 weeks, only 58.3% of infants with obesity were born to mothers with excessive GWG, and at 9–12 months and school age, less than 45% of children with obesity were born to mothers with excessive GWG.

At school entry childhood overweight and obesity decreased with lower levels of deprivation. Additionally, at 9–12 months, childhood obesity decreased with higher household occupations. At

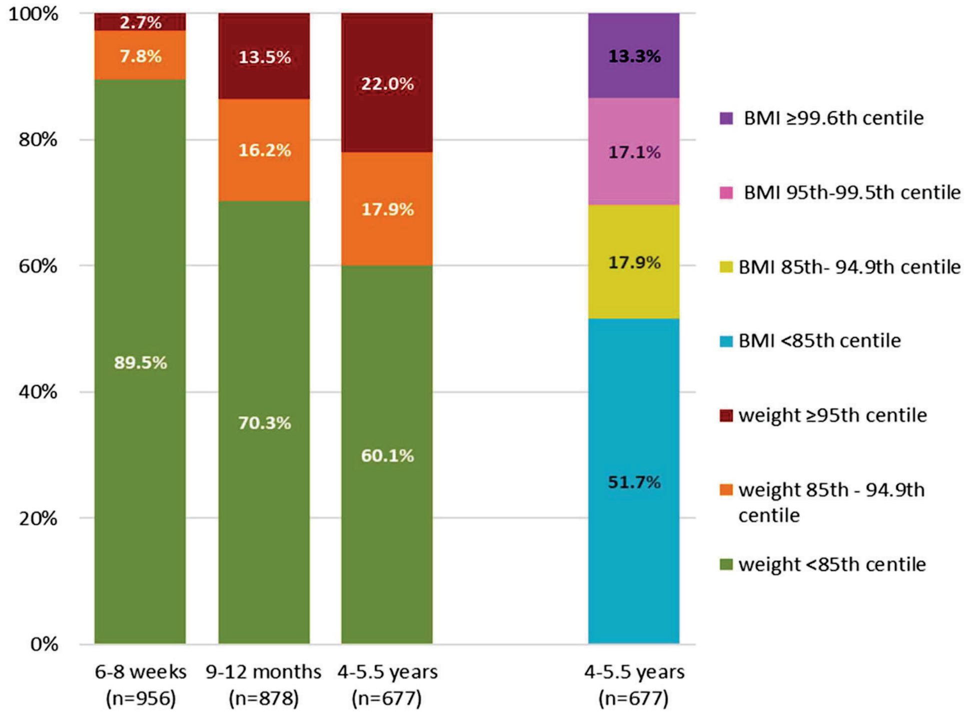


**FIGURE 1** Classification of weight centiles at 6–8 weeks, 9–12 months and weight and BMI centiles at school entry for children born to mothers with BMI ≥ 35. BMI, body mass index.

several timepoints, the odds of childhood overweight or obesity were also lower for women who were not single when registering for antenatal care. The infants of women who smoked when attending their first antenatal appointment had higher odds of obesity and severe obesity at school entry. Maternal ethnicity, maternal education, breastfeeding initiation or breastfeeding at discharge from the maternity unit, caesarean birth, maternal diabetes and pregnancy-induced hypertension or pre-eclampsia did not significantly increase the odds of childhood overweight or obesity at any timepoint in this cohort of women with a BMI ≥ 35 kg/m$^2$.

### 3.2 | Multiple logistic regression analysis

Multiple logistic regression models for factors associated at the different timepoints with childhood obesity (Table 3) and overweight (Table 4) are provided.

Once adjusting for other factors within the analysis, deprivation no longer added significantly to any of the models. Excessive GWG continued to increase the odds of obesity at school entry once adjusting for other factors. GWG outside of the recommended range, both inadequate and excessive, also increased the risk of overweight at school entry. Being a smoker at the first antenatal appointment no longer reached significance for increased odds of obesity at school entry but remained significant in the multiple logistic regression model for severe obesity at school entry.

Outliers or extreme points of leverage were only noted within the models at 6-8 weeks gestation. The multiple logistic regression model fitted less well at this timepoint for women gaining weight in accordance with IOM recommendations or below IOM recommendations due to the limited number of cases of children with obesity within these categories at this point in time.

## 4 | DISCUSSION

Prevalence of children with obesity (BMI ≥ 95th centile) by school entry was high in this cohort at 30.4%, with almost half of children (48.3%) having either overweight or obesity by school entry. The proportion of children with obesity at school entry was high compared to both the national average of 9.7% and the local prevalence of 11.4% in 2018–2019 (NHS Digital, 2019b). The proportion of children with severe obesity (BMI ≥ 99.6th centile) at 13.3% was far higher than the national average of 2.4% and the local prevalence of 3.1% for 2018–2019 (NHS Digital, 2019b). Indeed, within this cohort of women with a BMI ≥ 35 kg/m$^2$, there were more children with severe obesity at school entry than there were children with obesity at school entry (BMI ≥ 95th centile) in the local area when considering women of all BMI categories. Even when looking specifically at women with obesity the figures within this cohort were high, as nationally 26% of children born to mothers with obesity were themselves obese at school entry, and a further 16% were overweight (NHS Digital, 2019c). This may in part be due to this study only including women with class 2 or class 3 obesity as all had a BMI ≥ 35 kg/m$^2$. However, it clearly shows an association between maternal early pregnancy BMI and childhood weight outcomes up to

**TABLE 1** Crude ORs and 95% CIs for childhood obesity according to the uptake of the antenatal healthy lifestyle service, gestational weight gain and sociodemographic characteristics.

| | Weight ≥ 95th centile at 6–8 weeks (*n* = 26/956), OR (95% CI) | *p* Value | Weight ≥ 95th centile at 9–12 months (*n* = 119/878), OR (95% CI) | *p* Value | BMI ≥ 95th centile at school entry (*n* = 206/677), OR (95% CI) | *p* Value | BMI ≥ 99.6th centile at school entry (*n* = 90/677), OR (95% CI) | *p* Value |
|---|---|---|---|---|---|---|---|---|
| Number of healthy lifestyle sessions attended | | | | | | | | |
| Not attended | REF | | REF | | REF | | REF | |
| Attended | 1.703 (0.505, 5.736) | 0.391 | 0.943 (0.582, 1.528) | 0.811 | 0.750 (0.524, 1.074) | 0.116 | 1.120 (0.675, 1.859) | 0.662 |
| Weight gain according to IOM | (*n* = 838) | | (*n* = 771) | | (*n* = 601) | | (*n* = 601) | |
| Less than recommended | 0.482 (0.134, 1.728) | 0.262 | 1.036 (0.601, 1.787) | 0.898 | 1.252 (0.790, 1.984) | 0.339 | 1.030 (0.533, 1.989) | 0.931 |
| Recommended | REF | | REF | | REF | | REF | |
| More than recommended | 1.940 (0.734, 5.131) | 0.182 | 1.565 (0.937, 2.614) | 0.087 | 1.723 (1.106, 2.684) | 0.016* | 1.778 (0.976, 3.241) | 0.060 |
| Parity | | | | | | | | |
| 1 | REF | | REF | | REF | | REF | |
| 2 | 1.605 (0.656, 3.925) | 0.300 | 1.205 (0.749, 1.941) | 0.442 | 0.745 (0.500, 1.110) | 0.148 | 0.699 (0.403, 1.215) | 0.205 |
| 3+ | 0.659 (0.213, 2.036) | 0.468 | 1.287 (0.799, 2.075) | 0.300 | 0.857 (0.576, 1.277) | 0.448 | 0.951 (0.562, 1.610) | 0.851 |
| Deprivation | | | | | | | | |
| Most deprived quintile | REF | | REF | | REF | | REF | |
| Second most deprived quintile | 0.293 (0.066, 1.293) | 0.105 | 0.838 (0.516, 1.362) | 0.476 | 0.996 (0.671, 1.480) | 0.985 | 0.985 (0.578, 1.677) | 0.955 |
| Middle quintile | 1.078 (0.351, 3.308) | 0.896 | 0.815 (0.440, 1.510) | 0.516 | 0.892 (0.531, 1.498) | 0.666 | 0.916 (0.455, 1.847) | 0.807 |
| Least deprived two quintiles | 1.347 (0.480, 3.782) | 0.571 | 0.654 (0.333, 1.284) | 0.217 | 0.491 (0.263, 0.916) | 0.025* | 0.536 (0.221, 1.302) | 0.169 |
| Highest occupation | (*n* = 930) | | (*n* = 856) | | (*n* = 656) | | (*n* = 656) | |
| Managerial and professional occupations | 1.340 (0.461, 3.896) | 0.591 | 0.534 (0.287, 0.994) | 0.048* | 0.619 (0.351, 1.094) | 0.099 | 0.779 (0.349, 1.737) | 0.542 |
| Intermediate occupations | 1.092 (0.389, 3.063) | 0.868 | 0.706 (0.418, 1.194) | 0.194 | 0.889 (0.548, 1.443) | 0.634 | 1.167 (0.600, 2.270) | 0.649 |
| Routine and manual occupations | 0.394 (0.114, 1.362) | 0.141 | 0.532 (0.317, 0.891) | 0.017* | 1.088 (0.693, 1.708) | 0.715 | 1.241 (0.663, 2.323) | 0.500 |
| Housewife/unemployed/student | REF | | REF | | REF | | REF | |

**TABLE 1** (Continued)

| | Weight ≥ 95th centile at 6–8 weeks ($n$ = 26/956), OR (95% CI) | $p$ Value | Weight ≥ 95th centile at 9–12 months ($n$ = 119/878), OR (95% CI) | $p$ Value | BMI ≥ 95th centile at school entry ($n$ = 206/677), OR (95% CI) | $p$ Value | BMI ≥ 99.6th centile at school entry ($n$ = 90/677), OR (95% CI) | $p$ Value |
|---|---|---|---|---|---|---|---|---|
| Maternal education | ($n$ = 339) | | ($n$ = 302) | | ($n$ = 184) | | ($n$ = 184) | |
| A'level/equivalent or lower | REF | | REF | | REF | | REF | |
| Degree or above | 1.979 (0.462, 8.471) | 0.357 | 0.676 (0.266, 1.716) | 0.410 | 0.758 (0.350, 1.640) | 0.481 | 0.960 (0.332, 2.774) | 0.940 |
| Marital status | ($n$ = 951) | | ($n$ = 874) | | ($n$ = 676) | | ($n$ = 676) | |
| Married/civil partner | 0.594 (0.199, 1.778) | 0.352 | 0.576 (0.316, 1.050) | 0.072 | 0.585 (0.333, 1.030) | 0.063 | 0.614 (0.300, 1.257) | 0.182 |
| Partner | 0.459 (0.156, 1.350) | 0.157 | 0.543 (0.305, 0.967) | 0.038* | 0.637 (0.373, 1.088) | 0.098 | 0.593 (0.301, 1.169) | 0.132 |
| Single | REF | | REF | | REF | | REF | |
| Smoker at first antenatal appointment | ($n$ = 955) | 0.115 | ($n$ = 877) | 0.330 | ($n$ = 676) | 0.033* | ($n$ = 676) | 0.003** |
| | 0.312 (0.073, 1.330) | | 1.250 (0.798, 1.958) | | 1.507 (1.034, 2.197) | | 2.077 (1.291, 3.340) | |
| Ethnicity | ($n$ = 951) | | ($n$ = 872) | | $N$ = 674 | | ($n$ = 674) | |
| Not W/B | 0.988 (0.130, 7.494)[a] | 0.991 | 1.346 (0.503, 3.599) | 0.554 | 1.484 (0.706, 3.116) | 0.298 | 0.960 (0.328, 2.810) | 0.940 |
| Breastfeeding initiation | ($n$ = 941) | 0.831 | ($n$ = 858) | 0.184 | ($n$ = 662) | 0.930 | ($n$ = 662) | 0.417 |
| Yes | 0.918 (0.420, 2.007) | | 1.309 (0.880, 1.947) | | 1.015 (0.728, 1.415) | | 0.830 (0.528, 1.303) | |
| Breastfed at hospital discharge | ($n$ = 923) | 0.439 | ($n$ = 845) | 0.748 | ($n$ = 659) | 0.909 | ($n$ = 659) | 0.465 |
| Yes | 1.361 (0.624, 2.968) | | 1.067 (0.720, 1.580) | | 0.981 (0.701, 1.372) | | 0.845 (0.537, 1.329) | |
| Caesarean section birth | ($n$ = 955) | 0.997 | $n$ = 877) | 0.372 | ($n$ = 676) | 0.697 | ($n$ = 676) | 0.414 |
| | 1.001 (0.449, 2.231) | | 1.196 (0.808, 1.771) | | 0.934 (0.662, 1.318) | | 1.210 (0.766, 1.910) | |
| Maternal diabetes (GDM or pre-existing) | ($n$ = 840) | 0.938 | ($n$ = 769) | 0.622 | ($n$ = 587) | 0.535 | ($n$ = 587) | 0.433 |
| | 0.957 (0.322, 2.844) | | 0.870 (0.499, 1.516) | | 1.166 (0.781, 1.892) | | 1.286 (0.686, 2.411) | |
| Pregnancy-induced hypertension/pre-eclampsia | ($n$ = 882) | 0.988 | ($n$ = 812) | 0.077 | ($n$ = 638) | 0.729 | ($n$ = 638) | 0.935 |
| | 0.991 (0.288, 3.413) | | 0.526 (0.258, 1.073) | | 0.918 (0.566, 1.488) | | 0.973 (0.506, 1.874) | |

Abbreviations: BMI, body mass index; CI, confidence interval; GDM, gestational diabetes; IOM, Institute of Medicine; OR, odds ratio; REF, referent category; W/B, White/British.

[a]Single case only in one category.

*$p < 0.05$; **$p < 0.01$.

**TABLE 2** Crude ORs and 95% CIs for childhood overweight according to the uptake of the antenatal healthy lifestyle service, gestational weight gain and sociodemographic characteristics.

| | Weight ≥85th centile at 6–8 weeks (*n* = 100/956), OR (95% CI) | *p* Value | Weight ≥85th centile at 9–12 months (*n* = 261/878), OR (95% CI) | *p* Value | BMI ≥85th centile school entry (*n* = 327/677), OR (95% CI) | *p* Value |
|---|---|---|---|---|---|---|
| Number of healthy lifestyle sessions attended | | | | | | |
| Not attended | REF | | REF | | REF | |
| Attended | 1.170 (0.667, 2.053) | 0.584 | 0.888 (0.618, 1.274) | 0.517 | 0.762 (0.543, 1.068) | 0.115 |
| Weight gain according to IOM | (*n* = 838) | | (*n* = 771) | | (*n* = 601) | |
| Less than recommended | 1.405 (0.566, 1.929) | 0.888 | 0.752 (0.505, 1.119) | 0.160 | 1.507 (1.001, 2.269) | 0.049* |
| Recommended | REF | | REF | | REF | |
| More than recommended | 2.319 (1.323, 4.063) | 0.003** | 1.360 (0.932, 1.983) | 0.111 | 1.839 (1.229, 2.752) | 0.003** |
| Parity | | | | | | |
| 1 | REF | | REF | | REF | |
| 2 | 1.824 (1.115, 2.985) | 0.017* | 0.913 (0.642, 1.296) | 0.610 | 0.957 (0.664, 1.380) | 0.815 |
| 3+ | 0.863 (0.485, 1.533) | 0.614 | 1.005 (0.707, 1.430) | 0.976 | 0.781 (0.538, 1.133) | 0.193 |
| Deprivation | | | | | | |
| Most deprived quintile | REF | | REF | | REF | |
| Second most deprived quintile | 0.633 (0.364, 1.099) | 0.104 | 1.035 (0.722, 1.483) | 0.853 | 1.089 (0.752, 1.576) | 0.653 |
| Middle quintile | 0.700 (0.356, 1.375) | 0.301 | 0.861 (0.541, 1.369) | 0.527 | 0.826 (0.512, 1.332) | 0.433 |
| Least deprived two quintiles | 0.625 (0.310, 1.259) | 0.189 | 1.049 (0.665, 1.657) | 0.836 | 0.542 (0.322, 0.912) | 0.021* |
| Highest occupation | (*n* = 930) | | (*n* = 856) | | (*n* = 656) | |
| Managerial and professional occupations | 0.873 (0.430, 1.773) | 0.707 | 0.911 (0.570, 1.456) | 0.696 | 0.759 (0.462, 1.248) | 0.277 |
| Intermediate occupations | 1.635 (0.917, 2.917) | 0.096 | 1.192 (0.785, 1.809) | 0.411 | 1.043 (0.669, 1.627) | 0.851 |
| Routine and manual occupations | 1.005 (0.559, 1.806) | 0.988 | 0.861 (0.575, 1.290) | 0.468 | 0.964 (0.633.1.468) | 0.864 |
| Housewife/unemployed/student | REF | | REF | | REF | |
| Maternal education | (*n* = 339) | | (*n* = 302) | | (*n* = 184) | |
| A'Level/equivalent or lower | REF | | REF | | REF | |
| Degree or above | 0.794 (0.313, 2.016) | 0.627 | 0.681 (0.360, 1.288) | 0.237 | 0.850 (0.428, 1.689) | 0.642 |
| Marital status | (*n* = 951) | | (*n* = 874) | | (*n* = 676) | |
| Married/civil partner | 0.526 (0.283, 0.976) | 0.042* | 0.768 (0.473, 1.248) | 0.287 | 0.671 (0.388, 1.160) | 0.153 |
| Partner | 0.525 (0.292, 0.945) | 0.032* | 0.644 (0.402, 1.030) | 0.066 | 0.701 (0.415, 1.183) | 0.184 |
| Single | REF | | REF | | REF | |
| Smoker at first antenatal appointment | (*n* = 955) | 0.477 | (*n* = 877) | 0.572 | (*n* = 676) | 0.580 |
| | 0.823 (0.482, 1.407) | | 1.105 (0.781, 1.564) | | 1.107 (0.773, 1.584) | |

**TABLE 2** (Continued)

| | Weight ≥85th centile at 6–8 weeks (*n* = 100/956), OR (95% CI) | *p* Value | Weight ≥85th centile at 9–12 months (*n* = 261/878), OR (95% CI) | *p* Value | BMI ≥85th centile school entry (*n* = 327/677), OR (95% CI) | *p* Value |
|---|---|---|---|---|---|---|
| Ethnicity | (*n* = 951) | | (*n* = 872) | | (*n* = 674) | |
| Not W/B | 2.060 (0.880, 4.820) | 0.096 | 1.263 (0.579, 2.754) | 0.558 | 1.321 (0.640, 2.724) | 0.451 |
| Breastfeeding initiation | (*n* = 941) | 0.469 | (*n* = 858) | 0.057 | (*n* = 662) | 0.398 |
| Yes | 1.172 (0.763, 1.800) | | 1.334 (0.992, 1.796) | | 1.141 (0.840, 1.549) | |
| Breastfed at hospital discharge | (*n* = 923) | 0.298 | (*n* = 845) | 0.166 | (*n* = 659) | 0.884 |
| Yes | 1.249 (0.822, 1.897) | | 1.232 (0.917, 1.656) | | 0.977 (0.718, 1.330) | |
| Caesarean birth | (*n* = 955) | 0.756 | (*n* = 877) | 0.154 | (*n* = 676) | 0.835 |
| | 0.934 (0.609, 1.434) | | 1.240 (0.923, 1.667) | | 0.967 (0.705, 1.327) | |
| Maternal diabetes (GDM or pre-existing) | (*n* = 840) | 0.123 | (*n* = 769) | 0.915 | (*n* = 587) | 0.768 |
| | 0.597 (0.310, 1.150) | | 1.022 (0.687, 1.521) | | 1.071 (0.680, 1.684) | |
| Pregnancy-induced hypertension/ pre-eclampsia | (*n* = 882) | 0.742 | (*n* = 812) | 0.259 | (*n* = 638) | 0.581 |
| | 1.107 (0.605, 2.025) | | 0.771 (0.492, 1.210) | | 0.883 (0.568, 1.373) | |

Abbreviations: BMI, body mass index; CI, confidence interval; GDM, gestational diabetes; IOM, Institute of Medicine; OR, odds ratio; REF, referent category; W/B, White/British.

*$p < 0.05$; **$p < 0.01$.

5 years later, with increasing maternal weight at the start of pregnancy associated with an increased risk of childhood severe obesity at school age. The noticeably higher prevalence of childhood overweight and obesity within women with the most severe forms of obesity is of concern given the rising prevalence of obesity within the United Kingdom. Furthermore, the potential importance of assessing outcomes separately according to a class of obesity is highlighted.

Compared to GWG within the recommended range, excessive weight gain (above IOM recommendations) was seen within the multiple logistic regression analysis within this study to be associated with increased odds of childhood overweight and obesity at school entry. Much other research has also looked at the long-term association between GWG and offspring obesity (Lau et al., 2014; Sridhar et al., 2014; Tie et al., 2014; Voerman et al., 2019). One systematic review found each additional 1 kg of GWG increased the child's BMI *z*-score by between 0.006 and 0.06 units and elevated the risk of overweight or obesity by 1%–23% after adjusting for confounders (Lau et al., 2014). Further studies have also shown exceeding IOM guidelines to be associated with a 46% increase in odds of childhood overweight/obesity at age 2–5 years after adjusting for multiple confounding factors (Sridhar et al., 2014) and to increase the odds of childhood overweight or obesity from age 2–18 years (adjusted OR: 1.33 [95% CI: 1.18–1.50]) (Tie et al., 2014). The most recent individual participant analysis has similarly shown excessive GWG to increase early childhood obesity (age 2–5 years), mid-childhood obesity (5–10 years) and late childhood obesity (10–18 years) (Voerman et al., 2019). There is some disagreement over which maternal BMIs show the most evident effect of excessive GWG on childhood weight. An American cohort suggested the most notable effect was among women with a prepregnancy BMI in the recommended range (Sridhar et al., 2014), but the individual participant analysis saw the largest effects in women with prepregnancy obesity gaining excessive weight gain (Tie et al., 2014). This lack of clarity may in part be due to the inherent limitations of exploring the association between child weight and GWG given the issues with GWG measurement, especially regarding the timing of weighing, and the potential for unmeasured confounding factors such as familial characteristics to influence the results (Lau et al., 2014). However, the important impact of maternal health and diet both before and during pregnancy on long-term offspring health and development through the role of epigenetics is known to be important and requires continued focus to obtain optimal long-term childhood outcomes (Aldhous et al., 2018; Lorite Mingot et al., 2017).

Little has been done to date to evaluate the association between pregnancy lifestyle interventions and long-term infant health. Two systematic reviews of randomised controlled trial (RCT), quasi-randomised or cluster randomised study evidence (Dalrymple et al., 2018; Raab et al., 2021), found only five studies that evaluated childhood anthropometric outcomes up to 5 years of age (Chiavaroli et al., 2018; Dodd et al., 2020; Grotenfelt et al., 2020; Kolu et al., 2016; Ronnberg et al., 2017). Three of these studies recruited very few children born to women with obesity during pregnancy. Only 16% of the infants within a Swedish RCT were noted to have had mothers with obesity (Ronnberg et al., 2017) and within a Finish

**TABLE 3** Multiple logistic regression models of factors associated with childhood obesity (≥95th centile) at each of the different timepoints and severe obesity (≥99.6th centile) at school entry.

| Predictor | Weight ≥ 95th centile at 6–8 weeks, Nagelkerke $R^2$ = 0.501, $\chi^2$ = 101.3, $p < 0.001$, $n = 813$ aOR (95% CI)[a] | p Value | Weight ≥ 95th centile at 9–12 months, Nagelkerke $R^2$ = 0.148, $\chi^2$ = 64.4, $p < 0.001$, $n = 749$ aOR (95% CI)[a] | p Value | BMI ≥ 95th centile at school entry, Nagelkerke $R^2$ = 0.113, $\chi^2$ = 48.0, $p < 0.001$, $n = 583$ aOR (95% CI)[a,b] | p value | BMI ≥ 99.6th centile at school entry, Nagelkerke $R^2$ = 0.133, $\chi^2$ = 42.9, $p < 0.001$, $n = 583$ aOR (95% CI)[a] | p Value |
|---|---|---|---|---|---|---|---|---|
| Weight gain according to IOM | | | | | | | | |
| Less than recommended | 0.395 (0.082, 1.905) | 0.247 | 1.001 (0.554, 1.807) | 0.998 | 1.350 (0.820, 2.223) | 0.239 | 0.938 (0.460, 1.913) | 0.861 |
| Recommended | REF | | REF | | REF | | REF | |
| More than recommended | 0.598 (0.168, 2.131) | 0.428 | 1.119 (0.636, 1.967) | 0.696 | 1.640 (1.012, 2.656) | 0.044* | 1.726 (0.900, 3.312) | 0.101 |
| Parity | | | | | | | | |
| 1 | REF | | REF | | REF | | REF | |
| 2 | 2.264 (0.621, 8.254) | 0.216 | 1.071 (0.620, 1.852) | 0.805 | 0.659 (0.411, 1.057) | 0.084 | 0.685 (0.356, 1.319) | 0.258 |
| 3+ | 1.021 (0.189, 5.505) | 0.981 | 1.045 (0.553, 1.973) | 0.893 | 0.682 (0.396, 1.174) | 0.168 | 0.740 (0.362, 1.513) | 0.409 |
| Deprivation | | | | | | | | |
| Most deprived quintile | REF | | REF | | REF | | REF | |
| Second most deprived quintile | 0.177 (0.028, 1.132) | 0.067 | 0.916 (0.524, 1.599) | 0.757 | 1.363 (0.865, 2.147) | 0.182 | 1.044 (0.561, 1.941) | 0.892 |
| Middle quintile | 0.769 (0.167, 3.533) | 0.736 | 0.965 (0.488, 1.907) | 0.918 | 1.127 (0.606, 2.095) | 0.706 | 0.997 (0.432, 2.299) | 0.994 |
| Least deprived two quintiles | 1.599 (0.364, 7.023) | 0.534 | 0.721 (0.322, 1.611) | 0.425 | 0.650 (0.314, 1.345) | 0.246 | 0.507 (0.164, 1.560) | 0.236 |
| Occupation | | | | | | | | |
| Higher managerial or professional | 0.453 (0.083, 2.480) | 0.361 | 0.451 (0.209, 0.970) | 0.042* | 0.410 (0.200, 0.841) | 0.015* | 0.540 (0.202, 1.443) | 0.219 |
| Intermediate occupations | 0.389 (0.082, 1.844) | 0.235 | 0.649 (0.348, 1.212) | 0.175 | 0.759 (0.432, 1.331) | 0.336 | 0.979 (0.452, 2.118) | 0.957 |
| Routine or manual | 0.180 (0.033, 0.972) | 0.046* | 0.547 (0.304, 0.985) | 0.044* | 0.931 (0.557, 1.556) | 0.785 | 1.045 (0.514, 2.128) | 0.902 |
| Unemployed/housewife | REF | | REF | | REF | | REF | |
| Smoking | 0.685 (0.090, 5.228) | 0.715 | 1.384 (0.805, 2.380) | 0.240 | 1.554 (0.973, 2.482) | 0.055 | 2.695 (1.448, 5.018) | 0.002** |

Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; IOM, Institute of Medicine; REF, referent category.

[a]Adjusted for maternal weight when booking for pregnancy, maternal height, maternal age, birthweight, gestation at birth and infant gender.

[b]Additionally adjusted for birthweight squared.

*$p < 0.05$; **$p < 0.01$.

**TABLE 4** Multiple logistic regression models of factors significantly associated with childhood overweight (≥85th centile) at each of the different timepoints.

| Predictor | Weight ≥ 85th centile at 6–8 weeks, Nagelkerke $R^2$ = 0.456, $\chi^2$ = 215.6, $p$ < 0.001, $n$ = 813 aOR (95% CI)[a] | $p$ Value | Weight ≥ 85th centile at 9–12 months, Nagelkerke $R^2$ = 0.165, $\chi^2$ = 92.9, $p$ < 0.001, $n$ = 749 aOR (95% CI)[a] | $p$ Value | BMI ≥ 85th centile school entry, Nagelkerke $R^2$ = 0.134, $\chi^2$ = 61.5, $p$ < 0.001, $n$ = 583 aOR (95% CI)[a,b] | $p$ Value |
|---|---|---|---|---|---|---|
| Weight gain according to IOM | | | | | | |
| Less than recommended | 1.432 (0.656, 3.127) | 0.367 | 0.730 (0.471, 1.131) | 0.159 | 1.815 (1.163, 2.832) | 0.009** |
| Recommended | REF | | REF | | REF | |
| More than recommended | 1.783 (0.880, 3.609) | 0.108 | 0.987 (0.649, 1.501) | 0.951 | 1.651 (1.062, 2.567) | 0.026* |
| Parity | | | | | | |
| 1 | REF | | REF | | REF | |
| 2 | 1.906 (0.970, 3.744) | 0.061 | 0.866 (0.571, 1.312) | 0.496 | 0.758 (0.492, 1.166) | 0.207 |
| 3+ | 0.911 (0.384, 2.164) | 0.833 | 0.956 (0.590, 1.550) | 0.855 | 0.526 (0.317, 0.871) | 0.013* |
| Deprivation | | | | | | |
| Most deprived quintile | REF | | REF | | REF | |
| Second most deprived quintile | 0.527 (0.259, 1.073) | 0.077 | 1.074 (0.702, 1.641) | 0.743 | 1.303 (0.851, 1.995) | 0.223 |
| Middle quintile | 0.484 (0.192, 1.224) | 0.125 | 0.935 (0.549, 1.595) | 0.806 | 0.887 (0.504, 1.562) | 0.679 |
| Least deprived two quintiles | 0.757 (0.300, 1.913) | 0.557 | 1.285 (0.742, 2.224) | 0.371 | 0.643 (0.349, 1.186) | 0.157 |
| Occupation | | | | | | |
| Higher managerial or professional | 0.410 (0.147, 1.140) | 0.087 | 0.893 (0.492, 1.621) | 0.711 | 0.577 (0.307, 1.082) | 0.087 |
| Intermediate occupations | 1.072 (0.493, 2.333) | 0.861 | 1.181 (0.714, 1.953) | 0.517 | 0.828 (0.490, 1.399) | 0.482 |
| Routine or manual | 0.809 (0.391, 1.674) | 0.569 | 0.917 (0.569, 1.477) | 0.720 | 0.766 (0.470, 1.249) | 0.286 |
| Unemployed/housewife | REF | | REF | | REF | |
| Smoking | 1.701 (0.846, 3.421) | 0.136 | 1.375 (0.896, 2.111) | 0.145 | 1.217 (0.782, 1.893) | 0.384 |

Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; IOM, Institute of Medicine; REF, referent category.
[a]Adjusted for maternal weight when booking for pregnancy, maternal height, maternal age, birthweight, gestation at birth and infant gender.
[b]Additionally adjusted for birthweight squared.
*$p$ < 0.05; **$p$ < 0.01.

RCT, the two women with a BMI ≥ 40 kg/m$^2$ were excluded from the analysis due to being outliers (Kolu et al., 2016; Luoto et al., 2011). Within the New Zealand trial women had a mean BMI of 25.4 ± 2.9 kg/m$^2$ in the control group and of 25.5 ± 4.3 kg/m$^2$ in the exercise group, with no women in the control group having a BMI ≥ 35 kg/m$^2$ and the maximum BMI in the exercise group being 37.1 kg/m$^2$ (Chiavaroli et al., 2018; Hopkins et al., 2010). The other two studies looking at the long-term influence of antenatal interventions either exclusively focussed on women with overweight or obesity (Dodd et al., 2020) or recruited a sizable sample of women with obesity, with 294 of the 493 pregnant women recruited having a BMI ≥ 30 kg/m$^2$ (Grotenfelt et al., 2020; Rönö et al., 2014). Within this current study, attendance at the midwife-led antenatal healthy lifestyle service was not associated with childhood overweight or obesity at any timepoint within the univariate analyses. While the previous research in this area provides limited evidence surrounding interventions in women with a raised BMI, they similarly showed no statistically significant differences in child growth at 3–5 years (Dodd et al., 2020), at 5 years (Grotenfelt et al., 2020; Ronnberg et al., 2017) or at 7 years (Chiavaroli et al., 2018; Kolu et al., 2016) from a lifestyle intervention during pregnancy. Of interest, is that while two of the above studies showed no differences in child BMI, the infants of mothers who received the intervention compared to those who received the control, were shown to have worse metabolic health especially related to lipid metabolism at 5 years (Grotenfelt et al., 2020) and significantly increased body fat and abdominal adiposity at 7 years of age (Chiavaroli et al., 2018). The reason for these differences was unclear within both studies. The lack of association between childhood weight and attendance at the midwife-led antenatal healthy lifestyle service within this study, as well as in previous RCTs with long-term follow up could potentially be due to the limited impact of the interventions on GWG. GWG did not differ in women attending the antenatal healthy lifestyle service (Fair & Soltani, 2024), and was only significantly different between control and intervention groups within one of the RCTs (Ronnberg et al., 2017) and even then GWG was only reduced by 1.1 kg. Therefore, further establishment of interventions that are effective at reducing GWG and enhancing clinical outcomes in women with obesity is warranted. Given that the association between long-term child health and intervention, along with other maternal factors, was similar within this matched data to the results from RCTs, further use of matched cohort data is suggested as a more cost-effective solution for intervention follow up than expensive RCTs.

While 33% of children classified as overweight or obese at 6–8 weeks had been born LGA, this proportion had dropped to only 15.6% of children who were overweight or obese at school entry who had been born LGA. The literature from several cohort studies has noted that children born LGA are more likely to be overweight or obese at 6–12 months (Moschonis et al., 2008) and at 4–6 years old (Kaul et al., 2019). Within the second cohort study, there was a 39.4% increase in overweight or obesity in children born LGA; with LGA noted to have a larger impact than maternal diabetes during pregnancy (Kaul et al., 2019). However, maternal BMI or weight status was not considered as a confounder within that study (Kaul et al., 2019) and the other cohort study only classified women as overweight or not overweight in pregnancy without considering women with obesity as a separate subcategory (Moschonis et al., 2008). The literature has also shown high infant birthweight to be associated with childhood overweight up to 2 years of age in a meta-analysis of prospective studies (Weng et al., 2012) and to be a predictor of overweight/obesity at school age (Apfelbacher et al., 2008). However, again the second of these studies did not consider the potential impact of maternal BMI or weight status by adjusting for this factor within the analysis (Apfelbacher et al., 2008). The independent risk of being born LGA to a woman with prepregnancy obesity therefore remains unclear.

Caesarean birth was not linked to childhood obesity in this sample of women with raised BMI. Numerous previous studies and reviews have shown Caesarean birth to be linked to an increased risk of overweight or obesity up to school age (Kaul et al., 2019; Keag et al., 2018). However, limitations of previous research have been noted especially around the lack of adjustment for maternal BMI (Masukume et al., 2019). A British study that carefully adjusted for maternal prepregnancy BMI showed no association between mode of birth and childhood overweight and therefore hypothesised that the previously noted link was likely to be mediated by the additional risk of giving birth by Caesarean with a raised maternal BMI (Masukume et al., 2019). An additional review of prenatal factors that predict later childhood obesity found Caesarean birth may influence childhood obesity (Liao et al., 2019); however, they noted being born by Caesarean is also linked with antibiotic exposure and poor early breastfeeding, both of which are other factors known to be associated with childhood obesity.

Once controlling for other factors within the multiple logistic regression analysis, infants of women who smoked at the first antenatal appointment had higher odds of severe obesity at school entry, as well as a trend towards increased obesity at school entry, but not at earlier timepoints. Several meta-analyses have also previously identified that infants of mothers who smoked during pregnancy are at higher risk of overweight and obesity during childhood (Riedel et al., 2014; Weng et al., 2012). Within one previous meta-analysis, the effect of higher childhood obesity in children of women who smoked during pregnancy remained after excluding studies that did not adjust for potential confounders including maternal BMI, parental education and birthweight (Riedel et al., 2014). A further systematic review of prediction models of childhood overweight or obesity from 1 to 13 years also found smoking during pregnancy to be significantly associated with overweight and obesity within four of the eight included models (Ziauddeen et al., 2018). The association between smoking and child weight may only be evident by school entry within this study as smoking during pregnancy is known to increase the risk of having infants of low birthweight (Inoue et al., 2017). There may therefore be a lag before seeing an association between smoking during pregnancy and childhood obesity, as the infant has first to overcome the initial growth restriction during pregnancy.

There was also a relationship between childhood weight and socioeconomic status within this study. It was noted that lower deprivation levels were no longer significantly associated with lower levels of childhood overweight or obesity at school entry once controlling for other factors, including household occupation. However, being in a household where no-one was in employment increased childhood obesity at different timepoints. Others have also previously noted the importance of sociodemographic factors. An American study has shown the highest prevalence of overweight (BMI ≥ 85th centile) in elementary school among those of low socioeconomic status, although the potentially confounding effects of maternal BMI or birthweight were not considered within this study (Moreno et al., 2013). A further Canadian cohort found childhood overweight and obesity decreased at age 4–6 years with increasing household income (Kaul et al., 2019). The systematic review of prediction models of childhood overweight or obesity from 1 to 13 years also found that sociodemographic factors such as marital status, paternal and maternal education, paternal income, maternal occupation and ethnicity were included within different models, although each factor was only present within one of the eight included models (Ziauddeen et al., 2018). However, it clearly shows the importance of developing interventions that do not just focus on the mother as an individual during pregnancy, but on wider social determinants of health. Consideration should be given to utilising a socioecological framework when developing future interventions that incorporates not only the woman, but other influences including her family and home, work and peers, community, industry and government and culture and society, as well as the interaction between these aspects (Hill, 2021). Additionally, given the large proportion of children with overweight and obesity born to women with a raised pregnancy BMI demonstrated within this study, the importance for long-term child health of addressing maternal weight before pregnancy is highlighted.

### 4.1 | Strengths and limitations

This cohort study explored the association between an antenatal healthy lifestyle service and child weight among a large number of women with a BMI ≥ 35 kg/m$^2$, a category often lacking in previous research. Additionally, it is one of the few studies taking advantage of data linkage to investigate long-term infant weight outcomes. Some limitations however need to be acknowledged. *p* values were not corrected for multiple hypothesis testing within the analysis. It is acknowledged that the large number of statistical tests performed increases the risk of a type I error. Some of the statistically significant findings may therefore be due to chance. There was variation within the timing of data collection for each infant at the different timepoints. However, to account for this weight and BMI were converted into age-appropriate centiles within the analysis. Furthermore, retrospective data collection is well known for its limitations around data collection completeness (Hasson et al., 2015). It was particularly evident within this study that education was poorly documented within the maternity notes. While factors within the analysis were identified within the literature, the retrospective nature of the study also limited the availability of some factors, for example, longer-term breastfeeding outcomes. Additionally, childhood anthropometric data was collected within routine care and therefore recorded by various personnel, which may limit standardisation. Finally, the wider generalisability of the study is limited by the higher rate of social deprivation within the cohort than across England in general (Office for Health Improvements and Disparities, 2022b).

## 5 | CONCLUSION

Matching data between two datasets was shown to be feasible using pseudoanonymised data. Current data did not suggest any association between healthy lifestyle service attendance compared to no attendance on the odds of childhood overweight or obesity up to school entry. Sociodemographic characteristics such as household occupation and maternal smoking during pregnancy were noted to be associated with long-term childhood obesity. Future interventions need to consider how to address wider determinants of health and not just the individual woman's behaviour.

### AUTHOR CONTRIBUTIONS

Frankie J. Fair and Hora Soltani developed the protocol. Frankie J. Fair assisted with data collection. Frankie J. Fair analysed and interpreted the data. Hora Soltani supervised the analysis and interpretation of the data. Frankie J. Fair wrote the manuscript. Hora Soltani revised the manuscript. Frankie J. Fair and Hora Soltani agreed on the final manuscript.

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### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not publicly available within a repository as they belong to the Hospital Trusts, but the data is available from the corresponding author on reasonable request. For the purpose of open access, the author has applied a Creative Commons Attribution (CC BY) licence to any Author Accepted Manuscript version arising from this submission.

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## 7.5 Summary and implications for thesis

This article considered the association between attendance at an antenatal healthy lifestyle service and long-term child weight up to the age of 5 years. It also considered the influence of other sociodemographic characteristics on child weight.

The research showed that almost a third of children born to women with a BMI ≥35kg/m² were classified as obese by the age of 5 years. Antenatal healthy lifestyle service attendance was not associated with the odds of childhood overweight or obesity at any timepoint up to the age of 5 years. Childhood obesity was however significantly associated with excessive gestational weight gain, household occupation and maternal smoking when booking for pregnancy care.

Given the lack of impact of the antenatal healthy lifestyle service on clinical outcomes related to pregnancy or on long-term child weight, determining women's experiences of weight management during pregnancy and the perceived barriers and facilitators to weight management was essential. This was explored through qualitative interviews and is presented in the next chapter.

# Chapter 8: Experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above

## 8.1 Introduction

This chapter presents Article E, the final study from the programme of research. This was a qualitative exploration of the experiences of weight management among women with a BMI of 40kg/m² or above. The aims of the study are provided below, alongside the details of publication and impact of the article. The full published article is then presented. The chapter concludes by summarising the key findings of this qualitative element of the research programme.

## 8.2 Aim of the qualitative component

The overview of systematic reviews presented within this thesis, alongside the quantitative components of the research programme have demonstrated the limited impact of lifestyle interventions in women with obesity on GWG or other clinical outcomes, including on child weight outcomes up to 5 years of age. Quantitative research however cannot contextualise these results. Qualitative research can provide such context by considering factors that may impact upon women’s ability to manage their weight during pregnancy. The development of the interview schedule (Appendix I) was informed by the lack of impact of the antenatal healthy lifestyle service noted within the results from the quantitative phase. This is an essential component of a sequential explanatory mixed methods design.

This qualitative component therefore aimed to explore the experiences of antenatal healthy weight service provision in women with a BMI ≥40kg/m², alongside the barriers and facilitators experienced by these women to weight management during pregnancy. This addressed the final aim of this programme of research: "*To explore the experiences of weight management during pregnancy among women with the highest class of obesity*".

## 8.3 Published article: Article E

The title of the published article was ""*Everything is revolved around me being heavy … it's always, always spoken about." Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above*." It is reproduced in full on the following pages, in the format in which it was published[(335)]. The supplementary data to accompany this article can be found in Appendix I.

## 8.4 Publication and impact

The article was accepted for publication in PLOS One and was published fully open access in June 2022. PLOS One is a multi-disciplinary, fully open access, peer reviewed journal. It is focussed on scientific rigour regardless of subject area. In 2022 PLOS One had an impact factor of 3.7.

Since publication the article has been viewed 1,772 times online and according to Google Scholar it has been cited 7 times (as of 31st January 2024). The article has an Altmetric score of 20 and is therefore in the top 25% of all research outputs scored by Altmetric.

PLOS ONE

RESEARCH ARTICLE

# "Everything is revolved around me being heavy . . . it's always, always spoken about." Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m$^2$ or above

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## Abstract

### Introduction

Maternal weight management services have been recognised as a good opportunity to influence lifestyle and dietary behaviour of mothers and families. Exploring women's views of maternal weight management services is paramount to understand what constitutes the most suitable service. This study therefore explored experiences among women with a raised body mass index (BMI) of maternal weight management service provision and the barriers and facilitators to weight management during pregnancy.

### Method

Thirteen women with a BMI$\geq$40kg/m$^2$ undertook semi-structured interviews around weight management experiences during pregnancy. Interviews were audio recorded and transcribed verbatim. Inductive thematic analysis was undertaken.

### Results

Four themes emerged. 1). "Understanding where I am at" showed current readiness and motivation of women varied, from being avoidant to being motivated to make changes. 2). "Getting information" revealed inconsistent information provision during pregnancy. Women particularly wanted practical advice. Some attempted to find this for themselves from friends or the internet, however this left some women feeling confused when different sources provided inconsistent advice. 3). "Difficulties I face" identified physical, emotional and financial barriers and the strategies some women used to overcome these. 4). "Encountering professionals–a mixed experience" demonstrated women wanted to be treated with respect and sensitivity and that how weight management information was addressed was more important than who provided it. The fine line professionals tread was demonstrated by women thinking that they had received inadequate information and yet too much focus was placed

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on their weight and the associated risks during pregnancy without practical solutions to their weight management challenges.

## Discussion

Women were empowered when practical advice was provided, not just the continual repetition of the risks of being obese during pregnancy. Antenatal weight management services need to be clear, sensitive and respectful. Services centred on individual women's needs and on their current and previous experiences are required. The psychological and social contexts of weight management also need to be addressed.

## Introduction

Globally obesity and overweight (body mass index (BMI)$\geq$25kg/m$^2$) has been estimated to affect 38% of women [1], with rates varying by country. One recent study has found the proportion of women with the most severe form of obesity (BMI$\geq$40kg/m$^2$) to vary from 1.6% in Spain to 9.7% in the United States of America (USA) [2]. Alongside increased overweight and obesity in the general population over recent decades, maternal obesity during pregnancy has significantly increased [3,4]. Within England a recent cohort has shown 1.6% of pregnant women to have a BMI$\geq$40kg/m$^2$ [5]. Furthermore, childbearing itself has been acknowledged to contribute to the rise of overweight and obesity in women [6].

Obesity during pregnancy has been associated with a wide range of adverse outcomes for both the mother and the infant [7,8]. For the mother this has included increased risk of pre-eclampsia [9,10], gestational diabetes [8,9], preterm birth [8], induction of labour [7], Caesarean Section [11] and surgical site infection [7]. The adverse outcomes noted for infants born to women with obesity during pregnancy include increased risk of being large for gestational age [8], admission to neonatal intensive care [7], stillbirth [11,12], neonatal mortality [11,13] and childhood obesity [14]. For all of these adverse outcomes women with a BMI$\geq$40kg/m$^2$ were at the greatest risk; with their risk not just being higher when compared to women of normal BMI but also when compared to women with lower levels of obesity (BMI 30–39.9kg/m$^2$) [15]. Overall, it has been estimated that 23.9% of pregnancy complications are attributable to maternal overweight or obesity prior to pregnancy [8].

Women with obesity prior to pregnancy have also been shown to be more likely to gain excessive weight during pregnancy [16], with a recent meta-analysis of individual participant data suggesting 44% of women with obesity gain excessive gestational weight [17]. Increased gestational weight gain has itself been associated with adverse maternal and neonatal outcomes both in the short and long term [18], including increased risk of Caesarean Section [17], induction [19], large for gestational age [18], poorer breastfeeding outcomes [20] and childhood obesity [14], especially when excessive weight gain occurred in women with obesity.

Traditionally pregnancy has been viewed as a good time to influence maternal healthy lifestyle as women are believed to be particularly receptive to healthy eating and physical activity messages at this time [21]. Furthermore, it has been seen as an opportunity to influence the long-term health of the woman and her family if changes made during pregnancy were sustained [22]. Many national and international guidelines have therefore recommended counselling women regarding healthy eating and physical activity during pregnancy [23–25]. However, a recent meta-review of lifestyle interventions during pregnancy has only found a minimal decrease in gestational weight gain and no other clear benefits on other adverse pregnancy outcomes from lifestyle interventions during pregnancy for women with overweight or obesity [26].

As the proportion of women with a pre-pregnancy BMI≥40kg/m$^2$ has continually increased globally, understanding how these women approach weight management in pregnancy and their attitude towards maternal weight management services is important. The context of the study provided additional significance given the region has been shown to have one of the highest rates of maternal obesity in England [27]. Deprivation scores have also been found to be among the worst in England, with indicators such as life expectancy, proportion of children living in low-income families and employment all falling below the average for England [27]. Previous research has also suggested potential differences in the experiences of women with a BMI of 30-40kg/m$^2$ and those with higher BMIs [28], highlighting the necessity for additional research among women with higher BMIs. While quantitative methods such as surveys can reach a greater number of participants and allow generalizability of results, qualitative research is considered the most appropriate methodology for providing context through in-depth exploration of the topic from the participants' perspective [29]. The aim of this research was therefore to explore the experiences of maternal healthy weight service provision in women with a BMI≥40kg/m$^2$, alongside the barriers and facilitators experienced by these women in weight management during pregnancy.

## Methods

### Theoretical framework

This study used a qualitative interpretive approach, from a constructivism philosophical position as the aim was to understand the meanings the women created and attributed to their experiences [30]. Ontologically the study was grounded in relativism, as the researchers acknowledged that multiple realities exist which are subjective and shaped through individual lived experiences. [30,31]. At an epistemological level, a transactional position was adopted. This recognized that the researchers did not come into the research process as blank slates but brought with them their own previous histories and perspectives of weight management [30]. It was recognised that this could impact on the interpretation the researchers formed. Therefore, to ensure trustworthiness of the research reflexivity was undertaken, where the researchers critically reflected on how their social background, assumptions, positioning and behaviour impact on the research process [32,33].

Within the social sciences multiple competing theories exist which allow a phenomenon to be viewed from multiple perspectives, with each perspective providing a reasonable explanation of a phenomenon [34]. This research was influenced by aspects of both the Capability, Opportunity, Motivation, Behaviour (COM-B) model [35] and the socio-ecological framework [36]. The COM-B model views behaviour to be generated from an interaction of capability, motivation and opportunity [35], while the socio-ecological framework views behaviour being influenced by multiple levels of factors including intra-personal, inter-personal, organisational, community and public policy factors [36]. These methodological and theoretical orientations were used to interpret and understand experiences among women with obesity of weight management services and their barriers and facilitators to weight management during pregnancy.

### Study setting

The exact name of the study setting is not included for data protection and anonymity purposes. The study was conducted in a region within Yorkshire and Humber with high rates of maternal obesity and deprivation compared to the rest of England [27].

## Recruitment and data collection

A purposive sampling strategy was used. Pregnant women who had a BMI≥40kg/m$^2$ when booking for antenatal care were approached at their 36 weeks gestation anaesthetic review appointment between December 2018 and February 2019. The 36 weeks gestation review appointment was chosen as that was the last universal appointment at the maternity unit for women with a BMI≥40kg/m$^2$. Women were offered an interview (face-to-face or over the telephone) or participation in a focus group. All women chose an individual interview. Interviews were semi-structured using an interview schedule that covered weight management advice given during this pregnancy, awareness of services and facilitators and barriers to weight management during pregnancy (see S1 File). The schedule was developed in collaboration with a maternity service user group to confirm acceptability and clarity to a wide audience. All interviews were audio recorded.

Nineteen women expressed an interest in participating in an interview. These women were followed up with either 2 emails or 2 telephone calls depending upon their stated preference. After this no further contact was attempted. In total 13 women completed an interview. All interviews were undertaken by a female interviewer. After 13 interviews no new concepts were emerging, therefore data saturation was felt to have been achieved and further recruitment stopped.

## Data analysis

Interview data was transcribed, anonymised and managed using NVivo. An inductive or 'bottom up' thematic analysis approach was undertaken without trying to fit the data onto a predefined coding structure or theoretical framework [37]. An inductive approach allowed the themes to be determined from the data rather than the researchers' preconceptions [37]. A systematic methodology was used for identifying, analysing and reporting patterns within the data, applying the six-phase process described by Braun and Clarke [37]. After familiarisation with the data, two researchers independently open coded the transcripts line by line to summarise the elements discussed. These initial codes were close to and derived from the text. Both researchers individually grouped and refined the initial codes into categories. From these categories and through discussion the researchers agreed the themes and sub themes emerging from the data. All coded data was then fitted within these themes to ensure completeness of the analytical themes and inclusion of all relevant data. After further reviewing and revision of the generated themes, clear definitions and names were given to each of the emerging themes.

Development of the themes was iterative and included a reflexive process where the researchers acknowledged their pre-understanding and biases to ensure the themes remained close to the original data. The complexity of women's experiences was reflected by describing within each theme the contradictory aspects and diverse nature of the multiple realities of the interviewees. Extensive direct quotations have been presented to illustrate and confirm the researchers' interpretations within each theme and subtheme. All interviewees were given the option of commenting on the initial interpretation for member validation; with four women choosing this option. The initial themes to which their data had contributed were sent to these women to confirm their own viewpoint was represented within the researchers' interpretation.

## Ethical considerations

Ethical approval (IRAS 17/EE/0378) and research governance approvals were obtained prior to commencing this study. Written informed consent was obtained from women prior to undertaking the interviews. Women were given a £10 voucher to compensate the time they had given to participate in the interview. Pseudonyms have been used to protect confidentiality.

## Results

Of the 13 women who participated, nine undertook face-to-face interviews and four telephone interviews. All women were in the late third trimester of pregnancy. Five women were primigravid, seven women had one previous child and one had 2 previous children. Three women had experienced care in a different hospital Trust during their previous pregnancy, while the other women had received care within the same hospital Trust for all of their pregnancies. Six women had other people present during the interview, three had their partner present, one their child, one their mother and one both their mother and their partner. However, these companions only contributed to the interview on three brief occasions and these comments were not coded within the analysis.

Four themes emerged from the data; "Where I am at", "Getting Information", "Difficulties I face" and "Encountering professionals–a mixed experience". Fig 1 illustrates the themes and subthemes.

### Where I am at

**Historical weight management.** Women were noted to be at different stages on their weight management journey, each bringing their own story of weight management over the years. Over half of the women described previous efforts at weight management with the majority using weight management support groups, seeing dieticians or participating in

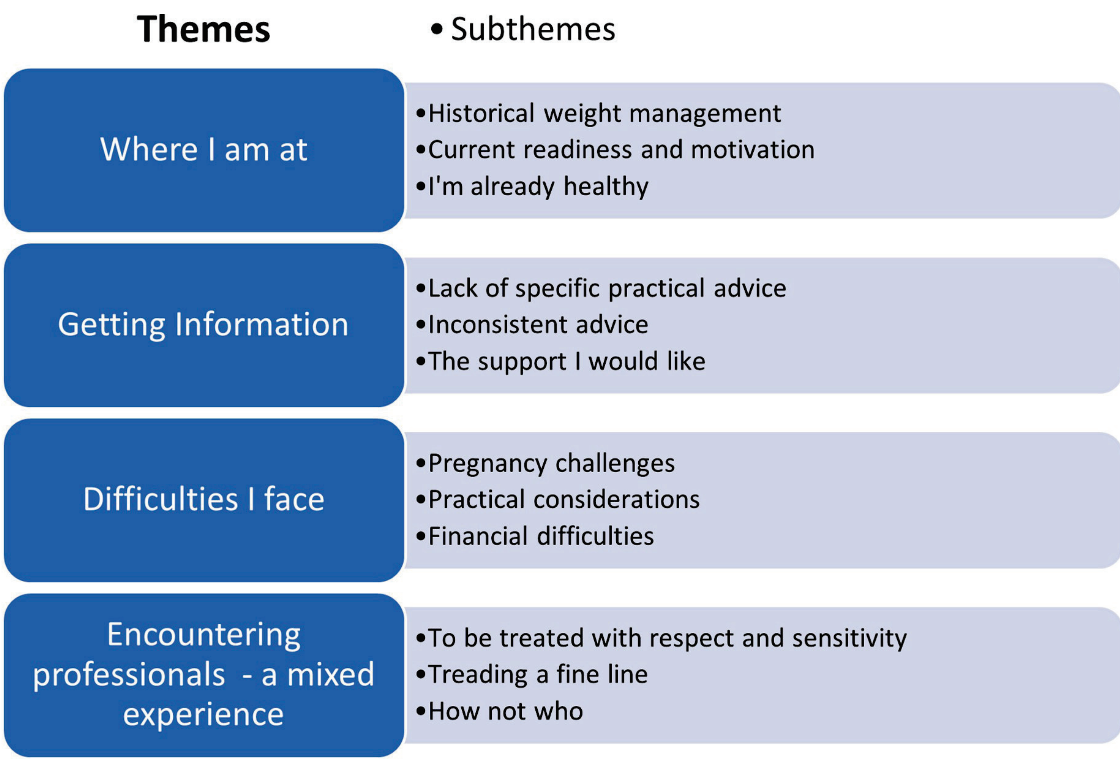


**Fig 1. Themes and subthemes within the analysis.**

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exercise such as going to the gym. Some had also used weight loss shakes, tablets, or followed special personalised diets. Most had seen success in their previous attempts at weight management although many had seen weight return with pregnancies or over time.

> *"I used to do Slimming World before . . . I have tried like pills, I had stuff like that. I have been to dieticians and tried the gym."* Danielle

**Current readiness and motivation.** Some women were already following their own weight management plans prior to and during pregnancy, noting the fit of certain clothes or frequently weighing themselves to monitor their own weight gain. These women were motivated to prevent excessive weight gain which would need losing again post pregnancy. The recognition that everything they were eating was being passed onto the baby also motivated some women to manage their weight during pregnancy.

> *"I have been watching my own weight anyway because obviously . . . I put a lot of weight on in my first pregnancy and then I've not really got it off, so I don't want to put any more on in this pregnancy."* Joanne

> *"It's [my diet's] changed during pregnancy because I've started eating more healthier . . . Making it better for the baby."* Emma

While acknowledging a need to address their weight, some women did not feel ready to at present. These women talked positively about their plans to lose weight in the postnatal period by increasing exercise or starting to attend a commercial weight management group (private company offering weight management support that the women could independently access and finance). Other women however did not want the issues of weight management being raised, for example declining offers of support from dietetic services or not wanting to receive information from community midwives around healthy eating or physical exercise. Several women linked their avoidance of weight management to their low self-confidence.

> *"I think most women who are overweight and pregnant just feel low in themselves . . . I don't know about anyone else, but from my experience that's how I feel."* Rebecca

Whether or not women felt ready to receive weight management support, they all recognised that the motivation to manage weight had to be internal, with services only able to be effective if the woman herself was ready to address her weight.

> *"You can tell somebody something, but if they don't want to do it they will not do it."* Danielle

For most women, their readiness to receive weight management advice appeared to influence their acceptability of being weighed during pregnancy. The majority were happy to be weighed at appointments and felt weighing should be a part of routine practice. In contrast a few women were ambivalent, not minding one way or the other and two women felt uncomfortable with being weighed for example feeling anxious about how much they would weigh and not wanting to know the figures.

> *"I have seen a dietician as well with the diabetes side of things. It's been really useful actually . . . I get weighed at every appointment that I go to . . . I'm happy to have that." Zoe*

*"I honestly don't mind [being weighed] because in my opinion it is what it is, I know within myself if I've been over-indulging with things."* Laura

*"I don't like being weighed, but they have got to do what they have got to do."* Lindsay

**'I'm already healthy'.** Numerous women described themselves as already healthy, eating healthily and exercising in the recommended way. They were happy with the way things were and did not see a need to address weight management. Some therefore felt professionals could offer them no further advice and found it difficult when professionals assumed that their obesity was due to current unhealthy eating.

*"Some people are quite happy being the way that they are, and they don't necessarily feel like they need to change."* Samantha

*"It was very much assumed you must be eating too much or you must be not moving enough. But actually, I'm more active in pregnancy and I'm eating healthier in pregnancy because I'm focusing on the baby."* Natalie

It was however noted that the diets several women described as 'eating healthily' didn't appear to fully fit current healthy eating recommendations:

*"Well jacket potatoes, tuna pasta, do you know what I mean. I don't really like salad or vegetables you know what I mean just healthy food."* Joanne

## Getting information

Women described a lack of information provision during their pregnancy, confusion when inconsistent information was given and the information they would have liked to receive.

**Lack of specific practical advice.** Information provision experiences differed between women. Many reported receiving no information regarding weight management during their current pregnancy. When probed further some of these had received information, however information provision was minimal for example just being handed a leaflet or being told verbally the foods they should or shouldn't eat while being pregnant. This information was usually provided at the booking appointment alongside a plethora of other information and women therefore felt the information was 'glossed' over or it remained in a pile of unread leaflets. This had led to the impression that they had received nothing.

*"I have been given leaflets about weight, but I've just gone home and then I've put them on the side and just well obviously they're still in the pile."* Joanne

Those who had received information mainly received it from their community midwife, with two women with gestational diabetes also receiving information from a dietician and another couple of women at a hospital midwife appointment. Examples of information provided around healthy eating included the eat well plate; advice to eat fruit, vegetables, wholegrain foods or complex carbohydrates; advice around portion sizes; avoiding snacks and too much sugar; discussions around iron rich foods; not to try to lose weight during pregnancy and to eat 'everything in moderation'. Very few women received information on exercise during pregnancy and where they did, it consisted of being told to walk, swim or use the treadmill at the gym.

*"I've also noticed that this time round there's not been a lot of information on your group exercises. Like before they'd tell you . . . aqua aerobics or stuff like that and this time I've not*

*really had that. So I think for women in general I think they need that information of what they can do, where they can go."* Rebecca

Women wanted specific advice such as menu ideas, meal plans or exercise plans rather than having to try to work out for themselves what would be beneficial for their body and the baby. Women also wanted practical advice on weight gain in pregnancy, especially what target weight gain they should aim for and how to achieve it. Several women had found USA recommendations regarding gestational weight gain on the internet; but were unsure if those guidelines were the correct ones for them to follow.

*"A meal plan, like a weekly example . . . meal ideas and meal plans, so you know you can follow."* Claire

*"For me the weight gain is important because I'm big anyway, so I want to know how much you're going to gain or what's going to make you gain. So you can then work on right well if that's what I'm going to gain then I need to cut down and do more exercise."* Rebecca

*"They don't tell you what's the average [weight gain], like what's a good weight gain, what's a terrible weight gain, . . . what's going to make things difficult. It was very much a right you are overweight already, there's not much else we can do . . . It wasn't like a how can we prevent you gaining too much weight that it then becomes difficult for you to do anything?"* Chloe

While women wanted practical information a few women felt that professionals could only really offer general advice. The guidance that pregnant women should not lose weight or go on restrictive diets, prevented specific support being provided.

*"I think sometimes when it comes from like a professional, there's not really that much that they can offer, or that's how it feels, because I don't think much can be done to a certain extent but it's just advice isn't it."* Alice

For many women the times they were weighed were seen as a missed opportunity to discuss progress and offer weight management advice, as all too often the professionals just noted down their weight with no discussion. Women appreciated being encouraged when their weight gain was minimal or being provided with practical examples of things they could do about excess weight gain such as eating foods that were more filling to reduce the requirement to snack. Instead, they often felt that professionals overlooked their success during pregnancy.

*"With my community midwife . . . she will tell you how much you have put on and whether that's good, bad, maybe slow down, maybe you need to eat some more food. Whereas here they just sort of write it down and nobody discusses nothing."* Chloe

*"I lost over a stone between Christmas and new year because I was poorly. No-one seemed to really acknowledge any of that. It was just really odd."* Michelle.

*"My midwife, she's been very encouraging in the fact that I haven't put on much at all, she's been really . . .you know encouraging me just to stick with whatever I'm doing."* Natalie

For some the information they received during this pregnancy was deemed adequate because of the advice they had received during previous pregnancies. They therefore felt advice should be offered more intensively to first time mothers with optional sessions for subsequent pregnancies, as some felt it took a while to become familiar with the new concepts introduced.

*"If this was my first pregnancy and I didn't go there [specialist clinic] I wouldn't know, I wouldn't know what foods would be good for me and the baby. I wouldn't know what sort of exercises to do, because that's another thing that she told me about."* Rebecca

Inconsistent advice. Clear information that was consistent between professionals was received by some of the women. However, many experienced inconsistencies in information, for example healthcare providers telling women that the information received from other healthcare providers was incorrect or differences in the information found in online parenting forums among women from different geographical areas of the country. One woman even reported feeling that she had to explain to a professional the policy of referring women with a raised BMI to consultant led care. It was felt one consistent set of information would be helpful to avoid women feeling confused as to what was correct.

*"I think it's just a case of consistency across everybody. So that everybody is . . . reading from the same book. I am getting information from one side and information from another side . . . and then they don't talk to one another. So it's [this] one information–[that] one lot information, that never even matches up."* Chloe

Women also found it difficult to work out what to do when professionals told them to eat healthily but not to lose weight and to allow themselves treats. It left them uncertain of what actions they should actually take.

*"I think you're between a rock and a hard place to be honest . . . They advise you not to diet but to eat healthy but to still treat yourself and you're kind of like, what do I change?"* Alice

**The support I would like.** Electronic resources were particularly desired where women could access clear information at their own pace, rather than feel overwhelmed by information during appointments. Many women reported finding information for themselves online or through apps anyway, for example healthy alternatives to cravings and weight gain guidance, but often wished they had found such information earlier on in their pregnancy.

*"A website that they can go on and look because most of the time when you're in your appointments everything just kind of goes in and then you forget certain points of things."* Laura

Feeling socially isolated was also reported, with some women wishing for a group with other women who were larger like them.

*"I found that there's not many big girls to talk to, that kind of thing. I always felt I was on my own, that there were a lot of smaller women around in the clinics and . . . it felt like you were a bit on your own."* Claire

Women felt weekly group support where their progress could be monitored would be beneficial; particularly peer support groups where others could share their encouraging stories, rather than just professionals discussing information leaflets. Several women felt that their attendance at a commercial weight management group, which had adapted healthy eating plans for pregnancy, had been invaluable for getting advice and in providing support for sticking to a healthy diet. A desire was also expressed by some women to be informed about forums for women with similar pregnancies where they could offer each other support and advice.

*"If you're in an environment where you've got support from other people who are going through it as well or, like, they share their success story. Rather than just maybe sitting at a desk and . . . having a midwife, like, just hand you a leaflet showing you what you should be eating and what you shouldn't be eating."* Samantha

A few women however voiced that they would not have the confidence to attend group sessions where their weight would be discussed in front of others.

*"Some people aren't confident being around other people with their weight issues as well, like me."* Emma

## Difficulties I face

**Pregnancy challenges.** Cravings during pregnancy were a struggle for many women as it was recognised that they craved unhealthy foods. Women wanted more advice on how to control these and appreciated times practical guidance had been given on healthy ways to obtain the nutrients craved. One woman had sought this information for herself, finding out what vitamins or minerals the craving may indicate she was lacking and finding healthy alternatives to meet this need.

*"I've got a huge thing for pork, so I'm just constantly eating, bacon and sausages and pork chops and ham and that's my main protein source I think at the minute . . .. I've always quite enjoyed bacon, but not as much as literally every day I have to have a bacon bagel."* Natalie

*"This time I've not craved sweets and chocolate and stuff like that, it's been the opposite really . . . It's made it loads easier."* Joanne

The common 'eating for two' myth was endorsed by many women's peers or families. While many knew it was not true, others wanted more concrete information and explanation to help them to follow correct advice.

*"You hear it from people, oh it's okay you can have that extra cake because you're 'eating for two'."* Laura

*"I suppose that they do always try and say, you know, like, try and reduce your BMI, eating healthy, don't do all this 'eating for two' kind of things, which I definitely did in my first pregnancy because sometimes I think you might—you're just a bit oblivious to it or a bit naïve towards the information that they're giving you and the reasons why they give it you."* Samantha

Other women found it emotionally difficult to address weight management while pregnant as they knew they would gain weight as their baby grew. Others described finding it just too difficult to think about a strict diet while pregnant. Furthermore, women noted weight management was difficult due to excessive tiredness in early pregnancy, needing to eat during the night due to hunger and difficulties in exercising when advanced in pregnancy.

*"It's hard isn't it in pregnancy especially when you get further on, I think you get a bit lazier don't you and you get bigger and you're not exercising, you're sitting a lot."* Joanne

*"I say it's [watching weight's] one of the last things I wanted to really focus on, having to like be strict with diets, especially with having a toddler as well."* Laura

**Practical considerations.** Many women were unaware of community-based services that they could access while pregnant to support them with healthy lifestyle and weight management. Furthermore, one woman who was aware of such groups reported barriers to accessing them as she was told pregnant women could only access the group if they were already members prior to pregnancy.

Women also voiced difficulties with eating healthily due to personal taste and difficulty in accessing fresh rather than convenience food, especially in deprived areas. Time pressures with a young family or when trying to work were also noted to restrict their ability to access social support groups, exercise activities or healthy eating. However, those with young children noted they were more active than in previous pregnancies as they had an active child to follow around or needed to be physically active to undertake the school run.

> *"I do confess I am not a healthy eater because I don't like veg."* Lindsay

> *"Now with the school run and I've got my little one who's not in his pushchair no more, he wants to go for walks so now I've got the extra time I'm just out and about more."* Rebecca

**Financial difficulties.** Financial constraints were also discussed, particularly the cost of buying healthy foods especially if they had to consider their whole family and not just themselves.

> *"It's hard being healthier anyway because I mean if you've, if you have a family, fruits not cheap . . .if you have got to eat seven a day or five a day now like, but it's not cheap to do that."* Lindsay

Women also voiced that finance restricted their attendance at commercial weight management groups, especially given the emotional difficulty of paying out money to see themselves gain weight. More co-operation between hospital Trusts and community commercial groups was desired for example offering free sessions to women during pregnancy. Impending maternity leave made financial matters even more pertinent to some women.

> *"I know that I did stop going to Slimming World to pay to weigh because for me it was disheartening paying £5 every week when I know that it's going to say that I'm gaining weight."* Samantha

## Encountering professionals–a mixed experience

Women wanted to be treated with sensitivity when discussing weight management. However, there was a fine line for professionals with women describing both too much and too little focus on the issue. In the future, how advice is provided was considered more important to women than by whom.

**To be treated with respect and sensitivity.** The way some professionals talked to women made them feel uncomfortable, patronised and stigmatised due to their weight. Being spoken to in a demeaning or judgemental way made women feel worse. In contrast a professional's positive attitude was appreciated by women and enabled them to think about making changes.

> *"I just find it quite judgemental here. Very judgemental here . . . Everything is revolved around me being heavy. And it's always, always spoken about. That it's kind of like well this isn't a new risk factor*!*"* Michelle

*"I know obviously when people are overweight or whatever it carries a stigma with it, but I think the way that people speak to you and the way it comes across, it should be looked at more, if you know what I mean, because if someone's awful to you and they say it in a negative way you're going to leave . . . feeling like crap. Whereas if someone talks to you really nicely and just says look you just need to do this or whatever then you don't really like worry about it as much."* Alice

All too often women also felt their concerns were dismissed and they were not listened to. They felt policy was frequently adhered to in a rigid way without listening to or addressing women's concerns or viewing the woman as an individual. Women also reported questions they had around the risks of being obese while pregnant or how to mitigate these risks were left without clarifications.

*"I don't seem to get listened to about that [questioning a policy] which is really frustrating."* Michelle

Professionals were appreciated when they were friendly, interested, sensitive, encouraging and had time to listen, explained things well, answered women's questions or concerns and provided non-judgemental information. Good communication between the woman and the healthcare professional and between different healthcare professionals helped women to feel supported. Health professionals were especially valued where they were committed to help the woman achieve a good result, for example through positive reinforcement of the healthy changes the women had made or wanted to make.

*"I sat and spoke to the Dietician, she gave us pointers of what kind of food to avoid and how much to eat of it which, she was really quite friendly and helpful."* Claire

*"I didn't feel uncomfortable, it was really relaxed and it was just nice to talk to someone that wasn't patronising or looking down at you."* Rebecca

**Treading a fine line.** Women reported simultaneously not receiving enough information around their weight, but also that too much focus was placed on it. Women described excessive focus on the risks associated with their raised BMI during pregnancy along with their need for consultant led care during pregnancy. These risks were often discussed at every appointment, leaving them upset and worried. Moreover, women felt frustrated when these risks were highlighted without any practical advice regarding eating, exercise or weight management. Women also reported feeling that healthcare providers assumed that they would have all of the complications associated with a raised BMI.

*"It's consideration of how that person might be feeling. I was already quite nervous and when you are coming all the time hearing like risk, risk, risk, it doesn't help. It really doesn't."* Michelle

*"When I was going [to appointments] I was like right here we go again and you knew what they were going to say before they said it, but at the same time they didn't really give you any information in regard to changing anything . . . it was more kind of . . . that I was overweight not the fact that you needed to do anything or anything like that."* Alice

*"I find it quite amusing when I go for my appointments and it's always the same midwife that sees me, there's always an element of surprise when they take my blood pressure, oh, oh it's*

*perfect, it's very good. It's like they expect because I'm bigger that my blood pressure is going to be too high."* Natalie

After having a scan suggesting the baby was putting on weight rapidly one woman reported:

*"They were like you have got to go, you have got diabetes because you are so big, you have got to go and get this checked, and I haven't. But that's how it was attributed, that there must be something physically wrong with me because I am big . . . I just felt really bad when I left, . . . it kind of makes you feel quite deflated. . . . Quite anxiety raising."* Michelle

This constant raising of weight as an issue meant some women felt like not attending further antenatal appointments. This was especially reported when women saw different people at every hospital appointment, with each new individual repeating the same information around the risks associated with a high BMI.

*"I think in the first pregnancy they were a lot, kind of, more forceful with it, in letting you know . . . Every appointment it was brought up and it really kind of upset me the first time . . . to a point where I was saying to my partner they should have, like, something on your chart that says you've discussed it. You don't need to hear it every time you go because you already know. You're aware that you're overweight, you don't need somebody to tell you at every appointment, which they did."* Alice

In contrast women reported that some professionals wanted to avoid the issue, either not wanting to talk about weight or assuming the woman didn't require support. This was especially difficult when women themselves reported finding it difficult to ask for help, so appreciated professionals proactively addressing weight management and making them aware of different options available. One lady who received more intensive support in a previous pregnancy really missed this additional advice in her current pregnancy.

*"I found xxxx [current] hospital to be a lot more helpful towards me, whereas xxxx [previous hospital] just left me to it."* Zoe

*"I've missed the advice and the encouragement because . . . in this one [pregnancy] I've not really seen a lot of people this time, it's like they've just let me get on with it . . . I was quite a bit . . . gutted I guess that I wasn't transferred there [maternal obesity service]."* Rebecca

Many women felt the focus of maternity care appointments was on the health of the baby. They longed for more focus on them, to reassure them that they were gaining the right amount of weight and to provide advice so they could create the best environment for their baby.

*"Nobody seems to really give a toss that I've been so poorly . . . They just kept saying well the babies still gaining weight, so you are okay, that's all they kept saying."* Michelle

*"I think it's got to be a 50/50 where you're being looked after as well as your baby. We know your baby's fine, we know that, but what about the mum?"* Rebecca

**How not who.** Given the difficulties they had previously encountered, in the future it mattered more to women how weight management was approached than who provided advice. Women desired weight management advice from someone with whom they could establish a relationship and who could follow their progress. For many women the ideal person to do this was their community midwife whom they developed a bond with throughout pregnancy. Women felt that community midwives knew them as an individual and listened to their concerns. For others they would also be happy to have weight management discussed by dieticians or health visitors or other professionals such as commercial weight management group consultants. People who had achieved effective weight management themselves were considered to be the best people to offer advice.

> *"The midwife actually I find that I have a good bond with her, I trust her opinion. And if she were to suggest something to me, I would take it on board."* Zoe

> *"I think I just feel like maybe the Slimming World consultants, especially if they've experienced it themselves, they're the best people to give you the advice."* Samantha

## Discussion

This study highlighted women with a BMI≥40kg/m$^2$ felt there was too much emphasis placed on the potential risks that they faced during pregnancy, which left many feeling anxious and stigmatised by healthcare providers. Women also reported receiving inconsistent information with insufficient provision of clear practical advice. Furthermore, women were all at different stages of readiness to address weight management during their pregnancy.

Within this study women reported an overemphasis on the risks associated with being obese during pregnancy. Current United Kingdom (UK) National Institute for Health and Care Excellence (NICE) guidance [24] recommends women with a BMI≥30kg/m$^2$ should be advised of the risks of her being obese during pregnancy for both the health of the mother and her infant. However, it appeared that this guidance led some women within this and previous studies to describe that their weight and the associated risks were focussed on repetitively [38,39] rather than receiving clear information on what to do about it. Others have particularly noted an emphasis on the risks for women with a BMI≥40kg/m$^2$ [38]. Furthermore, women described that because they were at increased risk it was assumed that they would experience all of the associated complications [40–42].

Health services' focus on risk management, rather than taking individual factors into account, coincides with an increasingly prevalent medical model of care for these women. This model views pregnant women with obesity as needing to be 'managed' by obstetricians [43,44], as professionals becoming progressively interventionist in an attempt to protect themselves from litigation should an adverse outcome occur [45]. However, this focus on risk is at odds with women's own focus, as clinical outcomes only cover a subset of the factors they consider to be important during pregnancy [46]. A systematic review of patient reported outcomes has shown that women with obesity viewed adequate healthcare provider support and an emphasis on their emotional wellbeing as key elements of care [46]. A move towards a social model of maternity care is argued for which integrates women's physiological, psychological and spiritual wellbeing; with women and professionals working in partnership to support women to focus on health promoting activities [44]. The social model views the three most significant factors for women during pregnancy and childbirth to be choice, continuity of care and control [47], with maternal satisfaction an important outcome of pregnancy, not just a live, healthy mother and infant [48].

Treating women with a raised BMI as 'high risk' and in need of additional monitoring or prevented from accessing certain options such as having a waterbirth can increase their feelings of stigmatisation [41–43,49]. Stigma itself has been associated with poorer maternal health behaviours, mental health and stress, all of which have a negative impact on infant outcomes [50]. The stigma women face has also been identified as an issue within almost all of the previous studies and reviews read [28,38,40,49,51–58]. Stigma is particularly perceived if women feel weight management advice is offered solely due to their size not due to their need [43] or when professionals assume that obesity is due to a current lack of exercise or poor eating habits [39,40,53,55]. Despite evidence showing that BMI does not provide a full picture as it cannot differentiate adipose tissue from lean body mass [59], health professionals still place an over emphasis on BMI alone. Furthermore, it has been shown that it is possible to be 'fit and fat', with fitness being more important than fatness for long term prognosis [60]. Of note however is that women felt equally dissatisfied with the care they received when healthcare professionals avoided the topic of weight. Others too have noted this to be an issue due to professionals' worry about women's potential sensitivity and due to their own discomfort about addressing weight [28,39,51,52,56,61,62]. A lack of change in the concerns that women have highlighted regarding stigmatisation over the last decade emphasises how essential it is for enhanced healthcare providers' training, to raise their confidence to discuss weight with women and to approach weight in a way that avoids stigmatisation.

This study has highlighted the lack of uniformity in the care that women with a BMI≥40kg/m$^2$ received around weight management during pregnancy, even within one hospital Trust over a short period of time. While a few received good information around healthy eating, physical activity and weight management during pregnancy, the majority of women described inadequate information provision. The lack of consistency in advice may in part be because of a lack of clear national guidance, as well as due to limited resources. The emphasis on risk without concurrent provision of practical advice noted in this and other studies, left many women feeling dissatisfied, disempowered and feeling guilty about their weight and the implications this may have on the outcomes of their pregnancy [49,51,55,62]. Women's information needs around weight management during pregnancy not being met by healthcare professionals has been a recurrent theme within the literature among women with obesity [28,38,52,54,56,61]. A lack of information around gestational weight gain has been particularly evident [39,51,52,54] especially in areas without a bespoke weight management service [38].

The information many women described wanting was clear, practical, consistent advice that incorporated clear strategies for them to implement, not just telling them of the things they shouldn't do. Others too have found women with obesity to want constructive advice, for example around the contents of a balanced diet [62], specific nutritional components required during pregnancy [53] or how to manage common pregnancy conditions such as morning sickness and cravings [51]. In contrast both in this study and others, some women reported feeling that they received no new information from professionals around weight management [43,55,62]. While the focus of professionals was on adhering to policy and advising women of the risks associated with being obese during pregnancy, women's focus was more on their individual needs and on their requirement for practical advice. As a result, women frequently perceived that their informational and support needs were inadequately met by professionals. Provision of information tailored to the individual woman's needs is therefore essential.

Many of the women who had previously had a baby voiced regret for the choices they had made in their earlier pregnancies, only realising in retrospect that it was inadvisable to 'eat for two' during pregnancy and that the excess weight gained in pregnancy would need to be lost after the birth. This is supported by evidence that primigravid women with a BMI≥40kg/m$^2$ gain significantly more weight than multigravida women [17]. Many women have also been noted to almost double their calorie intake during pregnancy [63]. The difference in information needs between first and subsequent pregnancies was recognised by several women. One parous woman was very grateful that she had received support in her first pregnancy even though she had not received the same support during her current pregnancy and others raised the potential requirement for more intensive information provision during the first pregnancy.

A further theme identified within this current study was 'where I am at' depicting the need to respect women's previous weight management attempts and the influence they may have on her readiness to accept or enact advice provided during her pregnancy. The continual focus for women outside of pregnancy had been around losing weight, the change in advice to not losing weight during pregnancy but minimising weight gain left some women uncertain of what they could or should be doing. Others too have recognised that women often have a long history of trying to manage their weight [38,39,52,53,55]. The majority of the studies we reviewed that reported this aspect were noted to have included either exclusively or a high proportion of women with a BMI$\geq$40kg/m$^2$. Of interest was that some women, both in this study and in previous research, defined themselves as healthy. For example, women have described following healthy eating advice such as eating fruit and vegetables or running 10 km; emphasising these healthy aspects as countering the risks of obesity during pregnancy [42,43,51,55]. This further highlighted the need for individualised care and sensitivity when providing advice, without automatically assuming that current energy imbalance is the cause of the woman's obesity. Furthermore, several women within this and previous studies have described being unable to think about their weight during pregnancy due to feeling that weight gain was inevitable, but they had plans to address weight management in the postnatal period [52,54,55,58]. A lack of focus by healthcare providers on the postnatal period has however been shown, with pregnancy weight management support ceasing once the baby is born [38,55]. Assisting women to address weight management in the postnatal period could help to reduce their BMI prior to any subsequent pregnancies. This is essential given that pre-pregnancy BMI has been shown to be a stronger predictor of adverse outcome that gestational weight gain [64].

Historically pregnancy has been viewed as a 'teachable moment' for women due to changes mainly in their motivation, related to their concern for the developing fetus's health [21]. Women's frequent contact with health professionals during pregnancy also provides an opportune time to deliver health promotion [21]. The COM-B model however sees behaviour as having three determinants not just from motivation, but also capability and opportunity [35]. Furthermore, the socio-ecological model views multiple factors influencing behaviour including the personal, organisational, community and public policy [36]. This research clearly showed that while some women were motivated during pregnancy to change their lifestyle, not all women were personally motivated simply because they were pregnant. Women's motivation could also be impacted at an organisational level, if they felt stigmatised or unvalidated by healthcare providers. Women's psychological capability to achieve weight management during pregnancy was decreased due to inadequate information provision, in part because of healthcare providers lack of knowledge and skills leading to their avoidance of conversations or the provision of inconsistent information at the organisation level. Barriers were also noted to the women's physical capability due to personal factors such as the associated tiredness and cravings in pregnancy, but also due to inter-personal factors such as lack of childcare. Women's physical opportunity to achieve weight management during pregnancy was impacted personally by financial and time constraints, but also at the community level due to a lack of access to healthy foods or suitable support groups. This study also emphasised the influence on women's social opportunity to achieve weight management during pregnancy especially from organisational factors that resulted in inadequate provider interactions and stigmatisation. Additionally at the policy level an over emphasis on providing information about the risks and a lack of gestational weight management guidance was also detrimental to women's successful weight management.

The multi-factorial barriers identified within this research highlight the complexity of weight management in pregnant women with a raised BMI. While previous research has mainly concentrated on the woman as an individual, the need for a wider systems approach for effective management of obesity during pregnancy has been shown [65]. This requires a focus not just on the woman but also on wider organisational, community and policy factors that can impact on a women's ability to achieve weight management [65]. Moving forwards, to better address the complexity, a better understanding of women's motivation, capability or opportunity to change their behaviours during pregnancy is also required [66]. This necessitates a recognition of the competing demands on a woman's attention during pregnancy, including financial, emotional and other health promotional activities [67]. Furthermore, women need support to implement the advice given [28,43] rather than assuming that education alone leads to behaviour change [68], as the majority of women with overweight or obesity indicate that they would like to make diet or physical activity related behaviour changes during pregnancy but only half feel confident to do so [69]. Providing women with a better understanding of the psychological and social context of their eating is essential to achieve this [43]. Furthermore, the amount of control each woman feels she has over her weight requires exploration, alongside her motivation to change [51] so that tailored support can be provided to women on how to implement advice that is given.

## Strengths and limitations

This study exclusively recruited women with a BMI$\geq$40kg/m$^2$, whose voices are frequently missing within the literature around weight management during pregnancy. Several limitations were however acknowledged including that the women were only recruited from one setting and that while the sample was representative of the local population, with all women being from a White background, the views of women from other ethnicities were therefore not provided. Furthermore, six women who initially expressed an interest could not be followed up, although this is not too surprising given the proximity of all women to the due date of their baby when approached. Finally, the women who consented may have held stronger views on weight management services during pregnancy than the population in general.

It was ensured within the research that the interviewers were not involved in the women's care in any way. As part of the process of reflexivity, which is essential in qualitative research since no research occurs within a vacuum [32,33] it was noted that the researcher who undertook the face-to-face interviews was a health professional with a BMI in the normal range. This may have influenced what the women themselves felt comfortable with sharing during the interviews.

## Implications for policy and practice and research

Weight management services during pregnancy need to be sensitive, respectful and centred on the individual woman and her current and previous experiences to reduce the stigmatisation that many women currently feel. To empower women, services should particularly focus on the provision of practical information, however this should not simply become a 'tick box' exercise. Information provision should follow a personalised approach that identifies and adapts to each individual woman's information needs. To effectively achieve this and to enhance professional's confidence around addressing weight management, all professionals require training on addressing the complex psychological and social context of weight for each woman, not just on the additional risks that women with obesity face during pregnancy.

Furthermore, incorporating a range of behaviour change techniques when developing weight management services and focussing not just on individual factors, but other socio-ecological factors such as organisational, community and policy aspects is recommended to cater for women at different stages and with different barriers to weight management [51]. Given the higher weight gain among primigravid women with a BMI≥40kg/m$^2$, it could be argued that there is an additional requirement to focus on their needs. Services should also give more consideration to the advice and support women receive to tackle their weight in the postpartum period. Changes to current UK guidance to balance the focus on risk against practical recommendations is also required to combat stigma within maternity care. This requires further robust evidence of what interventions are effective at promoting weight management during pregnancy, particularly among women with obesity and within the UK context. A move away from exclusively using a medical, risk focussed, model of care is required to attend more satisfactorily to women's individual needs.

## Conclusions

Women with obesity brought into pregnancy their history of past efforts at weight management which impacted upon their current motivation to engage with weight management advice. Services therefore need to be centred on individual women's needs. Professionals faced a challenging task to ensure that women received adequate information without leaving them feeling stigmatised. Advising women of the risks associated with obesity during pregnancy left women feeling disempowered, unless there was concurrent provision of clear and consistent advice regarding healthy lifestyles and appropriate gestational weight gain.

## Supporting information

**S1 File. Interview schedule.**
(DOCX)

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## 8.5 Summary and implications for thesis

This chapter has presented the qualitative phase of the programme of research. It explored women's experiences of weight management during pregnancy and the barriers and facilitators they experienced to weight management.

The findings showed that women were at different stages on their weight management journey, with some already trying to manage their weight and others not feeling a need to address weight management. They described facing physical, financial and emotional barriers to achieving weight management during pregnancy. Women found that healthcare providers frequently highlighted the risks they faced during pregnancy due to their obesity, however healthcare providers often did not provide them with practical advice of what they could do to mitigate those risks. This left women feeling stigmatised and confused.

This chapter raises issues that need addressing within future interventions for them to be more effective and ensure women are not stigmatised. This includes ensuring clear practical advice is given and considering group sessions where women can meet others to prevent them from feeling socially isolated. Some of the inter-related barriers to weight management that women face including financial, social and environmental factors also need addressing in future interventions to enhance effectiveness.

The following chapter aims to demonstrate how the original aims have been answered within the programme of research. It also considers the findings across all aspects of the programme of research and integrates them into some overarching findings.

# Chapter 9: Integration of the findings

## 9.1 Introduction

This thesis has presented an overview of systematic reviews of lifestyle interventions for GWG management in women with overweight or obesity, followed by four original research articles; three quantitatively evaluating an antenatal healthy lifestyle service for women with obesity and one exploring the experiences of weight management during pregnancy among women with a BMI ≥40kg/m².

This chapter begins by returning to the original research aims and demonstrates how they have been answered within this programme of research. The chapter then synthesises the findings from the systematic review, and the quantitative and qualitative components. As discussed in the methodology chapter (Chapter 4), a sequential explanatory mixed methods design was followed. Within mixed methods research the quantitative and qualitative data are analysed separately to answer the research question[(308)]. Within this research, priority was given to the quantitative components. The qualitative component then expanded upon the quantitative findings. The findings were then compared, contrasted and integrated across the different constituent parts of the research to create an overarching answer to the research question[(308)]. The integrated findings are presented within this chapter.

## 9.2 Review of the original aims

The original aims of this programme of research were to address some of the gaps identified within the literature. Specifically, these were:

- To establish from the current research literature the effectiveness of lifestyle interventions for women with overweight or obesity for reducing GWG and other adverse outcomes for the mother and the infant.
- To explore the impact of a service supporting women with the highest class of obesity to achieve adequate GWG and improve maternal and infant outcomes.

- To investigate the association between providing a weight management service to women with a high BMI during pregnancy and long-term child weight outcomes.
- To explore the experiences of weight management during pregnancy among women with the highest class of obesity.

These aims have been addressed throughout this programme of mixed methods research. How each has been addressed is discussed below.

*To establish from the current research literature the effectiveness of lifestyle interventions for women with overweight or obesity for reducing GWG and other adverse outcomes for the mother and the infant.*

The first aim was met through the overview of systematic reviews (Chapter 3). This concluded that current lifestyle interventions among women with overweight or obesity are effective at reducing GWG, but only by a minimal amount of between 0.3kg and 2.4kg. The clinical significance of this reduction was however questioned, due to the lack of clear benefit of lifestyle interventions on maternal and infant adverse health outcomes.

*To explore the impact of a service supporting women with the highest class of obesity to achieve adequate GWG and improve maternal and infant outcomes.*

This aim was addressed through two separate analyses. The first in Chapter 5 compared one visit at an antenatal healthy lifestyle service to an enhanced offer of three visits at the service. The second analysis in Chapter 6 compared the antenatal healthy lifestyle intervention to a comparative cohort of women in the neighbouring Trust who were not offered the antenatal healthy lifestyle service. Being offered three visits at the antenatal healthy lifestyle service was generally ineffective at reducing GWG when compared to both one visit and no service. Additionally, except for an increase in the proportion of women breastfeeding at discharge compared to the neighbouring Trust no beneficial clinical outcomes were noted, with the potential that the antenatal healthy lifestyle service may have made outcomes such as rate of Caesarean births poorer compared to the Trust with no service.

*To investigate the association between providing a weight management service to women with a high BMI during pregnancy and long-term child weight outcomes.*

This aim was addressed through matching data from the pregnancy records with data from health visitor records and the National Child Measurement Programme (Chapter 7). This concluded that there was no effect of attending the antenatal healthy lifestyle service on child overweight or obesity at 6-8 weeks, 9-12 months or at school entry.

*To explore the experiences of weight management during pregnancy among women with the highest class of obesity*.

This aim was addressed through the qualitative interviews with women with a BMI ≥40kg/m² (Chapter 8). These interviews showed that women felt too little emphasis was placed on providing them with clear, consistent advice regarding healthy lifestyles and appropriate GWG especially with regards to practical advice. This left women feeling disempowered. However simultaneously women described too much focus on the risks that being obese during pregnancy may pose. As a result, many described feeling stigmatised and dreaded attending antenatal care appointments.

## 9.3 Integration of the research findings

The key findings of this programme of research were the limited impact of antenatal healthy lifestyle services, the importance of socio-demographic context, the role of parity and the influence of stigma and therefore the need to refine interventions. Each of these integrated findings will be discussed below.

### 9.3.1 Integrated finding 1 – Lack of impact of antenatal healthy lifestyle services

The effectiveness of any intervention aimed at managing GWG or promoting healthy lifestyle in pregnancy is essential. The first integrated finding was evident across the research components. Results from the overview of systematic reviews of interventions that aimed to reduce GWG showed a small reduction in GWG of between 0.3kg and 2.4kg within the different meta-analyses. The results within the quantitative phase were similar. When comparing the impact of the antenatal healthy lifestyle service women receiving the enhanced service gained 0.9kg less GWG than those receiving the low intensity service. Those receiving the enhanced service also gained 0.9kg less GWG than women within the comparison cohort who did not receive an antenatal healthy lifestyle service. In neither instance did the difference in GWG reach significance. Weight gain above IOM recommendations was lower within the enhanced service compared to the low intensity service, however the gestation at which women's final weight was recorded was also lower within the enhanced service, meaning these women had less time over which to gain weight. When using rate of weight gain to account for the differences in gestation at which women were weighed, no differences were evident between the low intensity and enhanced service. Of interest was the lower proportions of women gaining over IOM recommendations than expected, even among those who had received no antenatal healthy lifestyle service.

The overview of systematic reviews also showed no consistent impact of interventions aimed to reduce GWG on clinical outcomes such as GDM, pre-eclampsia, Caesarean birth, preterm birth or birthweight. Within the quantitative phase of the research programme minimal impact of the healthy lifestyle service was also noted on pregnancy, birth and early postnatal outcomes or on longer term child weight outcomes. The only clinical outcome to favour the service compared to the comparison cohort was the increased rate of breastfeeding at discharge from hospital. While macrosomia was also reduced with the antenatal healthy lifestyle service, this was mainly due to differences in gestation at birth, with no differences noted in the proportion of infants born LGA.

The lack of clinical impact of current healthy lifestyle interventions during pregnancy, especially on clinical outcomes is an important overarching theme within this research.

### 9.3.2 Integrated finding 2 – The importance of socio-demographic context

Within the quantitative research component, fewer women with a BMI ≥40kg/m² were in the most deprived quintile in 2012-2015 compared to 2009-2011. While the most extreme forms of obesity had therefore become less related to deprivation over time, over 50% of women booking for pregnancy with a BMI ≥40kg/m² between 2012 and 2015 were still within the most deprived quintile. Women who were from the most deprived quintile were also less likely to attend the antenatal healthy lifestyle service. Additionally, when considering other factors closely related to deprivation, women who smoked at booking or whose highest household occupation was in the housewife, unemployed or student category rather than employed were also less likely to attend the antenatal healthy lifestyle service. Within the long-term child weight outcomes, deprivation per se was not significantly associated with childhood overweight or obesity once controlling for other confounders. However, women from households with some form of employment were less likely to have a child with obesity and women who smoked when booking for pregnancy care were significantly more likely to have a child with severe obesity by school entry, with a trend also towards being more likely to have a child with obesity at school entry. The difficulties of achieving a healthy lifestyle among women from deprived backgrounds was further highlighted within the qualitative research. Women talked about the competing demands they faced financially. Finance acted as a barrier to buying healthy foods which were seen as more expensive. Additionally, it prevented some women from accessing commercial support groups such as Slimming World due to the cost implications.

This therefore highlights the need to look not just at the individual when developing interventions, but at the wider social context.

### 9.3.3 Integrated finding 3 – The role of parity

The differential impact of lifestyle interventions according to parity was another integrated finding across the different research components.

Within the quantitative analysis comparing the enhanced antenatal healthy lifestyle service to one service visit, subgroup analysis revealed that parous women had a lower average GWG than nulliparous women. Parous women also had a significantly lower proportion of women with GWG above recommendations and a significantly reduced rate of weight gain with the enhanced service. Additionally, after adjusting for confounding factors parous women had fewer infants born SGA with the enhanced service. Long-term follow-up also suggested that once controlling for other factors, women with three or more children were less likely to have a child who was overweight by school entry than women with just one child. Evidence from the qualitative phase further supported differences between nulliparous and parous women. Women talked about being naïve during their first pregnancy, voicing regret over gaining too much weight that they needed to lose again afterwards. This made some women more determined not to gain excessive weight during their subsequent pregnancies. Several women also recognised that they needed more information around achieving a healthy lifestyle during their first pregnancy. They therefore felt services should focus on nulliparous women, with additional optional input available for parous women. This was also evident within the quantitative findings as nulliparous women were significantly more likely to attend the antenatal healthy lifestyle service than parous women.

### 9.3.4 Integrated finding 4 – The influence of stigma

The influence of stigma was another integrated finding to emerge from this research. Within the qualitative research some women described supportive encounters with healthcare providers where these professionals helped women to achieve a good result in terms of their weight management. They were appreciated by women. In contrast many women described feeling stigmatised and judged by professionals. This included when the risks of obesity were continually repeated by multiple healthcare providers throughout pregnancy without any practical support or advice on how to mitigate the risks. There was also an assumption by some professionals that women would get all of the complications associated with obesity during pregnancy. Additionally, some women perceived professionals to be dismissive of their concerns. Other professionals completely avoided the issue of weight during pregnancy. It was clear from the qualitative research that this component of feeling stigmatised cannot be ignored if professionals are to provide effective care during pregnancy and to develop successful interventions.

### 9.3.5 Integrated finding 5 – The need to refine interventions

The final integrated finding is a culmination of the previous integrated findings, revealing a need to refine interventions. This integrated finding covered the three aspects; the components that need to be incorporated into interventions, the timing of interventions and the format of interventions.

#### 9.3.5.1 Intervention components

It was clear within the overview of systematic reviews that current interventions aimed at reducing GWG are very heterogenous. For example, healthy eating interventions offered women between one and 16 dietary sessions lasting between 5 minutes and 2 hours. Similarly, physical activity could simply be providing women with a pedometer or generic encouragement to ‘be active’ during pregnancy or could adopt a more structured approach with physical activity sessions offered from once a month to five times a week. It was unclear within many of the interventions included within the overview of reviews what specific behaviour change components the intervention was targeting. Additionally, very few interventions focused on psychological components or on using the behavioural strategy of social support. Within the qualitative research women described wanting, but largely not receiving, very practical advice such as meal plans, exercise plans, weight gain guidance or how to manage pregnancy cravings. Women also noted the importance of encouragement. They wanted their progress monitoring and commented upon so they knew if they were doing well or if they needed to make more adjustments. Co-design of future interventions with women is essential to ensure they are sensitive to women’s needs. The behaviour change techniques they incorporate also need clearly articulating to allow the most effective components of lifestyle interventions during pregnancy to be established.

### 9.3.5.2 Intervention timing

As well as a lack of impact of interventions during pregnancy noted within this research, several factors pointed to the need to address weight management at additional points in time. The long-term quantitative data showed that children born to women with obesity were at greatly increased risk of obesity at school entry compared to the general population. Interestingly, within this cohort of women with a BMI ≥35kg/m², once confounding factors were adjusted for within the multiple logistic regression analysis, increased weight when booking for pregnancy was not associated with any additional risk of childhood overweight or obesity within any of the models. To reduce the risk of childhood obesity it therefore seems that a woman's BMI is ideally reduced to less than 35kg/m² at the start of pregnancy. To achieve this preconceptual or intra-conception interventions will be required. This was further substantiated by women within the qualitative component who described being provided with a plethora of public health information during pregnancy which they could not assimilate. Additionally, it was clear that not all women were ready to consider making changes to their lifestyle during pregnancy, with some women talking about wanting to make changes during the postnatal period. By better considering the place a woman is at on her weight management journey and offering interventions at different points in the reproductive cycle, rather than just assuming that pregnancy is a teachable moment will better enable women to achieve their goals regarding weight management.

### 9.3.5.3 Intervention format

Within the qualitative component many women described wanting contact with other women 'like them' in pregnancy i.e. others with a raised BMI. Many felt this could best be achieved through a group scenario that involved peer support. Women also talked about wanting to have digital resources available to look at in their own time as they felt unable to retain the information that was provided during appointments.

Future interventions must therefore consider multiple additional aspects to address weight management among women with obesity during their childbearing years.

## 9.4 Summary

As described within this chapter, the original aims have been addressed throughout this programme of research. The findings from the different research components have been integrated into five overarching findings. The following chapter will discuss each of these integrated findings in turn, situating them in the wider research literature and evidence base.

# Chapter 10: Discussion

## 10.1 Introduction

As seen in the integration of findings chapter (Chapter 9), five main overarching themes emerged from this research: the limited impact of antenatal healthy lifestyle services on clinical outcomes; the influence of stigma; the importance of socio-demographic context; the role of parity and finally the need to refine interventions. These provide insight into the needs and experiences of women with the most extreme forms of obesity during pregnancy and the impact this has on their own health, as well as the health of their infant. Each theme is discussed below in the context of the wider academic literature and the current knowledge base on the topic. Finally, the strengths and limitations of this programme of research are considered.

## 10.2 Discussion of key findings

### 10.2.1 Lack of impact of antenatal healthy lifestyle services

The findings of this programme of research indicated a lack of impact of the evaluated antenatal healthy lifestyle service, as well as previous randomised controlled trial interventions once synthesised into an overview of systematic reviews. Additionally secondary analysis of the data from this cohort showed that the number of appointments attended at the antenatal healthy lifestyle service was not a predictor of GWG(336).

Three other UK based observational studies have evaluated specialist antenatal clinics, one(337) among women with a BMI ≥30kg/m², one(338) among women with a BMI ≥35kg/m² and the final one(339) for women with a BMI ≥40kg/m².

Only an abstract evaluation of the first service is reported, which was a six-week community based course that 57% of women completed(337). They reported some differences between those who completed and those who did not complete the course, including a higher intake of fruit and vegetables, less sedentary behaviour, and more self-efficacy towards engaging in physical activity, although there were no actual changes in physical activity[337].

Within the second study, women with a BMI ≥35kg/m² were invited to attended midwife-led education around diet and exercise, alongside receiving personal guidance around dietary change[338]. They found average GWG was lower among women who attended the service (4.5kg), compared to women who did not attend (10.3kg), with the most impact among women with a BMI ≥40kg/m² [338]. Those attending the intervention also had a reduction in gestational hypertension and pre-eclampsia and increased rates of breastfeeding at discharge from hospital, but no difference in mean birthweight or prematurity[338]. However, half of women approached about taking part in the education intervention chose not to do so. Women who attended the educational sessions may therefore have been more motivated to manage their GWG, which could explain the significant impact on GWG. It was not however possible to formally evaluate this as data such as motivation, readiness to engage with lifestyle changes or influence of other commitments such as time pressures were not collected[338]. Attendance within the educational intervention study also differed markedly from our study where 27.4% of women did not attend the healthy lifestyle service appointment when offered one appointment and only 8.5% when offered three appointments.

The final observational study evaluated a specialist clinic for women with class III obesity[339]. A limitation of this study however was that women could choose whether to attend the specialist clinic or routine care, resulting in those attending the service having significantly higher BMI and being more likely to be nulliparous[339]. While GWG was not reported, women attending the specialist service had slightly fewer neonates with low birthweight[339]. However, women attending the specialist clinic were also more likely to be screened for and to have GDM, to be induced, to give birth by Caesarean and to require more obstetric triage visits[339]. The differences noted in baseline characteristics however make it difficult to evaluate the specialist clinic service per se.

Further randomised controlled trial (RCT) evidence has additionally been published after the inclusion periods of the systematic reviews incorporated into the overview. Eight additional RCTs of interventions among women with overweight or obesity or with subgroup analysis for those women were found. The additional RCTs were from five different countries including four RCTs from the USA[257,340-342] and one RCT each from Germany[256], New Zealand[343], Sweden[258] and the UK[344]. The majority of interventions targeted both diet and physical activity[256-258,340,341,344], with one just focussing on nutrition and weight gain[343] and the final study stated the intervention was to control GWG but did not provide specific details of how this was achieved[342]. One study also incorporated behavioural strategies to reduce stress[257]. One intervention was largely telephone based[257] and one was app based[258].

The impact of the RCTs on GWG was mainly positive. Three studies found total GWG was significantly lower, with GWG being 1.6kg[340], 2.2kg[257] and 2.68kg[342] less with the intervention. Three studies found no significant difference in total GWG, although GWG was lower in the intervention group within two of these studies, 1.33 kg lower in the first study[258] and 1.7kg lower in the second[343]. Only in one study was GWG higher in women with obesity in the intervention group by 0.9kg[256]. All three studies reporting rate of weight gain found this was significant with two finding the rate of weight gain was lower in the intervention group than the control group[257,340] and one finding the intervention group were more likely to gain the recommended weekly rate[341]. However, when considering GWG in accordance with IOM recommendations only one study found significantly fewer women in the intervention group exceeded recommendations[257] with the other studies all reporting no difference in those exceeding recommendations[256,340,341,343,344].

Several studies considered the impact of the intervention on diet and physical activity. Interventions resulted in changes to maternal diet such as consumption of fewer calories[257], better healthy eating scores[258], more fruit[342], less fat[341,342] and higher fibre in the diet[341]. However, changes in physical activity between control and intervention groups were not seen[257,258,341]. Additionally, one study looked at maternal biomarkers and found no differences between control and intervention groups[258].

Similarly to the previous research, these new RCTs showed limited impact on any clinical outcomes. There were no significant differences between the control and intervention groups in most studies reporting clinical outcomes including in GDM[256,257,340,343], pregnancy induced hypertension[257,340], rate of Caesarean birth[257,340,343,345], preterm birth[257,340,343], stillbirth[343] or admission to neonatal intensive care[340,343]. Additionally, two studies suggested more adverse outcomes in the intervention group. In the first of these studies the intervention group had higher rates of pre-eclampsia, preterm birth and admission to neonatal intensive care, although the significance was not reported[341]. The second study found increased rate of elective Caesarean birth in the intervention group with this difference remaining after adjusting for maternal BMI[256].

When considering birthweight outcomes four studies found no significant differences between control and intervention groups[257,340,343,345]. One final study that included women with a BMI ≥18.5kg/m² found that after adjusting for maternal BMI, average birthweight was 44g lower in the intervention group, however as separate figures were not given for women with obesity it is unclear whether the intervention had a specific impact on women with a higher BMI[256]. No studies found any differences in LGA or SGA with the intervention[256,257,340,343].

This lack of effectiveness of interventions across a range of clinical outcomes is suggested to be the primary reason behind the lack of cost effectiveness of lifestyle interventions to reduce excessive GWG in women with overweight or obesity seen within a systematic review[346]. They found the intervention was cost effective in only one of the six included studies that had considered cost effectiveness[346].

Both this programme of research and other published evidence highlight the continued lack of certainty over the most effective interventions to optimise GWG and clinical outcomes in women with obesity during pregnancy. The lack of effectiveness of interventions during pregnancy at reducing the risks associated with pre-pregnancy obesity such as GDM and infant macrosomia means more emphasis is required on normalising maternal weight prior to pregnancy[40].

### 10.2.2 Stigma/ communication

Within the qualitative aspect of this programme of research women described feeling stigmatised when professionals continually highlighted the risks of obesity during pregnancy without providing clear practical advice on how to mitigate the risks. Women also reported some professionals were dismissive of their concerns. It is essential to understand stigma and how healthcare providers can reduce stigma, both are therefore discussed below.

#### 10.2.2.1 Cause of stigma

Healthcare providers are seen to make assumptions and hold stereotypes about women with obesity. This can include thinking that women with obesity are lazy, lacking will power and self-discipline, unsuccessful, unintelligent, lacking in motivation and unwilling to try lifestyle modifications(347-349). This stereotyping of women with overweight and obesity is a key component of weight stigma(349), with internalised stigma seen as leading to shame(350).

To understand shame and stigma regarding weight gain and obesity in pregnancy an understanding of Foucault's ideas around truth and knowledge are a crucial concept. Foucault viewed knowledge circulated at a societal level to become the dominant discourse(351). This dominant discourse has the power to create 'norms' which shape the way individuals think and act(351). For example, obesity is believed to be self-induced and within the individual's control(352). Women with obesity are deemed to be outside of the social 'norm' of having a BMI in the normal range and considered personally responsible for achieving a recommended BMI(353,354). Additionally, women with obesity during pregnancy are increasingly viewed as responsible for the health of their fetus and a plethora of pregnancy risks(353,354), which they can manage through multiple individual lifestyle behaviours(353). Knowledge is therefore provided by the medical profession, including around the risks of maternal obesity and excessive GWG, to encourage individuals to monitor and change their behaviour(353). This is a form of what Foucault calls 'biopower', where control of the individual's physical body is used to regulate the wider population(355) and individuals are judged by whether they achieve the ascribed 'norms'.

Western healthcare is mainly based on a medical model which emphasises the risk discourse. Pregnancy is viewed as a time where risks must be identified and appropriately managed, with obesity viewed as one of those risks[356]. It is this focus on maternal risks and weight, which lead women to feel blamed for any negative consequences that may arise during pregnancy[349,356]. Indeed, some believe weight stigmatisation in the perinatal period is a direct result of policies that focus on management of women with a raised BMI during pregnancy, birth and postpartum[356,357]. In particular, the increased monitoring and screening for women with a raised BMI during pregnancy, while viewed by some women as reassuring, can also lead to feelings of blame and shame[349,356]. Some women however reject the ‘obesity identity’ portrayed on them during pregnancy, seeming largely unaware of the risk based discourse around obesity in pregnancy[358] or viewing the additional monitoring as an intrusion which they must comply with to prove their ‘normality’[356].

Placing the emphasis on self-management and self-responsibility of obesity however ignores the genetic and biological factors that science has shown play a role in the development and maintenance of obesity[347]. It is also known that once weight is gained it is very hard to lose, as the body resists attempts at weight loss, with weight regain common after lifestyle interventions[359]. Additionally, viewing obesity as the personal responsibility of the individual disregards the societal factors and social influences associated with obesity such as the decrease in manual labour and energy expenditure within the population at the same time as increased availability and affordability of unhealthy foods[347]. Higher rates of obesity among those from deprived areas and certain ethnic minorities means that focusing on self-responsibility for obesity further enhances social and health inequalities among those already marginalised with fewer resources to maintain a healthy lifestyle due to reasons beyond their individual control[360]. Consideration of socio-ecological factors such as deprivation and the obesogenic environment is therefore essential[360]. Further exploration of the intersectionality of discrimination especially around weight, gender, ethnicity and occupation is also required[349].

### 10.2.2.2 Prevalence of stigma

For most women pregnancy is not the first time they will experience weight stigma, with many feeling stigmatised within previous healthcare encounters[357]. Weight stigma from healthcare providers is reported by 69% of people with obesity[361]. Stigma is also perpetuated by the media with 72% of media images in the United States deemed as stigmatising to people with obesity[361]. In a survey of over 4000 adults across four different countries (Australia, New Zealand, UK, USA) respondents were more likely to stigmatise people with obesity if they identified over-eating, emotional eating or food addiction as causes of obesity, compared to those who viewed obesogenic environmental, physiological regulation or control mechanism malfunction as the cause of obesity[362]. Many respondents felt that obesity could be 'cured' by following a healthy lifestyle, including 62% of healthcare providers and 80% of respondents who were not healthcare providers[362]. Those who thought obesity could be 'cured' or entirely prevented through lifestyle choices were more likely to stigmatise individuals with obesity[362].

Experiencing weight stigma is more common among women than men[361]. Stigma can also be experienced on the grounds of gender, race, class and ability[361]. Given the known links between obesity and deprivation[21], lower levels of education[16,20] and ethnicity[352] sources of stigma other than weight may also interact with and shape women's experiences of weight stigma during pregnancy[354]. Weight related stigma may especially adversely affect those without the economic, social or emotional resources to follow the health promotion advice they have been provided[356].

### 10.2.2.3 The impact of stigma

Women with obesity describe healthcare providers' scepticism of their reports of healthy eating and physical activity behaviours due to assumptions about their current lifestyle[352,354]. Research is conflicting over whether conjectures about a woman's diet can be based solely on her BMI. A survey of Polish women in early pregnancy found women with overweight or obesity were significantly more likely to report eating a prudent (healthy) diet and less likely to eat a Western diet than women with a BMI in the recommended range[363]. However, others have demonstrated a less healthy diet in women with obesity. One Swedish cohort study found a higher BMI in early pregnancy was associated with greater consumption of white bread, meat and processed foods such as French fries, pizza, snacks and soft drinks at 34 weeks gestation and less consumption of cereals and fruits(364). Two further studies based in Europe and the United States similarly showed women with obesity to have a poorer dietary quality than women with a BMI in the recommended range(365,366). However, given unhealthy eating patterns are not synonymous with raised BMI, automatic referral to dieticians is viewed as contentious by many women with obesity who feel it only advances the misconception that women with obesity eat unhealthily and do not exercise(356).

There is a general misperception that weight stigmatisation may motivate people into losing weight(347). However, most evidence suggests the opposite is true. Weight stigma leads to less participation in physical activity or sports(347,349,367), decreased motivation to exercise and decreased perceived competence in physical activity(367). Increased nutritional intake has also been associated with experiencing weight stigma(349,367), including unhealthy eating patterns such as binge eating and overeating(347,350,367). A survey of over 500 women who were either pregnant or postpartum showed that the higher the number of sources a woman experienced weight stigma from, the more likely she was to report maladaptive eating behaviour during pregnancy and the postnatal period, even after controlling for factors such as pre-pregnancy BMI, age, ethnicity, parity and income(368). Given the impact of weight stigma on exercise and nutritional habits, it is of no surprise that weight stigma has been associated with increased weight retention in the postnatal period(368), long-term weight gain(349,367) and being less likely to achieve a weight loss of 10% or more of body weight regardless of baseline BMI(367).

A range of mental ill health conditions have also been associated with weight stigma both during the perinatal period and in the wider population. This includes depressive symptoms(347,368,369), stress during pregnancy and the postnatal period(368), anxiety(350,369), low self-esteem(347,369), body image dissatisfaction(347,369) and avoidance of social contact(350). These associations remained significant in several studies that controlled for factors such as pre-pregnancy BMI, age, ethnicity, parity and income(347,368). There was particular concern over the association with depression, given that depression itself is linked to poorer maternal-infant bonding, infant development and breastfeeding difficulties(349).

Weight stigma itself may also contribute to some of the negative adverse outcomes associated with obesity(347). Prolonged stress has been associated with long-term negative health outcomes such as heart disease and stroke, both of which are normally attributed to obesity per se, but the stress pathway may offer an alternative explanation(370). Research has also shown weight related bullying to elevate the recipient's blood pressure(367). Additionally, experiences of weight discrimination increase circulating C-reactive protein levels which is a marker of systemic inflammation(367). Furthermore, a systematic review of 33 studies found that weight stigma in adults with overweight and obesity was associated with diabetes risk(369).

Heightened concerns about maternal obesity(360), alongside weight stigma(349) may in fact drive some of the adverse pregnancy outcomes associated with maternal obesity. Assumptions about the pathology women may experience during pregnancy due to their size can often mean they cannot access the care they would like(354). Practices which restrict choice over the environment for birth such as being refused midwife care settings, water birth and active birth all lead to women with obesity giving birth in settings associated with higher rates of intervention and possibly leading to an unintended cascade of interventions simply from being labelled as 'high risk' at the start of pregnancy due to obesity rather than looking at other individual risk factors(371). Indeed, in this programme of research the increased emphasis placed on maternal obesity may offer one possible explanation for the higher Caesarean section rate within the antenatal healthy lifestyle service compared to the Trust with no service, which remained after adjusting for differences in baseline characteristics and rates of GDM. Healthcare providers perception of women with obesity being at higher risk has been associated in other research with differential treatment including earlier decisions to proceed to Caesarean during the second stage of labour(372). It may therefore be that by highlighting women with maternal obesity and their potential associated risks through their referral to the antenatal healthy lifestyle service may have inadvertently led to the higher Caesarean rates.

Additionally, some academics feel that healthcare providers who hold weight biases would provide substandard care(352). Weight stigma can therefore result in unhealthful behaviours such as avoidance of healthcare services(350,354). Additionally, in pregnancy if weight stigma causes the woman to feel they need to change their antenatal care provider it can impact on continuity of care(349). There is concern that disengagement from health and social care services due to the current shaming approach could end up being a far greater threat to long-term child health than maternal obesity itself(360).

It is also important to note that the current rhetoric around individual responsibility for obesity potentially means that effective public health strategies to tackle obesity are not implemented and inadequate funding is ringfenced for obesity(347). This was specifically noted in a survey, which found that higher levels of weight stigma among respondents was associated with a low prioritisation of government funding to tackle obesity(362). Thus, weight stigma could directly influence decision-making and offer an explanation into the current lack of prioritisation of research and support in this area despite the prevalence and impact(362). We therefore need further understanding of the impact of stigma outside of healthcare for example in the media, family and workplace(349).

#### 10.2.2.4 Education for healthcare providers

Given the prevalence and impact of weight stigma, particularly from healthcare providers, it is important to consider healthcare provider educational needs to tackle stigma.

##### 10.2.2.4.1 Current advice around gestational weight gain

A narrative review of 54 studies found a large proportion of women described not receiving guidance on GWG, ranging within the included studies from 17% to 90.5% of women(280), with an additional survey finding 26% of women reporting not receiving GWG advice from healthcare providers(373). Of interest was that more healthcare providers report providing GWG advice than women report receiving it(280). Counselling regarding GWG was also often inaccurate, with women receiving conflicting advice around GWG management from professionals[280]. One review found that the proportion of healthcare providers accurately able to identify GWG recommendations according to the woman's BMI varied from 4% to 80% within the included studies[280]. A scoping review of 14 articles further highlighted the lack of awareness among healthcare providers of GWG guidance for women with obesity[374]. It therefore follows that the proportion of women reporting receiving GWG guidance in line with IOM recommendations is low, ranging from 26.3%[373] to 50%[375]. A further study exclusively considering women with overweight or obesity reported 24% of women knew the correct GWG recommendations, although only 17% had been correctly informed of GWG guidance by a healthcare provider[376]. A survey of women in early pregnancy identified that half of women would like to receive more information around GWG management[375], particularly guidance around how to avoid excessive GWG and recommendations around specific nutritional components required during pregnancy[377]. Receiving adequate guidance is important as those not receiving any guidance are more likely to gain GWG below recommendations prevalence ratio (PR) 1.26 (95% CI 1.02-1.56) as well as above recommendations PR 1.17 (95% CI 1.04-1.32)[373].

The impact of obesity on the advice provided to women is slightly unclear. A narrative review found that healthcare providers were more likely to counsel women about GWG if they were overweight or obese[280]. It was suggested this may partly be due to the healthcare providers being aware of the lower GWG range for women with overweight or obesity than women with a BMI in the recommended range. However, it is also likely to reflect healthcare provider stigma and assumptions that women with overweight or obesity are less likely to engage in healthy lifestyle activities and so more likely to need advice[280]. In contrast others have found women with obesity to be asked fewer lifestyle questions within antenatal appointments[374], shown less approval and receive fewer affirming comments from healthcare providers than women with a BMI in the recommended range[352].

The readiness of midwives to provide support according to model of maternity care has been explored within a focus groups[378]. A continuity model of care provides women with care by a consistent midwife throughout pregnancy and the postpartum period and sometimes during the birth. Midwives practising in a continuity model of care reported more readiness to address weight management through woman-centred interventions and were more likely to regularly weigh women and offer specific advice[378]. Continuity model midwives showed more awareness of the women's environment and availability of food for example recognising that those living in hostels would have limited choice as their food is provided[378]. The continuity model also enabled the midwife to build a relationship of trust with the woman from which conversations could be initiated and discussions followed up[378,379].

10.2.2.4.2 Barriers to providing weight management advice during pregnancy

Within the literature, one of the most frequently cited barriers to healthcare providers giving advice around weight management was limited time in appointments[36,280,348,377,378,380-383]. The sensitivity of the topic was also widely seen as a barrier to weight management discussions during pregnancy[36,280,348,352,357,359,374,380-383] with healthcare providers concerned about coming across as judgemental[36,382], not wanting to cause discomfort or offence to women[36,280,353,381,382] or make women dread or avoid coming to antenatal appointments[378]. One survey found 28.5% of healthcare providers agreed or strongly agreed that it was difficult to discuss maternal obesity[36]. This meant healthcare providers avoided conversations around weight management[359,374,381] or only engaged in conversations instigated by the woman or if the woman was viewed as receptive[348,381]. Healthcare providers also reported being very careful about how GWG was addressed[382], which could lead to using vague or indirect comments to address weight[374]. However, a qualitative study of women with obesity who declined weight management services during pregnancy reported that being referred to the service was acceptable to them, that it did not illicit any negative emotions and that they expected the midwife to provide them with information that would increase their awareness of available services[384].

The literature widely reports healthcare providers lack of confidence in addressing weight management[280,348,374,378,382]. Healthcare provider's own struggles with weight especially influenced their confidence to address GWG management[36,382,383] due to the difficulty of promoting advice they did not follow themselves[378]. weight management during pregnancy [280,377,381,382] and lack of knowledge[348,382] including around how to support behaviour change[348].

Research has also shown confusion among midwives about the distinction between healthy eating, including aspects such as food hygiene, and weight management, with them tending to assume that healthy eating was synonymous with weight management[381]. While generally aware of iron and folate deficiency during pregnancy, the importance of other nutritional components such as vitamins A, B, C, D, zinc and iodine was not recognised[381]. Additionally, midwives struggled to state how care provided would differ for a woman with a BMI of 32 compared to a woman with a BMI of 38[381]. It is therefore unsurprising that the majority (74%) of healthcare providers in one survey[36] and all midwives in a separate study[378] wanted additional training; especially around the risks of maternal obesity[36,374], GWG advice for women with obesity, the safety of dieting and exercising during pregnancy[36], and how to sensitively discuss the issue of weight management[36,374,378]. Some healthcare providers also report uncertainty over BMI thresholds required for referral to local services[381], with training therefore requested around the available support services[374]. While multiple professional societies have developed guidance related to maternal obesity, little has been done to enhance healthcare providers' skills in communicating these messages to women[385]. Training around how to communicate risk, awareness of stigma and increasing healthcare provider confidence to discuss obesity and weight management is essential to reduce stigma[349] and address healthcare providers reluctance to engage in discussions around weight management due to their concerns over stigma[386].

A further barrier reported by healthcare providers to weight management discussions is their lack of belief that the information they provide will make any difference to the woman's behaviour, especially changing long-term choices[280,348,382,383]. Healthcare providers perceive women to be uninterested[380,382], with only 31% of healthcare providers thinking that people with obesity are motivated to lose weight[387]. However, this has not been demonstrated within an online survey of adults with obesity which found 46% of respondents were concerned about the health effects of their excess weight, almost half (48%) wanted to lose weight, and only 20% were uninterested in losing weight in the next 6 months[387]. While 68% of people with obesity wanted the healthcare provider to initiate a conversation about weight, 71% of healthcare providers assumed people would be uninterested in a conversation around losing weight[387]. Among those who had discussed their weight with a healthcare provider, 35% found conversations around weight either very or extremely helpful[387]. Interestingly only 3% of people with obesity stated that they would be offended by such a conversation[387]. Healthcare providers reticence to address weight management with some women may lead to inequitable access to services[380].

Healthcare providers generally considered weight management was part of their role but recognised their limitations and wanted support from a multi-disciplinary team, for example dieticians[348]. Some healthcare providers also voiced uncertainty over whose role it was to discuss GWG management with women[280,383], with midwives assuming discussions occurred as part of an onward referral, for example to the anaesthetic clinic[381].

A final barrier identified to providing GWG advice was the lack of clear guidance[348] especially around a healthy GWG pattern in UK guidance[381]. The absence of clear guidance can largely be attributed to the lack of effective interventions for improving maternal and infant clinical outcomes[284]. Limited resources to provide women with more detailed advice was also noted[348,378,383], with healthcare providers wanting more readily available resources to use within appointments, such as flashcards or infographics[382]. Additionally, many midwives were found to normalise obesity given the rising prevalence in society[381].

#### 10.2.2.4.3 Healthcare provider training content

Organisations and institutions providing midwifery education are responsible for ensuring students are sensitive and non-judgemental towards antenatal women with obesity[388]. Healthcare providers must be aware of stigma to prevent unacceptable practice[388]. Healthcare provider students also need opportunities to reflect on their own views around obesity during pregnancy, as well as their attitude towards their own weight[389]. It is essential that women themselves are involved in the development of any training content[383].

A recent expert review emphasised the importance of healthcare provider knowledge and training to discuss nutrition with women prior to and during pregnancy, as well as having the necessary time within appointments[390]. Limited research has however been conducted into the most effective interventions for healthcare providers. An initial systematic review of interventions to support healthcare providers to promote weight management among pregnant women with obesity found no literature, with all interventions at that point focussed on changing the woman's behaviour[391]. This lack of focus on the healthcare providers was despite numerous barriers to providing GWG management involving the healthcare providers themselves[391]. A more recent systematic review of interventions to support healthcare providers caring for women with obesity or providing GWG advice found interventions were generally well received by healthcare providers[392]. Training alongside adding alerts into the electronic records were particularly effective at improving GWG counselling[392]. Interventions to address specific knowledge needs were generally well evaluated by healthcare providers and improved their confidence, although some felt that actual implementation in a real world setting would take too much time within appointments[392]. It is therefore of concern that while healthcare provider skills or knowledge in specific areas were improved within the incorporated studies, none assessed how this translated into actual practice[392]. The review also found that training around motivational interviewing improved open ended question asking, but also increased closed questions and information giving and made no difference to healthcare providers empathy scores, despite this being a key component of motivational interviewing[392]. Motivational interviewing was also seen within a separate scoping review to help healthcare providers to become more aware of their own communication style[374]. The most recent review of healthcare professional training around GWG found midwives confidence increased after training and women felt better understood and more supported by the healthcare provider[383]. However limited influence has been seen to date from any healthcare provider training on actual GWG[383]. A recent cluster randomised trial of training sessions to improve midwives' confidence as well as information resources to share with women found the intervention increased midwives' self efficacy and intention to address areas such as weight communication, healthy eating, physical activity, weight management and signposting to other services[393]. However, more research in this area is required to determine the most effective content for healthcare provider training.

Concerns regarding weight and obesity stigma led the World Health Organization (WHO) to develop a technical document[361]. To reduce bias and address weight stigma the WHO has proposed sharing best knowledge and practices locally and nationally; as well as prioritising the exploration of weight stigma within different areas including health, public policy and education[361]. Others have noted the importance of language used by healthcare providers, particularly person centred language, to reduce stigma and prevent potential disruption of the healthcare provider-client relationship through lack of engagement with services[359]. A person centred approach is essential given that women react differently to discussions depending on their character, circumstances, body image and reasons for obesity as well as the approach used by the healthcare provider[36]. Components that facilitate healthcare providers to establish conversations around obesity are detailed in Box 10.1. A particular emphasis needs to be on 'how' things are said not just on 'what' is said[383]. Additionally healthcare providers need to be fully aware of the socio-ecological factors associated with obesity such as deprivation and education[388]. These factors are considered further within the next section of this thesis.

### 10.2.3 The importance of socio-demographic factors and social-ecological context

This programme of research showed differences according to socio-demographic characteristics. Women who smoked at booking or whose highest household occupation was in the housewife, unemployed or student category rather than employed were less likely to attend the antenatal healthy lifestyle service. Additionally highest household occupation and smoking status when booking for pregnancy care were associated with child obesity or severe obesity at school entry. It is also important to note that within this research half of those with a BMI $\geq 40 kg/m^2$ were from the most deprived quintile.

**Box 10.1. Factors to facilitate healthcare providers to establish conversations around obesity and gestational weight management**

Develop a good rapport before discussing weight[36,379,394].

Seek permission to talk about weight then ask open-ended questions to allow the woman to raise concerns or avoid conversations[359].

Don't make assumptions about the person's diet or exercise habits[359,379].

Listen to and believe their lived experience[354,357].

Treat the woman as an individual, not just as a weight category, and provide woman centred care[357].

Identify the woman's own concerns and circumstances[394].

Talk about 'some people' generically rather than 'you' specifically[359].

Where possible avoid the word 'obesity' as women can find this stigmatising. If the term is utilised, use person first language e.g. 'woman with obesity' rather than 'obese woman'[388,394].

Remember that increased risk does not equate to certainty that the woman will experience the outcome.

Ensure conversations are evidence based[359].

Emphasise the potential benefits for the baby of addressing weight management during pregnancy[36].

Re-enforce small positive changes, as this can lead to more changes[359,394].

Collaborate to set meaningful targets rather than focus on negative long-term consequences[359].

Focussing on health benefits, rather than an ideal weight reduces stigma[347].

Signpost to other services[359].

Encourage people to try different things until they find something that works for them as everyone responds differently to interventions[359]. Encourage people to return if one intervention isn't working[359].

Our understanding of the impact of socio-ecological factors is hampered by the limited focus within most research on these contextual factors. For example, a recent systematic review of the uptake of weight management interventions for adults with overweight or obesity showed that only 56 of the 103 included interventions considered any potential differential impact due to inequalities[395]. This was despite all interventions reporting more than one characteristic, such as age, ethnicity, occupation or socio-economic status, gender, education and area of residence. The review found less than 15% of studies considered whether there were any differences in intervention uptake or intervention adherence, 31.1% considered differential attrition and 30.1% considered differences in weight outcomes according to socio-demographic factors[(395)]. One study found healthcare providers generally showed good awareness of the wider determinants of obesity and weight such as family influence, socio-economic deprivation, psychological and genetic causes and the impact of ethnicity and culture[(348)]. However, a qualitative evidence synthesis revealed that women felt healthcare providers simply viewed their energy balance, without considering the other challenges they face such as social, physical or psychological barriers[(396)]. The importance of considering the socio-ecological context of obesity is therefore highlighted[(396)]. The wider literature available on the impact of socio-ecological factors is considered below.

#### 10.2.3.1 Deprivation

Household deprivation is classified in many ways, including household income, deprivation, socio-economic status or occupation status.

Secondary analysis of the data used within this programme of research has considered the association between GWG and measures of deprivation. It found women from the 2$^{nd}$ most deprived quintile gained more GWG than women in the most deprived quintile[(336)]. This remained significant after adjusting for other socio-demographic factors[(336)]. Similarly, women living in a household with any form of employment gained more GWG than women who lived in a household where the highest occupation was classified as housewife, student or unemployed, however this only remained significant where the highest household occupation was a manual occupation once adjusting for other factors[(336)]. A separate qualitative evidence synthesis viewed higher socio-economic status as a facilitator to adequate GWG[(396)].

Lower GWG among those from the most deprived households may partly be due to food insecurity preventing adequate nutrition. While one study found no significant association between household income and diet quality[(365)], other research has shown poorer diet quality among those with higher levels of deprivation[363,366,397]. For example, one study found current dietary quality was higher among pregnant women of higher socioeconomic status[397]. A separate cohort of Polish mothers identified two dietary patterns[363]. The first ‘prudent’ diet was high in fruit, vegetables, whole grain, poultry and low fat dairy products. This diet was associated with high socio-economic status and was more likely among married women[363]. The second diet type was the Western diet which was characterised by high intake of refined carbohydrates, processed meats and low intake of whole grains. This diet type was more commonly seen in those of low socioeconomic status and among unmarried women[363]. An individual participant meta-analysis of European cohort studies also found that women from low income households had a lower dietary quality compared to women from high income households[366]. Those from low and middle income households were also less likely to have an anti-inflammatory diet than those from a high income household[366]. Poorer diet in pregnancy may in part stem from a lack of understanding of the developmental origins of health and disease, as research demonstrates this is lower among those of low socioeconomic status[397].

A systematic review that considered intervention uptake, adherence and attrition according to inequalities mainly showed either no difference or favoured the least deprived[395]. Only 4 studies evaluated inequalities in respect to intervention uptake, with inconclusive results as some analyses favoured the less advantaged, some the more advantaged and some showed no differences in intervention uptake[395]. Intervention adherence was no different according to inequalities in twenty analyses, but adherence was higher in more advantaged groups in 11 analyses, especially among those with a full time occupation, married, from a less deprived background or older[395]. Similarly, most analysis found no difference in trial attrition according to inequalities, but those that did find a difference showed that participants who were older and less deprived were more likely to have been followed up within the intervention[395]. It was however acknowledged that there was insufficient power within many of the individual studies which may have led to the lack of significance[395]. The impact of inequalities should therefore not be ignored when developing interventions.

#### 10.2.3.2 Education

Several studies have considered dietary quality according to education level. One study found that education was not significantly associated with diet quality[365]. However, the remaining studies found higher education levels were associated with better diet including better overall diet quality, a more anti-inflammatory diet[366], a diet rich in fruit, vegetables, fish and whole grains[364], consumption of a prudent diet rather than a Western style diet[363] and increased intake of macronutrients such as vitamins, folate, iron and calcium, as well as dietary fibre[364]. Women with a tertiary education were also less likely to overestimate appropriate GWG[375]. One study considered dietary appointment attendance according to educational attainment among women with obesity and found no significant difference in those who did or did not attend[398].

#### 10.2.3.3 Smoking

One study of a lifestyle intervention for pregnant women with obesity looked specifically at those who did not attend an initial dietary advice appointment and found those women more likely to smoke than women who did attend[398]. When considering diet quality, one study found women who smoked had poorer diet quality and a more pro-inflammatory diet during pregnancy[366]. Within one USA cohort poorer diet quality during pregnancy was found among women who had ever smoked not just current smokers[365]. Women who smoked in early pregnancy were also more likely to eat a Western diet than non-smokers[363] and within a Swedish cohort smoking prior to pregnancy was associated with higher consumption of white bread, meat and processed foods such as French fries, pizza, snacks and soft drinks and less consumption of fish and fruit[364]. Smoking has also been negatively associated with intake of macronutrients such as vitamins, folate, iron and calcium as well as dietary fibre[364].

#### 10.2.3.4 Psychosocial aspects

As well as considering socio-demographic factors it is also essential to consider psychosocial aspects. It is recognised that psychological issues may precede obesity, with the woman’s mental wellbeing affecting their weight, however lack of psychological wellbeing may also develop because of weight related difficulties[399]. Without addressing these underlying issues, any changes in lifestyle are likely to be temporary[379]. Within the literature maternal obesity is noted to be associated with depression, anxiety and binge eating disorder for diagnosed disorders and at sub-clinical levels[399]. Maternal body dissatisfaction during pregnancy and the postnatal period are also suggested to increase both maternal and child obesity, highlighting the need to consider modifiable psychosocial factors within interventions[400].

Numerous studies have looked at the association between psychosocial factors and GWG. When looking at stress and anxiety, two reviews found that these psychosocial factors were not associated with excessive GWG[223,224]. While one review has found no association between depression and excessive GWG[224], another suggested depression was associated with excessive GWG[223]. This association between excessive GWG and depression may be explained as depressive symptoms are associated with poorer diet quality during pregnancy[365] and women themselves describe stress and depression as barriers to making behaviour changes related to nutrition or physical activity[401]. Several reviews have considered the association between self-efficacy or self-esteem and excessive GWG. One review found no association between them[223], but another suggested that women with high self-efficacy scores for healthy eating had lower GWG[224]. Self-efficacy is especially linked with motivation as to initiate a behaviour you must believe that change can be achieved[399]. Women with obesity are particularly believed to need support with self efficacy and low self-esteem, for example by addressing a woman's negative self talk[399]. Both reviews also found that body image dissatisfaction was associated with excessive GWG[223,224] as were concerns about weight gain, inaccurate perceptions of body weight, having a higher than recommended target weight gain, and less knowledge about GWG[224]. A further study has considered the impact of childhood maltreatment (such as physical abuse, emotional abuse or neglect) and found no association with excessive GWG[402]. However, when just considering women with prenatal anxiety, maternal history of childhood maltreatment was significantly associated with excessive GWG, including after adjusting for confounders such as maternal BMI and ethnicity[402]. The importance of considering multiple psychosocial factors is therefore highlighted. However, healthcare provider training to achieve this is essential as an integrative review demonstrated that although many midwives were aware of the association between obesity and psychological wellbeing, they felt inadequately trained to address it competently(399).

The impact of social support on GWG has also been considered. Perceived lack of social support has been associated with excessive GWG(223). A qualitative evidence synthesis has also suggested numerous social barriers to following healthy lifestyle choices during pregnancy, including friends or family encouraging the woman to overeat, family members not wanting to follow a healthy diet and loneliness(396). Women also reported pressure to follow family advice over that of the healthcare provider(396). In contrast a supportive family can be a facilitator of effective GWG management(396). Social support has also been recognised as an enabler of physical activity in pregnancy(403). In contrast a lack of social support such as no one to exercise with(396,404) or family disapproving of exercise during pregnancy and the lack of social norms(401) or cultural norms(403) regarding physical activity during pregnancy are all viewed as barriers to physical activity in pregnancy(396,404). Women themselves report wanting weight management services during or after pregnancy to include their partners, so that they understand the importance of supporting the woman(405). A further barrier to undertaking physical activity during pregnancy is women's perceptions that they are already active(396,404), especially as gentle walking was viewed as all that was required during pregnancy(396).

#### 10.2.3.5 Environmental factors

A qualitative evidence synthesis of women's views of GWG found women reported struggling with enacting healthy lifestyle advice during pregnancy due to physical, social and environmental factors over which they did not have any control(396). Environmental barriers identified include ready access to fast food(396), difficulty accessing fresh food(396), a lack of childcare to undertake physical activity(380,396,401,403,404), a lack of time for physical activity or to plan and make healthy nutritional choices(396,403,404), difficulty in fitting exercise or weight management service attendance in around work commitments(380,401,406) and the cost implications of both buying fresh food or undertaking physical activity(396,403,404). One service that provided home based visits reported high levels of acceptability among women, with the convenience of home visits seen as an advantage[405]. Women also felt more at ease discussing weight within their own home[405]. Additional barriers at the environmental /organisational level were adverse weather which could affect outdoor exercise[396,403,404], a lack of physical activity facilities[403,404], poor transportation links to physical activity venues[401,404] or weight management services[406], as well as a lack of programmes targeted at pregnant women[403,404]. One study has also considered the impact of environment on diet, with a Western (unhealthy) style diet shown to be more likely and a prudent style diet less likely in women living in more rural areas (an area with a smaller number of inhabitants)[363]. It was suggested this may partly be due to limited access to varied food sources within rural areas[363].

The above research highlights the importance of future interventions addressing some of these barriers, particularly family engagement, social support[404] and environmental barriers for those from deprived backgrounds.

### 10.2.4 Parity

This programme of research found the enhanced service was more effective at managing GWG among multiparous women. Indeed, secondary analysis of factors associated with GWG found that compared to nulliparous women, those with one previous child gained on average 2.5kg less and those with two or more previous children gained 3.2kg less[336]. This difference between nulliparous and parous women remained significant after adjusting for potentially confounding factors[336]. However, parous women were also less likely to have GWG recorded[336]. This may be linked to parous women also being significantly more likely not to attend the antenatal healthy lifestyle service as seen within Article B of this research programme. Parous women were therefore not present at the 36 week appointment when women were usually weighed. Fewer parous women having a GWG available may have influenced the results, as women choosing not to routinely attend the healthy lifestyle service may also have been more likely to have a higher GWG.

An individual participant meta-analysis found similar results to ours, showing that multiparous women gained less GWG on average than nulliparous women within both univariate analysis [-1.12kg (95% CI -1.55 to -0.69kg)] and multivariate analysis that accounted for baseline weight differences [-0.73kg (95% CI -1.24 to -0.23kg)[221]. A separate systematic review and meta-analysis looking specifically at parity as a risk factor of excessive GWG showed a more complex picture as their crude analysis found that parity was both positively and negatively associated with GWG in different studies[216]. Within the 32 studies providing data for this outcome, 14 found primiparous women gained more weight during pregnancy, 9 studies reported multiparous women to gain more weight and 10 studies found no association between parity and weight gain[216]. However, when only including the 16 studies that controlled for pre-pregnancy BMI within the meta-analysis, average GWG in parous women compared to nulliparous women almost reached significance (weighted average effect -0.08, 95% CI -0.19, 0.03)[216]. A further meta-analysis that considered the differential effect of interventions according to parity, found no difference in GWG according to parity; with multiparous women receiving an intervention gaining 0.1kg (95% CI -0.60 to 0.39kg) less on average than nulliparous women[221]. This differed from our research where the enhanced antenatal healthy lifestyle service was more effective in multiparous women at reducing GWG.

A Danish lifestyle intervention for pregnant women with obesity found women who did not attend the initial dietary advice appointment or who declined randomisation into the study were more likely to be multiparous[398]. They hypothesised nulliparous women may be more willing to change their behaviour during pregnancy to optimise fetal health[398]. Parous women may also be less likely to seek out information in their current pregnancy, instead relying on previous ‘experience’ of pregnancy[397]. However, our qualitative study (Article E) suggested the opposite as parous women with a BMI ≥40kg/m² described themselves as more engaged with nutritional advice in their second pregnancy[335]. They described themselves as being ‘naïve’ in their first pregnancy and did not want to repeat their previous excessive GWG[335]. Additionally, parous women generally have a higher BMI at the start of pregnancy than nulliparous women[216] and those with two or more previous children are more likely to have obesity during their next pregnancy[21]. As GWG decreases with increasing BMI[2], the discrepancy in BMI between nulliparous and parous women may also partly explain their lower GWG.

Before considering a focus on nulliparous women within interventions, it is essential to consider women's awareness of GWG and healthy eating advice in pregnancy and their actual diet quality.

#### 10.2.4.1 Awareness of weight gain and healthy eating guidance

One survey exploring women's knowledge of GWG, found one third of women could identify a GWG that was consistent with guidelines(375). However, parous women were not more likely than nulliparous women to over or underestimate an appropriate GWG range(375). Several studies have also looked at women's awareness of healthy nutrition. Two studies found lower nutritional knowledge among nulliparous women. The first was a small scale study of 27 women which showed that only 16.7% of nulliparous women passed the Nutrition Knowledge Questionnaire compared to 40% of those who had a previous pregnancy(407). They also showed that after providing nutritional education 66.7% of both multiparous and nulliparous women showed adequate nutritional knowledge(407). Regardless of parity, education therefore improved nutritional knowledge. A second study found nutritional knowledge was generally poor among all ethnic minority women but was particularly low among women who had never had a pregnancy(408). Interestingly, they found most women were certain that they could engage in healthy behaviours such as eating a healthy diet or undertaking physical activity, but very few actually undertook these behaviours(408). In contrast, a final study that looked at women's understanding of the developmental origins of health and disease was higher among those of lower parity(397). However, developmental origins of disease awareness was far lower than general understanding of pregnancy advice such as not 'eating for two', not smoking during pregnancy and taking daily vitamins(397). Those with better knowledge of the developmental origins of health and disease had better diet quality in pregnancy(397). This suggests communicating to pregnant women the importance of pregnancy health and nutrition for long-term fetal development and health may encourage adherence to better nutrition during pregnancy and therefore optimise the child's long-term health outcomes(397).

Although some differences in nutritional knowledge have been shown above, when exploring intention for healthy eating during pregnancy, it was found that parity alongside area of residence (metropolitan or not) only accounted for a small proportion of the variance (just 3%) within a multiple regression model[409]. This study did not however explore whether an intention for healthy eating actually changed future behaviour.

#### 10.2.4.2 Diet quality and physical activity during pregnancy

Differences in diet quality according to parity have also been noted. A suboptimal diet is common during pregnancy[365], with most studies finding poorer diet quality among multiparous women. An increasing number of previous births is associated with poorer dietary quality[365,366,397] and a more pro-inflammatory diet[366]. A further study also found parous women were less likely to have a prudent diet type (high in fruit, vegetables, whole grain, poultry and low fat dairy products) and more likely to have a Western diet type (high intake of refined carbohydrates, processed meats and low intake of whole grains) than nulliparous women, however this did not reach significance[363]. When entering maternal characteristics into a multivariable model, only increasing parity and decreasing BMI remained significantly associated with a Western style diet[363]. A Swedish cohort that considered macronutrient intake at 34 weeks pregnancy also found increasing parity was associated with increased intake of sugar, fatty acids, and lower levels of vitamin B6 and E, but slightly higher intake of wholegrain than nulliparous women[364].

Physical activity during pregnancy shows similar differences according to parity. One study showed multiparous women were more physically inactive than nulliparous women[410]. When physical activity was split into quartiles, 36.4% of the women in the lowest quartile were nulliparous and 63.6% were multiparous[410]. Overall, 34.9% of nulliparous women reached the recommended level of physical activity (the highest quartile) compared to only 19.9% of multiparous women[410].

It could have been argued from this programme of research that nulliparous women require more focussed interventions due to their higher GWG. However, the wider evidence base generally shows multiparous women have poorer diet quality, lower physical activity levels during pregnancy and only equivalent knowledge around GWG recommendations. Therefore, parous women could benefit from nutritional education to improve diet quality[366] and encouragement to participate in physical activity. Effective counselling of women regardless of parity appears to be essential to ensure all women have the information required around GWG management and nutritional adequacy during pregnancy. This is especially important as pregnancy places additional nutritional demands on the woman[49].

### 10.2.5 Refining interventions

Given the lack of effect of traditional diet and physical activity interventions on GWG and clinical outcomes, noted within this research as well as previous literature especially for women with obesity, there is recognition of a need to refine interventions[411]. This requires a better understanding of the individual components of any intervention, group interventions should be considered, interventions need to consider the socio-ecological context and not just target an individual's behaviour and there should be a change of focus onto the preconception period. Each of these aspects will be discussed below.

#### 10.2.5.1 Better consideration of the detail within interventions

Many lifestyle interventions in pregnancy do not provide adequate detail for effective replication and differ in outcome measures. Additionally, the lack of clarity around the most appropriate diet to follow in pregnancy to provide adequate fetal nutrition is debated. These areas all need closer consideration in future interventions.

##### 10.2.5.1.1 Understanding of individual components

The literature has highlighted a need for a better understanding of the key components of effective lifestyle interventions[412]. One review has specifically looked into different aspects of interventions to determine which were predictive of success[264]. No optimal intervention characteristics could be determined for aspects such as the trimester in which the intervention started, how long the intervention lasted, how many hours contact the woman had and the type of diet advised[264]. They however suggested that training professionals to initiate conversations around weight management during pregnancy may be effective and that interventions delivered 1-3 times may be equally effective as those delivered 4-7 or 8 or more times[264]. Fewer sessions may help to reduce women's feeling of being barraged by repetitive discussions about their weight throughout pregnancy.

The necessity for a deeper understanding and consideration of behaviour change components incorporated into interventions has also been emphasised. A comprehensive Behaviour Change Technique Taxonomy of specific techniques used within interventions has been developed[413]. This allows clearer identification and reporting of the active behaviour change components within complex interventions. This then permits more effective comparison between studies and replication of effective components within future studies. A review of behaviour change components incorporated in gestational weight management studies however found techniques were poorly reported[265]. Where behaviour change techniques could be identified within studies, 'feedback and monitoring', 'shaping knowledge', and 'goals and planning' were the most successful categories[265]. A wider review of any public health intervention aimed at changing behaviour during pregnancy found that the main approach used was education[414]. Additionally, the studies all aimed to increase women's empowerment. To achieve this over half of the studies focussed on 'skills and competencies', for example by supporting women to develop new competencies, on 'innovation' by encouraging women to be open to changing their behaviour, on 'goal setting' and by increasing 'self-efficacy'[414]. The success of these different behaviour change components was however variable within the included studies[414].

The uniqueness of pregnancy as a time for behaviour change has been recognised, however a recent study concluded that current models do not satisfactorily explain changes in healthy eating behaviour during pregnancy[415]. For example, the teachable moments model which views natural life transitions such as pregnancy as a motivator for behaviour change, does not account for women's experiences of physical symptoms during pregnancy or for external influences on the woman's behaviour particularly social, practical or environmental influences[415]. Additionally, the bidirectionality of some influencing factors were not fully accounted for within the teachable moments model. For example, strong emotions elicited through stigma or judgement could encourage women to change their behaviour in either direction, e.g. increasing or decreasing physical activity(415). In contrast to the teachable moments model some women also describe pregnancy as a time when they can eat what they want and not have to worry about the social and cultural expectations around weight control(406,416).

The other model that was considered was the COM-B model, with all of the factors viewed to influence behaviour change during pregnancy mapping onto the model(415). However, neither model adequately accounted for the changing nature of factors influencing behaviour as pregnancy progresses, such as increased fatigue or decreased nausea, which could influence the effectiveness of interventions at different stages in pregnancy(415). When considering the utility of the two models to explain changes in healthy eating behaviours, the COM-B model only explained 18.4% of the variance, and the teachable moments model only accounted for 9% of the variance(417). Therefore, the need to develop a pregnancy specific model has been suggested(417).

Monday Clinic was established in 2009 following on from the Confidential Enquiry into Maternal and Child Health report into maternal deaths published in 2007 highlighting that women with obesity were disproportionately represented among those who died during pregnancy or in the year after birth within the UK(418). As a result maternal obesity became a priority area for both researchers and practitioners to reduce preventable maternal morbidity and mortality. Given the high rates of maternal obesity within the Trust(319) the need to commence a service to support these women in pregnancy was recognised. However the establishment of Monday Clinic pre-dated the National Institute for Health and Care Excellence guidance on weight management before, during and after pregnancy(10). The service also preceded the publication of the COM-B model of behaviour change(290) and the subsequent taxonomy of behaviour change(413). The individual components incorporated into the antenatal healthy lifestyle service were therefore not considered when the service was established and proved difficult to determine in retrospect given the intentional flexibility within the service to cater to each woman's individual needs. This limits the evidence obtained from evaluating Monday Clinic for the design, development and implementation of any future interventions. However, a new framework for developing and evaluating complex interventions has now been established jointly between the Medical Research Council (MRC) and the National Institute for Health Research (NIHR)[419]. This takes into account recent developments in theory and the need to ensure that research is efficient, useful and impactful[419]. This framework has six core elements. 1). The need to consider the context of the intervention. 2). Development and refining of the theory as to how the intervention is expected to lead to the anticipated effects as this can inform transferability of interventions between different settings. 3). Engaging with stakeholders at every phase of the research from development through to implementation and evaluation. 4). Identification of key uncertainties at each stage of the research to frame the research questions. 5). Intervention refinement to improve intervention acceptability and feasibility. 6). Consideration of the economic costs versus benefits of the research[419]. Future interventions within this area should therefore make use of this framework to ensure their optimum impact on health outcomes[419].

#### 10.2.5.1.2 Appropriateness of outcome measures

To successfully determine the effectiveness of interventions that aim to optimise GWG, minimising bias in GWG measurement is essential[420]. Weight at the first antenatal appointment is suggested as the best starting point, as this is less biased than self-reported preconceptual weight[420]. A review has shown that 20% of women misreported their pre-pregnancy weight by 4.5kg or more, with 20% of women misclassified as underweight, overweight or obese when using preconception weight[420]. Additionally, where weight at birth has not been obtained, it is essential to adjust for gestation at the final weight[420], as has been done within this programme of research. This is required as a review found that when weighed at 37 weeks only 47% of women exceed IOM guidance compared to 62% of women when weighed at 41 week gestation[420]. Similarly, when adjusting for gestational age at the final weight 57% of women exceeded IOM guidance compared to only 37% when not adjusting for gestation at final weight[420]. Gestation at the final weight is therefore an important confounder when considering the impact of GWG on adverse pregnancy outcomes[420].

It is well recognised that calibration of medical equipment is essential to ensure reliability of measures. However, other factors influencing weight are rarely addressed within research. For example, it is usual to weigh women fully clothed, but clothing weight itself varies across the year[421]. The time of day an individual is weighed can also affect weight. Additionally, weight in non-pregnant individuals varies across the week, with weekend weight gain and midweek weight loss, resulting in weight being highest on a Sunday and Monday and lowest on a Friday[422,423]. Variation has also been noted according to season, with weight especially increasing over the Christmas season and to a smaller extent over holiday periods[423]. Therefore, research needs to consider any potential impact of these natural variations.

There is also debate over whether IOM recommendations for women with obesity are applicable to all classes of obesity and as noted in Chapter 2 some have suggested far stricter GWG limits for women with a BMI ≥40kg/m². Studies vary in their suggested recommendations with one suggesting a weight loss of 7.6kg during pregnancy for women with obesity was associated with the lowest predicted prevalence of 5 adverse outcomes; preterm birth, LGA, SGA, weight retention and childhood obesity[204]. A weight loss of 5kg for women with a BMI ≥40kg/m² has been associated with the lowest incidence of both LGA and SGA[205]. Additionally, the presence of one or more adverse outcomes out of pre-eclampsia, gestational hypertension, GDM, Caesarean birth, preterm birth and SGA or LGA was lowest with a GWG between 0-5.9kg in women with a BMI ≥40kg/m² in a final individual participant metanalysis[20]. The optimal GWG for each BMI category is further debated as while GWG guidance has been based on the prevention of complications such as SGA, LGA and Caesarean within observational studies, there is a lack of evidence that actually complying with the recommendations produces health benefits for the mother or child[277]. It is suggested that future guidance should look at different classes of obesity separately[277] and consider GDM and pre-eclampsia among the complications for women with obesity as these are the most common adverse pregnancy outcomes for this group of women[277]. Additionally, the pattern of weight gain requires closer assessment as early pregnancy weight gain is thought to be the strongest predictor of adverse maternal and infant outcomes[390]. Finally, it is recognised that IOM guidance has largely been established from Caucasian cohorts, with the IOM cautioning that additional research is required before universal acceptance of GWG guidance for women of all ethnicities[420]. Full evaluation of different BMI thresholds in women of different ethnicities is particularly required(420).

More consideration of the long-term impact of any interventions is also vital, for example maternal weight retention in the postnatal period and childhood overweight and obesity, as most interventions of pregnant women with obesity currently do not consider long-term outcomes(277).

10.2.5.1.3 Better understanding of diet in pregnancy per se

Our understanding of the impact of maternal diet on fetal development and long-term child health outcomes is developing. It is suggested that dietary intake should increase in pregnancy by no more than 10% above recommendations for the non-pregnant population(277). However, the specific components that should be included within a pregnancy diet for optimal fetal and subsequent infant growth are still debated(390). Specific diets for pregnant women with overweight or obesity are especially insufficiently understood.

Within the general population, a Mediterranean diet which is high in whole grains, fruit, vegetables and seafood is considered one of the healthiest dietary patterns(161). Among young adults the Mediterranean diet improves microvascular function which may reduce the risk of cardiovascular disease(424). Several reviews have explored the benefits of a Mediterranean diet during pregnancy and found that it reduces complications including GDM, prematurity(425,426), preeclampsia(425), Caesarean birth, urinary tract infections and low birthweight(426) and results in lower GWG(425). A Mediterranean diet is also suggested to reduce long-term offspring metabolic ill-health(161,426). Separate reviews similarly showed that diets higher in vegetables, fruits, whole grains, nuts, and fish and lower in meat and highly processed grains were associated with lower rates of gestational hypertension, pre-eclampsia, GDM(427) and lower rates of preterm birth(428) but no conclusions could be drawn about dietary patterns in pregnancy and birthweight outcomes(428). It should however be noted that most current research has been conducted in Caucasian women who have access to healthcare throughout pregnancy(427,428) and that many current studies poorly adjust for confounding factors(428). To establish the optimal nutritional pattern more consideration of the timing of individual nutritional components on adverse outcomes is required, as the optimal diet may vary throughout the course of pregnancy[390]. Furthermore, it is possible that the most advantageous diet may vary between individuals, given the complex interaction between an individual's epigenome, environment and metabolism[390].

Given our incomplete understanding of the specific nutritional components required during the preconceptual period and pregnancy, guidance currently varies. For example, the International Federation of Gynecology and Obstetrics (FIGO) have developed recommendations for preconception nutrition, which includes a requirement to ensure adequate folate, iron, calcium, vitamin D, iodine and vitamin B12[429]. This is of particular importance given that women with overweight or obesity have higher rates of vitamin B12, vitamin D and folate deficiency during pregnancy than women with a BMI in the recommended range[159]. A recent Early Nutrition project group endorsed recommendations for pregnant women to avoid vitamin A and to eat two portions of oily fish, or alternatively to take omega 3 supplements[277]. An expert review has suggested that the phrase "eat better, not more" is best suited to pregnancy[390]. For example, nutritional density can be achieved through whole foods, fruit, vegetables, legumes, whole grains, and omega 3 from nuts, seeds and fish instead of poor quality processed fats[390]. It is recommended to limit red meat, highly processed foods and processed meats, with diets limited in these components less likely to lead to excessive energy intake[390].

To summarise, dietary advice around healthy eating given to non-pregnant adults may not be the most beneficial diet to follow for pregnant women. More research is required into the specific nutritional components that optimise GWG, as well as maximise maternal and infant health. This will ensure the dietary advice provided to pregnant women is optimal.

#### 10.2.5.2 Group care

Several women within the qualitative component of this research programme stated that they would have liked access to group support for gestational weight management. Previous research generally shows group care is as effective as individual care. A systematic review of 89 RCTs found that interventions to optimise GWG were more effective, particularly for physical activity, when delivered as a group or when combining group and individual elements[264]. A further systematic review considered the effectiveness of group antenatal care per se, including 13 studies with the majority targeting a specific population, for example adolescents, women with obesity or women from a specific ethnicity[430]. They found no differences in excessive or recommended GWG with group prenatal care compared to usual care, although GWG was not consistently a primary outcome within the included studies[430]. Two studies within the systematic review provided results for women with obesity. The first study exclusively recruited women with obesity and found they gained significantly less GWG with prenatal group care (5.29kg) compared to traditional care (8.64kg)[431]. Subgroup analysis in the second study found no difference in either total GWG or GWG in accordance with IOM guidance for women with obesity receiving group care compared to traditional care[432]. The difference in results may be explained by the first study[431] specifically focussing on GWG management through six one hour sessions around nutrition, compared to a discussion around nutrition typically only included in the first group session within the second study[432]. A separate review of healthcare providers experiences of delivering group care found they were mainly positive about the experience[433]. They particularly felt able to provide women with more personal care and continuity of care[433]. Healthcare providers also felt it was a better use of their time and they valued the peer support community that developed within group care[433]. Providers also felt that group care enhanced women's autonomy and independence[433]. Additional research is required into the effectiveness of group care for women with obesity and the potential impact that social support may have on both clinical and psychological outcomes. However, not all women included within the qualitative component of this research programme would have welcomed this type of antenatal care, so the woman's preferences regarding care delivery should also be considered.

#### 10.2.5.3 Consider the social ecological context not just focus on the individual

Traditionally pregnancy has been viewed as a teachable moment as a woman's motivation shifts as she becomes aware of the health risks associated with pregnancy and takes on the new social and emotional role as she transitions to motherhood[434]. However, viewing pregnancy as an opportune time to provide lifestyle advice to women, only reinforces the individual approach and responsibility for weight[352]. True reproductive justice requires tackling structural inequalities, as well as social, economic and political injustices[360]. This can be achieved by employing a wider socio-ecological perspective. The social-ecological model considers demographics factors (such as age, income, education), as well as psychological aspects (anxiety, depression, stress, body image) and social elements (social support, culture), as well as organisational or governmental policy[299]. This removes the individual from being the centre of focus, which can lead to stigmatisation and blame[299]. Consideration of wider socio-ecological context is rarely seen within the literature. A review of public health interventions aimed at changing any behaviour during pregnancy found that organisational change did not come up in any of the studies, with education being the main approach[414]. An overview of systematic reviews of interventions to improve healthcare providers weight management behaviours for the general population not just in maternity also highlighted a need to address more organisational and system-level barriers[386].

To be effective complex interventions must consider complex social inequalities. This requires the development of interventions that support women who live in socio-economic disadvantage[396,412,435,436] and address factors such as education, parity and age[435]. This is essential as some women do not have access to resources to appropriately manage GWG[396]. Furthermore, environmental changes are needed to enable healthful choices[347,360]. For example, adequate access to exercise programmes within a community is required otherwise the boost in energy many women experience in the second trimester will not lead to effective behaviour change and increased physical activity[434]. Some socially disadvantaged women may also need support with the cost implications of buying fresh food or accessing physical activity programmes[396]. Limiting advertisement and selling of nutritionally poor and energy dense foods and beverages is also required, at the same time as helping families to develop good food habits and lifestyles[385]. A focus on addressing social support is also important[435]. The women's partner and family especially have an influence on the woman's motivation, opportunity and capability[434]. Co-production of interventions with women is an effective way to ensure they are non-stigmatising and address women's actual needs[412].

Psychological components need incorporating into interventions to optimise GWG[223] and into national policy regarding weight management in pregnancy[399] as these are frequently interrelated with obesity[349]. It is essential that interventions target psychological factors such as body image dissatisfaction[411,435,436], self-efficacy[411,436], concerns about weight[411], depression, anxiety, stress and maternal self-esteem[435]. Interventions also need to target internal motivation as it is a key component required to make behavioural changes[411]. Women themselves have also called for more psycho-social support around how to manage weight in pregnancy[356]. However, a recent review of interventions to prevent excess GWG, found only one study directly addressed psychosocial factors within the intervention by using cognitive behavioural therapy to challenge unhelpful cognitions[411]. The review also noted that pregnancy food cravings were very common, especially for high calorie sweets and carbohydrates[411]. As cravings are cognitively motivated, psychosocial approaches to help women manage their cravings during pregnancy were also suggested[411].

A whole systems approach to obesity which considers the multifactorial drivers behind obesity and weight management is viewed as essential by some academics[437]. A systems approach has multiple features including capacity building, relationship development, effective communication, policy development, clear leadership, and effective monitoring and evaluation[437]. A systematic review of 65 articles on whole systems approaches for health challenges such as obesity, smoking and alcohol consumption found effective approaches fully engaged with community partners and allowed time to build relationships and trust with the local community[437]. Additionally, successful approaches embedded the intervention in a wider policy context, undertook local evaluation and had adequate finance[437]. However, it was acknowledged that research into whole systems approaches is still limited and further evaluation is required[437].

### 10.2.5.4 Preconception care

Maternal lifestyle prior to and during pregnancy is viewed as essential, as epigenetics underpin the intergenerational cycle of obesity(438). The need to focus on maternal weight status prior to pregnancy to reduce childhood obesity(164,167) and optimise the health of future generations is increasingly being recognised(277). A focus on the preconception period is considered more important for reducing childhood obesity than focussing on pregnancy complications such as GDM and hypertension(167), with pre-pregnancy BMI believed to predict adverse perinatal outcomes to a greater extent than GWG(390). Additionally, excessive weight gain in early pregnancy is thought to be the strongest predictor of adverse outcomes, highlighting the importance of targeting interventions at the preconception or early pregnancy phases(390). Traditionally the preconception period is viewed as the 3 months prior to conception, which correlates with the average time for fertile couples to conceive(439). However, to adequately address public health risk factors such as diet and obesity much longer is deemed necessary, from several months to several years(439).

The need for a dual focus at both individual and population levels, the effectiveness of current approaches in the preconception period and the willingness of women to delay conception to address their weight are all considered below.

#### 10.2.5.4.1 A dual focus

Optimising maternal health requires a dual approach that focuses on women who are planning pregnancy, but also improving general population health(438,440,441). This is essential as most women do not plan pregnancy far enough in advance to influence outcomes which require a longer time scale such as achieving adequate weight reduction(438,440). However, simply providing education is rarely enough to effectuate behaviour change(440). Population engagement is needed so that individuals remain motivated to change and are supported socially, environmentally and at a societal level to undertake preconception health improvements(440). To ensure health inequalities are reduced not widened preconception interventions also need to consider environmental determinants to health[440,441]. For example, behaviour change cannot occur unless the woman has resources available including access to healthy foods[440]. Additionally, it is acknowledged that women who are healthiest are least likely to experience difficulty in accessing care, therefore support is needed for those most at risk to avoid increasing social inequalities[442]. To engage the wider population, all healthcare services need to be involved, not just maternity services, to take advantage of any contact with healthcare providers[440]. Effective preconception care requires strong local and national leadership to support social change[440]. The Netherlands serves as a positive case example in a high income country. They have successfully promoted preconception health that reaches the poorest communities by addressing social deprivation, harnessing political will and considering determinants of maternal ill-health[440].

As well as focussing on both women and the wider population, a combined focus on physical activity and healthy nutrition is required to support women to modify their BMI prior to conception[277]. Maternal diets are known to fall below nutritional recommendations in both high and low income countries, including the UK[439]. Current UK guidance for the preconception period focuses almost exclusively on nutritional adequacy, without considering physical activity[438]. The lack of physical activity recommendations is concerning as women's pre-pregnancy activity is an important determinant of their physical activity level during pregnancy, therefore establishing exercise patterns during the preconception period is essential[438]. The guidance is also criticised for lacking specific recommendations[438]. For example, restricting eating to a 10-12 hour window during the day may assist with weight loss in the preconception period[438]. High intensity intermittent exercise, which comprises short bursts of intense activity interspersed with low-to-moderate intensity exercise, is also viewed as potentially beneficial for the preconception and antenatal periods[438]. However further research is required into timing of nutrition and high intensity intermittent exercise to understand their feasibility and impact on weight and glycaemic control in the preconception population, as well as whether they have an additive benefit or whether each intervention is as effective separately[438]. It is also important that any preconception weight management intervention should be linked with continued support during the antenatal period[443].

10.2.5.4.2 Research in the preconception and interpregnancy periods

A review of randomised controlled interventions to support women of childbearing age with overweight or obesity found that the majority focussed on preventing GWG (53%) or promoting weight loss or preventing weight retention in the postnatal period (21%) or a combination of the two (16%)[444]. Only 10% of studies looked at women of childbearing age in general, with only one RCT directly supporting women in the preconception period[444]. It was therefore not currently possible to determine the optimal delivery mode, intensity or duration of preconception interventions[444]. A further systematic review exploring dietary patterns either before or during pregnancy on the risk of hypertensive disorders, GDM, preterm birth and birthweight also highlighted limited evidence within the preconception period[445].

Several reviews, incorporating both randomised and observational studies, have considered interventions in the preconception period. One review of women who intended to become pregnant showed women receiving a lifestyle intervention had greater weight loss during the study and lower resultant BMI compared to those in a control group[446]. Similarly, a review that specifically focussed on women with obesity found most non-surgical interventions achieved a weight loss of between 4-6kg regardless of whether they were healthy eating, physical activity, behavioural or combined interventions[443]. These interventions lasted between 27 days and 6 months. However only 4 studies recruited more than 100 women, studies were affected by high dropout rates, and most studies did not include a control arm to establish superiority of the intervention over no care[443]. Another review among women with infertility showed lifestyle interventions increased weight loss[447]. However, the minimal weight loss achieved through lifestyle modifications is discordant with current recommendations of achieving a ‘healthy’ weight prior to pregnancy, which for women with extreme obesity would require far greater levels of weight loss[443]. Weight loss expectations prior to pregnancy must be realistic with regards to what the evidence shows is achievable[443]. Additionally, it is thought that everyone has a ‘biological set point’ for weight, which means that most women who lose weight will regain it again[443]. Therefore, preconceptual interventions need to occur early enough to allow time to lose the required weight, but not so early before pregnancy that weight loss is regained[443].

When considering fertility outcomes, those receiving a lifestyle intervention have an increased natural pregnancy rate[446], but no differences in achieving pregnancy overall (whether naturally or assisted)[446]. The evidence among women with overweight or obesity and infertility is however conflicting. One review found lifestyle interventions increased natural conception rates as well as the likelihood of any pregnancy (natural or infertility treatment) and increased livebirth compared to no intervention[447]. A second review found lifestyle interventions improved pregnancy and livebirth rates in two included studies, but no difference was shown in three other included studies[448]. Combining lifestyle interventions with medication similarly found no significant difference in livebirth rates compared to standard care[448]. The limited differences in outcomes were likely to have been impacted by the minimal weight loss achieved and sustained within the interventional trials for both lifestyle and medication interventions[448].

Other pregnancy outcomes have also been considered, although maternal and infant outcomes are under-reported within many studies[447]. In the review of women who intended to become pregnant, no differences were found in birthweight or pregnancy complications such as preterm birth or neonatal mortality among those receiving a lifestyle intervention[446]. However, a review of women with overweight or obesity found that lifestyle interventions aimed at preconception weight loss reduced the risk of hypertensive disorders in pregnancy and pre-eclampsia[449]. An additional recent RCT of a drink supplement in the preconception period containing probiotics and micronutrients decreased preterm birth[450], and was associated with a 20% shorter length of second stage of labour and reduced blood loss at birth[451]. However, it showed no impact on GDM, birthweight[450], induction of labour or mode of birth[451].

Given the difficulties of recruiting women in the preconception period who are not experiencing infertility concerns, several researchers have focussed on the postnatal period as this is the preconception period of any subsequent pregnancy[452]. Several reviews have shown that weight loss between pregnancies is associated with decreased birthweight and while it increased the risk of having an SGA infant[452,453], it was protective against recurrent LGA in women with overweight or obesity[452]. In contrast research suggests weight gain between pregnancies is associated with increased risk of GDM, hypertensive disorders, Caesarean birth, having an LGA infant(452,453), prematurity(452), stillbirth(453), and childhood obesity(452). Tackling weight change between pregnancies may therefore optimise outcomes in any subsequent pregnancy(452). However more research is required to assess the feasibility, acceptability and effectiveness of interventions between pregnancies with a particular focus on women from disadvantaged backgrounds(452) as well as from different ethnicities. Women also report multiple barriers to intervention participation in the postnatal period such as lack of sleep, stress and limited spare time. Postnatal interventions would therefore need to be supportive around these factors such as offering home visits, childcare or enable self-monitoring for example by providing weighing scales at home(440).

10.2.5.4.3 Women's willingness to delay conception

It is essential to understand women's willingness to delay conception to engage with preconception lifestyle interventions. A survey of women accessing fertility treatment found 69% of women with overweight or obesity were already attempting weight loss strategies at the time of completing the survey(454). While 47% of women with overweight or obesity were interested in receiving medically supervised support to lose weight, only 16% of women with obesity were willing to delay fertility treatment for more than 3 months(454). There was no effect of age or length of infertility on the willingness to delay fertility treatment(454). A separate study found 65% of women with obesity were willing to delay removing a contraceptive device by 6 months to undertake a meal replacement plan aimed at losing weight(455). Women's willingness to delay conception therefore requires further study, but current evidence suggests women may be willing to delay conception for 3-6 months to undertake lifestyle modification.

In summary, while there is limited current evidence the potentially low cost, but large health return makes the preconception period an area worth further investigation(440). However, any further investigation should place a focus on minimising stigma, as little is currently known about weight stigma in the preconception period(349).

## 10.3 Strengths and limitations

This programme of research had multiple strengths. The large sample of women with BMI ≥40kg/m² was bigger than in most previous studies. Additionally, the research showed that data matching between datasets was feasible which allowed the association between attendance at the antenatal healthy lifestyle service intervention and long-term child weight to be assessed. Such long-term evaluation of pregnancy interventions on child weight was particularly limited in previous research. This programme of research was one of very few UK based studies to opportunistically assess maternal obesity management in a real life situation, including its long-term impact. It has paved the way for future cohort studies or big data analyses using existing data to answer key public health challenges within the maternal and infant health field.

A strength of the overview of systematic reviews, was that discrepancies in results within the different included reviews were investigated by returning to the original studies. The overview of reviews then either highlighted these inconsistencies or corrected data inaccuracies. This minimised the ongoing impact of errors in data extraction and inadvertent inclusion of studies within the systematic reviews that did not fully meet the original review's inclusion criteria.

There were various limitations within this programme of research that also need to be considered. Limitations for each aspect are detailed within each included article individually. However, limitations applicable to all aspects of the research programme are detailed below.

Within the field in general, heterogeneity of interventions in terms of type of intervention makes comparisons difficult. Most GWG management interventions do not adequately report the behaviour change components and techniques incorporated within the study[265]. This was also a limitation within this study. Having not been present when the antenatal healthy lifestyle service was established meant it was very difficult to fully determine the behaviour change components utilised within the service. This was partly due to the service wanting to be flexible to each individual woman's need, but it made it difficult to evaluate the content of the service. It was also not possible to assess the provider-client relationship within the intervention and how this may have influenced the service impact.

Additionally, there was heterogeneity in the gestation of weighing for both the first and last weight from which GWG was calculated. This was especially an issue for the average gestation at the final weight between women offered the low intensity service and enhanced service. To account for this rate of GWG was considered which averaged weight gain over the time between first and last weight in pregnancy.

The retrospective nature of the study was a limitation for all aspects of the quantitative research. Retrospective data is known for issues regarding data completeness. This particularly affected the utility of the variable maternal education as this was poorly recorded within the medical notes. There were also issues around our primary outcome GWG as weight was only recorded from 34 weeks gestation onwards in 25% of women within the comparison cohort, compared to 79% of women offered the antenatal healthy lifestyle service. Retrospective data also limits the researcher to the variables available, rather than necessarily all variables of interest. For example, if data had been collected prospectively it would have been possible to collect data around maternal diet so specific components could have been assessed for their impact on GWG. Other factors like psychological well-being could also have been assessed, as these can mediate the impact of any intervention. Additionally, more accurate collection and categorisation of medical complications experienced during pregnancy would have been possible with prospective data collection, as well as gathering data on longer term breastfeeding outcomes.

All qualitative data was only collected from one Trust and the quantitative data was collected from only two neighbouring Trusts. Both Trusts had very few women of non-White British ethnicity compared to the national picture. The Trust demographics therefore limit both the quantitative and qualitative components with regards to applicability to a diverse ethnic population.

Among women who were offered the antenatal healthy lifestyle service, those who were already parous gained less weight during pregnancy. However, a lower percentage of parous women had GWG recorded compared to nulliparous women, which could have influenced the results as those who had a GWG recorded may have been more motivated to monitor their weight gain.

## 10.4 Summary

This chapter has discussed the key integrated findings from this programme of research in relation to the existing literature and wider evidence base. The chapter demonstrated that the lack of impact of the antenatal healthy lifestyle service seen within this programme of research corresponds with much of the literature within this area.

The stigma faced by women with obesity during pregnancy was also considered. The causes of stigma and the wide spread prevalence within healthcare was highlighted. The impact of stigma on women's weight related behaviours and mental health were discussed, as well as the potential influence of stigma on pregnancy related adverse outcomes. The requirement for more healthcare provider training to reduce stigma was highlighted.

The chapter also discussed the importance of socio-ecological context when addressing weight management, as well as the potential different needs and intervention impact on women of different parities.

This points to a requirement to refine the type of interventions we currently deliver. Interventions particularly need to explicitly detail the behaviour change strategies they aim to address; more consideration should be given to addressing weight management in the preconception period and a focus beyond the individual is essential when considering gestational weight management. The strengths and limitations of this programme of research have also been discussed, alongside their potential implications.

The next and final chapter concludes this programme of research by exploring the original contribution of each element of the research. The implications of the findings of this programme of research on policy and practice are considered, alongside identifying potential avenues for future research.

# Chapter 11: Conclusions

## 11.1 Introduction

This chapter discusses the original contribution of this programme of research to the overall topic area. Recommendations for research, practice and policy are also given.

## 11.2 Original contribution of this research to knowledge

Systematic reviews originally evolved within healthcare due to the large volume of primary research rendering decision-making for policy makers and practitioners difficult, especially in the face of contradictory evidence(456,457). As systematic reviews have increasingly been published, clinicians can again be left feeling overwhelmed by the plethora of evidence. Therefore, the requirement for overviews of reviews which compare and contrast current systematic reviews and provide an overall body of available information on a given topic is increasingly recognised(456). Given the rising number of systematic reviews within the area of lifestyle interventions in pregnancy with authors reporting contrasting results, including for women with overweight or obesity, a systematic synthesis of current reviews was deemed imperative. This provided an overall body of evidence that evaluated the most appropriate interventions for assisting women with overweight or obesity to avoid excessive GWG. Article A, the overview of systematic reviews, therefore added clarity within this area by collating the global evidence and providing an up-to-date summary of previously published works. By focussing on a wide range of maternal and infant outcomes it was able to demonstrate the limited impact of lifestyle interventions on clinical outcomes.

The quantitative work contained in Articles B, C and D has made a positive contribution to the field in several ways. Firstly, the analysis added evidence on both the short-term impact of a real-life lifestyle intervention among women with a BMI ≥40kg/m² and on the long-term outcome of infant weight among women with a BMI ≥35kg/m² attending an antenatal healthy lifestyle service. This is particularly important given the under-representation of women with a BMI of

35.0-39.9kg/m² and of those with a BMI ≥40kg/m² in previous research[2]. Secondly, the work explored the effect of an antenatal lifestyle service in a real-life clinical situation. Pragmatic interventions are increasingly recognised as the ideal way to determine the impact of interventions under real-world conditions[458]. The work therefore added to the debate over the most effective interventions for effective weight management during pregnancy for women with the highest classes of obesity. Article C provided new insights into the impact of an antenatal healthy lifestyle service in comparison to an NHS Trust that did not provide a specific service. Interventions to date have varied widely in intensity, ranging from simply providing information through to providing in depth interventions with multiple contacts every week during pregnancy. Finding the most effective intervention intensity has major cost implications for rolling out any effective intervention. The changing intensity within the delivery of the antenatal healthy lifestyle service provided a unique opportunity to evaluate the impact of the change to service intensity. Article B therefore further informed the debate around intervention intensity.

Finally, Article D provided a unique analysis by matching data from maternity records and child health records. Data matching in this way has not previously been undertaken within the UK. While much research had previously looked at the long-term impact of GWG on offspring obesity[164,252], little had been done to evaluate the association between pregnancy lifestyle interventions and long-term infant health, especially in women with obesity. This is despite the long-term impact of maternal health and diet prior to and during pregnancy on offspring health and development through the role of epigenetics being increasingly understood[160,161]. This work therefore contributed original knowledge around the association between antenatal healthy lifestyle service provision and long-term childhood weight outcomes up to age 5 in women with a BMI ≥35kg/m². Unlike previous research, this was undertaken exclusively in women with obesity and was in an English cohort.

In addition to the quantitative work, the qualitative interviews in Article E explored the experiences of antenatal weight management among women with a BMI ≥40kg/m². While there was existing research into the experiences of women with a raised BMI, those with a BMI in the higher ranges were less well represented within the literature. It was therefore important to add these women's voices to the evidence base.

## 11.3 Implications for research

This programme of research has identified numerous avenues for further work within the area.

Given the lack of benefit of gestational weight management interventions on maternal and infant clinical outcomes it is essential to explore the practicality and impact of interventions in the preconception or inter-conception periods.

Whether focussed on the preconception, inter-conception or antenatal period, future interventions should make use of the Medical Research Council (MRC) and the National Institute for Health Research (NIHR) framework for developing and evaluating complex interventions[(419)] to ensure their optimum impact on health outcomes. As part of this the context of the intervention needs to be considered. This includes placing more emphasis on socio-ecological factors within interventions, rather than simply focussing on individual behaviour. Consideration should be given to environmental, social, organisational, community, economic and policy factors that are barriers to weight management for women, as well as the interaction between these components[(299)]. For example, rather than simply focussing on traditional lifestyle interventions that encourage the individual with healthy eating and/or physical activity components, the psychological components need incorporating into interventions to optimise GWG[(223)]. This includes addressing body image dissatisfaction[(411,435,436)], self-efficacy[(411,436)], depression, anxiety, stress and maternal self-esteem[(435)] as they are all interrelated with obesity[(349)]. More consideration is also required of the influence of the woman's family and friends, how childcare accessibility, affordability and availability may impact her choices, how the environment in which she lives plays a role such as the cooking and fresh food storage options within her home, the types of food outlets or shops within her local area, the safety of her local area to participate in activities such as walking and the availability of local parks or leisure centres[(459)]. Wider environmental influences also need to be considered. Commercial companies produce processed foods and beverages that are nutritionally poor and energy dense which they promote through advertisement. This increases their prominence and appeal in comparison to non-processed foods which are not promoted in the same way. This determines product placement within shops, as well as availability[459] with shops stocking different food items in different stores to maximise their expected sales.

Any future interventions will also need to develop a theory as to how the intervention is expected to lead to the anticipated effects as this would allow better identification of effective components in managing GWG and maternal obesity to inform transferability of interventions between different settings. This may include consideration and explanation of the behaviour change components incorporated within the intervention. Additionally, engaging with stakeholders at every phase of the research from development through to implementation and evaluation is essential for any new intervention. Co-designing interventions with women will ensure they are sensitive to women's needs. It is essential to include as stakeholders women that are traditionally less likely to engage with services, including those from the most deprived quintile, who are not employed outside the home or who smoke, as well as those from ethnic minorities to enhance intervention acceptability to this group of women. The voices of the healthcare providers expected to deliver any intervention or provide weight management advice also need to be sought to identify potential barriers to implementation and how these could be addressed including through adequate training to enhance confidence.

Any lifestyle intervention that incorporates healthy eating or physical activity components should investigate the required frequency of contacts and the most beneficial level of supervision. This will enable a full understanding of the economic costs of the intervention to achieve the most benefit.

This programme of research clearly showed that any intervention evaluating weight management in women with obesity requires a relevant control group. While randomisation to the intervention or control group is the 'gold standard' as it controls for both known and unknown confounders allowing causal relationships to be established[460], pragmatic trials with adequate controlling for confounders can also provide valuable insight into how interventions work in real life settings. Whatever study design is chosen a relevant control group is crucial given the wide range of GWG seen in different regions across the globe, as well as variations over time. The need for robust, independent evaluation of any intervention was also clearly shown and is imperative to determine cost effectiveness of services and is essential before wider implementation or resource investment.

It is also essential that future research consider the different classes of obesity separately. Current evidence points to differences in effectiveness of interventions, but also differing levels of GWG that cause adverse outcomes within each subgroup of obesity. More careful consideration of different classes of obesity will enable clarification of the ideal GWG for each class of obesity, as well as more targeted approaches to supporting women with a BMI ≥40kg/m² with weight management prior to and during pregnancy. More UK based studies or big data analyses are particularly recommended to assess the impact of GWG for each BMI class on both maternal and infant short- and long-term outcomes.

To reduce heterogeneity between studies, a universal convention for the measurement of GWG would be beneficial. As a minimum adjustment for gestation at final weight is required where actual weight at birth is not recorded.

When compiling an overview of systematic reviews, researchers should be alert for inaccuracies within the included systematic reviews to prevent perpetuation of any errors.

## 11.4 Implications for practice

Weight management services in pregnancy must be sensitive, respectful and centred on the individual woman. Implementation of a personalised approach is essential, for example considering women's previous experience of weight management and her current readiness, rather than providing the same advice to everyone using a tick box approach. Services should focus on the provision of practical information, for example menu plans, exercise plans and recipes as this was what women requested. Most women within our interviews reported that they did not receive any information around physical activity in pregnancy. Therefore providing more advice around physical activity recommendations, benefits and its safety in pregnancy needs to be a particular priority for healthcare providers. Additionally, healthcare providers should develop ways to promote effective group support either physically or electronically which allows peer interaction and encouragement for the women that would like this option, while also continuing to offer individual care for women that lack confidence to engage with a group format. Any group support established should be monitored to ensure it provides the required engagement and support to enable women to make effective behaviour changes.

Women expressed a preference for discussing weight management in the context of a trusting relationship. They also valued opportunities to discuss their weight with the same person on multiple occasions so that their progress could be monitored and supported. Where staffing levels are adequate to accommodate a continuity of midwifery care model, this should be provided to women to enable ongoing conversations throughout pregnancy that can follow the woman’s progress and support her with any adjustments that are required throughout her pregnancy.

For healthcare providers to effectively address weight management during pregnancy, healthcare provider training is needed both as part of continued professional development as well as within pre-registration education. Training is required on the impact of stigma, how to sensitively address weight management and understanding of the complex psychological, social and environmental context in which weight management occurs. Many women with obesity felt that their healthcare providers assumed that they would encounter every associated adverse outcome, which only perpetuated the stigma that these women felt. There therefore also needs to be training for healthcare providers that increased risk of certain conditions among women with obesity does not mean that everyone with obesity will encounter those adverse events.

Calibrated weighing scales should be more readily available within all clinical environments as most women appreciated receiving encouragement when their weight gain was good and being provided with personalised support when weight gain was more than ideal.

As digital records become increasingly the norm within maternity care it provides an ideal opportunity for alerts to be set for healthcare providers to help them remember to incorporate aspects of weight management into each antenatal appointment. It also provides an ideal format in which to incorporate practical advice around healthy eating and physical activity for women that they can access at a time convenient to them. Where not provided digitally, resources incorporating practical advice should be readily available and accessible for women including those whose first language is not English or whose cultural expectations and norms around food differ.

Weight management services need to consider appropriate support of women not just during pregnancy but also in the preconception and postnatal periods, as the postnatal period will be the preconception period for any subsequent pregnancy.

## 11.5 Implications for policy

Current NICE guidance is felt to perpetuate weight stigma by stating that women with obesity should be informed of the risks during pregnancy, without explicitly detailing the practical advice they should be offered to manage GWG. This has led to a situation where healthcare providers adhere to policy by advising women of the risks associated with being obese during pregnancy, while women themselves are focussed more on their individual needs and on their requirement for practical advice. This leaves women feeling disempowered as their informational and support needs are not addressed by healthcare providers. Policy updates should provide detailed and explicit advice regarding healthy eating, physical activity and weight management in pregnancy and how healthcare providers can tailor this information for each individual woman so that her needs are addressed. Policy updates should also consider the impact of weight stigma on pregnancy outcomes and how stigma can be reduced during the perinatal period. As part of this policy updates should detail the biological, demographic, social, psychological, environmental, and organisational aspects that are known to be wider determinants of obesity so that all healthcare providers understand that obesity is not simply due to the lifestyle choices that a woman makes. Additionally, policy updates should encourage research into interventions that effectively address these wider determinants of obesity rather than focusing predominantly on individual lifestyle interventions.

Policy updates should also recommend midwife continuity of care during pregnancy and the postnatal period for women with obesity where feasible.

## 11.6 Implications for other PhD students

Throughout my PhD journey I have learnt that undertaking a PhD is about more than just producing a thesis. It is about developing as an individual. So much of my learning has been through interactions with other PhD students and researchers and learning from the challenges they were facing within their research. Additionally, I have attended numerous study days, workshops and seminars. These have served to broaden my understanding of research methodology and enhance my development as a researcher in areas related to my PhD topic and methodology, as well as in other unrelated areas. It has made me think about the diverse ways in which research questions can be answered and given me inspiration for avenues that I might want to explore as a post doc researcher. Attendance at topic related conferences during my PhD studies has also served to enhance my understanding of the current issues and advances within the field and influenced my understanding of the topic, as well as the interpretation of the results of this programme of research. It has also meant that I have been able to discuss my work with other researchers interested in this field. My advice to any PhD student would be to take hold of every opportunity that presents itself to you during your PhD journey, you will be amazed at how much they benefit you as you seek to become an independent researcher.

## 11.7 Summary

This thesis summarises a comprehensive, pragmatic mixed methods programme of research around the effectiveness of GWG management interventions for women with obesity. The findings suggest that although current interventions are sometimes effective at reducing average GWG, they are largely ineffective at influencing clinical outcomes. Additionally, current services leave many women with obesity feeling stigmatised, due to an excessive focus on the risks of obesity in pregnancy without providing practical advice or support on how to mitigate the risks.

The research has identified numerous areas that require further exploration, which have been captured in the implications for research, practice, and policy sections. Most notably the need for future interventions to address wider demographic, social, psychological, environmental, and organisational aspects has been highlighted. The current evidence also suggests more emphasis on addressing weight management prior to pregnancy may be needed to provide beneficial outcomes for the mother and their child.

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# Appendices

Included appendices:

Appendix A: Author contribution to each of the included articles and copyright permissions

Appendix B: Prospero registration for the overview of reviews

Appendix C: Supplementary information for overview of reviews

Appendix D: Ethical approval letter for the quantitative research component

Appendix E: Ethical approval letter for the qualitative interviews

Appendix F: Participant information sheet qualitative interviews

Appendix G: Participant consent form qualitative interviews

Appendix H: Supplementary material for the antenatal healthy lifestyle service intensity article

Appendix I: Supplementary information for the qualitative interviews article: the interview schedule

# Appendix A: Author contribution to each of the included articles

## Outputs

### Article A

| | |
|---|---|
| Title | A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity. |
| Authors | Frankie J Fair, Hora Soltani |
| Full Reference | Fair F, Soltani H (2021). A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women with overweight or obesity, *Obesity Reviews*, 22(5):e13199. |
| Contribution statement | This piece of work was led by Frankie Fair, who oversaw and was involved in all stages of the research process including study design and protocol development, developing and executing the search strategy, study selection, data extraction, critical appraisal, analysis and interpretation of the results. Frankie Fair also wrote the initial manuscript and agreed the final manuscript for submission. |
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## Article B

| | |
|---|---|
| Title | Differing intensities of a midwife-led antenatal healthy lifestyle service on maternal and neonatal outcomes: A retrospective cohort study. |
| Authors | Frankie J Fair, Hora Soltani |
| Full Reference | Submitted to Midwifery |
| Contribution statement | Frankie Fair helped with protocol development and assisted with data collection. Frankie Fair undertook data analysis and interpretation of the data; wrote the initial manuscript; and revised the manuscript after input from Hora Soltani. |

## Article C

| | |
|---|---|
| Title | A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index. |
| Authors | Frankie J Fair, Hora Soltani |
| Full Reference | Fair FJ, Soltani H (2023). A retrospective comparative study of antenatal healthy lifestyle service interventions for women with a raised body mass index. *Women and Birth,* 37(1), 197-205. doi: 10.1016/j.wombi.2023.08.010 |
| Contribution statement | Frankie Fair assisted with conceptualisation and funding acquisition, data curation, formal analysis and interpretation of the data, writing the original draft and approval of final manuscript. |
| Permissions | The open access articles published in Women and Birth are made available under the Creative Commons CC-BY license, which means they are accessible online and permit unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited. |

## Article D

| | |
|---|---|
| Title | Association of child weight with attendance at a healthy lifestyle service and sociodemographic characteristics among women with obesity during pregnancy |
| Authors | Frankie J Fair, Hora Soltani |
| Full Reference | Fair FJ, Soltani H (2024) Association of child weight with attendance at a healthy lifestyle service and sociodemographic characteristics among women with obesity during pregnancy. *Maternal and Child Nutrition*, 20(2):e13629. doi: 10.1111/mcn.13629. |
| Contribution statement | Frankie Fair helped with protocol development and assisted with data collection. Frankie Fair undertook data analysis and interpretation of the data; wrote the initial manuscript; and revised the manuscript after input from Hora Soltani and agreed the final manuscript. |
| Permissions | This article was published open access in Maternal and Child Nutrition and distributed under the Creative Commons CC-BY license, which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited. |

## Article E

Qualitative aspect

| | |
|---|---|
| Title | "Everything is revolved around me being heavy … it's always, always spoken about." Qualitative experiences of weight management during pregnancy in women with a BMI of 40kg/m² or above. |
| Authors | Frankie J Fair, Helen Watson, Katie Marvin-Dowle, Rachael Spencer, Hora Soltani. |

| | |
|---|---|
| Full Reference | Fair FJ, Watson H, Marvin-Dowle K, Spencer R, Soltani H (2022). “Everything is revolved around me being heavy … it’s always, always spoken about.” Qualitative experiences of weight management during pregnancy in women with a BMI of $40kg/m^2$ or above. *PLoS ONE*, 17(6):e0270470. |
| Contribution statement | Frankie Fair assisted with development of the protocol; undertook face-to-face interviews and some telephone interviews, analysed the data, interpreted the data; wrote the initial manuscript and revised the manuscript after contributions from other authors. |
| Permissions | The open access articles published in PLoS One are available under the Creative Commons Attribution (CC-BY) license, which means they are accessible online without any restrictions and can be re-used in any way, subject only to proper attribution of the original authors and the source. |

# Appendix B: Prospero registration for the overview of reviews

# A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women who are overweight or obese

*Frankie Fair, Hora Soltani*

## Citation

Frankie Fair, Hora Soltani. A meta-review of systematic reviews of lifestyle interventions for reducing gestational weight gain in women who are overweight or obese. PROSPERO 2019 CRD42019156883 Available from:
https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019156883

## Review question

What is the extent of systematic evidence regarding the effectiveness of lifestyle interventions on gestational weight gain in women who are overweight or obese? Lifestyle interventions include dietary interventions, physical activity or a combination of both.

Population – pregnant women who are overweight or obese

Intervention – lifestyle interventions, including dietary interventions, physical activity interventions, a combination of dietary and physical activity interventions.

Control – usual antenatal care

Outcome – gestational weight gain

Study design – systematic reviews of randomised controlled trial evidence

## Searches

The databases to be searched are CINAHL, MEDLINE, Maternal and Infant Health, PsycINFO, Scopus, DARE, PROSPERO, Cochrane Library.

The search strategy will include search terms around 'pregnancy', 'lifestyle interventions', 'obesity' and 'systematic review' with Boolean logic used to combine the search terms.

No date restrictions will be used, with databases searched from inception to date. Studies will be limited to those published in the English language only. Reviews will only be included where full text articles can be obtained.

The reference list of all included systematic reviews will be screened manually for further relevant citations.

The date of the initial searches will be recorded, with the searches re-run prior to the final analysis to identify any further systematic reviews for inclusion.

Authors of included systematic reviews will be contacted for further information if required.

## Types of study to be included

Systematic reviews will be included where the systematic review has only included randomised controlled trial evidence.

## Condition or domain being studied

Any lifestyle intervention aimed at reducing gestational weight gain in women who are overweight or obese. Lifestyle interventions can include dietary interventions, physical activity interventions or a combination of these.

## Participants/population

Inclusion criteria: Systematic reviews of women in the antenatal period who are overweight or obese.

Exclusion criteria: Interventions exclusively pre-conception or in the postnatal period or those including women with a BMI in the normal range, unless clear subgroup analysis has been performed on women who are overweight or obese.

## Intervention(s), exposure(s)

Lifestyle interventions, including dietary interventions, physical activity interventions or a combination of both aimed at reducing gestational weight gain.

## Comparator(s)/control

Routine antenatal care.

## Context

No inclusion/exclusion criteria have been included for the setting. Interventions may be home based, community based or in the clinical setting.

## Main outcome(s)

Gestational weight gain. Reviews must include the primary outcome of gestational weight gain to be included.

### * Measures of effect

All measures of gestational weight gain will be included - either weight gain from pre-pregnancy weight or from weight at booking.

## Additional outcome(s)

Where reported other outcomes will be reported including adherence to IOM weight gain recommendations, changes in dietary intake, physical activity outcomes such as step count. Where reported other maternal and neonatal outcomes will also be recorded such as proportion of women with gestational diabetes, birthweight, large for gestational age, small for gestational age.

### * Measures of effect

Not applicable.

## Data extraction (selection and coding)

Citations identified by the search strategy will be assessed by the information provided in the title and abstract for relevance by one researcher. A second reviewer will screen a sample of 10% of retrieved citations. Cases of uncertainty will be resolved by discussion. All reviews considered to be relevant will have their full articles reviewed and assessed for inclusion by two independent researchers. Reasons for excluding studies at full text will be provided. Screening of search results will be recorded using the PRISMA checklist (Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Group, P. Preferred reporting items for systematic reviews and meta-analyses: The prisma statement. PLoS Med. 2009, 6, e1000097).

Data extraction will be undertaken by two researchers using a pre-defined data extraction table from each included systematic review. Data extracted will include: author; date of publication; number of included studies, number of women included, interventions included, outcomes. Any ambiguous information will be checked with the authors of the systematic reviews or the original studies.

## Risk of bias (quality) assessment

Included systematic reviews will be assessed for risk of bias using the Assessment of Multiple Systematic

Reviews v2 (AMSTAR-2) checklist (Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358: j4008) by two independent researchers. Any disagreement will be resolved by discussion with a third reviewer.

## Strategy for data synthesis

Where included systematic reviews provide sufficient data, meta-analyses will be pooled. Effect sizes from meta-analyses will be converted to standardised mean differences where required. Overlap between individual primary studies incorporated into multiple systematic reviews will be taken into account. Any meta-analysis addressing the same research question and only analysing a subset of individual studies present in another meta-analysis will be excluded from data synthesis. Within each included review $I^2>50\%$ will be classified as high heterogeneity and $I^2>75\%$ very high heterogeneity. Meta-synthesis using the analytical procedure described by Tang et al (2013) will be conducted if heterogeneity is >50%.
Egger et al (1997) regression asymmetry test will be undertaken to detect any evidence of small study effects. Egger’s test $p<0.10$ alongside a more conservative effect size in the largest study than the random-effects model summary estimate will be regarded as indicative of small study effects.
Ioannidis & Trikalinos (2007) excess of significance test will be used to assess whether the observed number of studies with nominally significant results (positive studies, $p<0{\cdot}05$) within a meta-analysis is larger than the expected number. Excess significance for single meta-analysis will be considered if $p<0.10$.
A ‘Summary of Findings’ table will determine the strength of evidence for each outcome. GRADE assessment will be based on: risk of bias, inconsistency, indirectness, imprecision, small study effects and reporting bias. An overall grade, high, moderate, low or very low will reflect confidence in the evidence.
Where high heterogeneity (>50%) or lack of sufficient data within included systematic reviews prevents pool meta-analysis, a narrative synthesis will be performed. Whether evidence suggests gestational weight gain and other secondary outcomes are increased, decreased or there is no change after lifestyle interventions, or where results are inconclusive will be assessed. Differences in quality between included reviews will be discussed, in addition to comparing findings.

## Analysis of subgroups or subsets

Separate tables will be provided for dietary interventions only, physical activity interventions only, combined lifestyle interventions. Further subgroup analysis will be considered on AMSTAR2 areas of weakness within included systematic reviews.

## Contact details for further information

Frankie Fair
f.fair@shu.ac.uk

## Organisational affiliation of the review

Sheffield Hallam University

## Review team members and their organisational affiliations

Mrs Frankie Fair. Sheffield Hallam University
Professor Hora Soltani. Sheffiel Hallam University

## Type and method of review

Review of reviews, Systematic review

## Anticipated or actual start date

01 December 2019

## Anticipated completion date

31 December 2020

## Funding sources/sponsors

None.

## Conflicts of interest

## Language
English

## Country
England

## Stage of review
Review Ongoing

## Subject index terms status
Subject indexing assigned by CRD

## Subject index terms
Female; Humans; Life Style; Obesity; Overweight; Weight Gain; Weight Loss

## Date of registration in PROSPERO
06 December 2019

## Date of publication of this version
06 December 2019

## Details of any existing review of the same topic by the same authors

## Stage of review at time of this submission

| Stage | Started | Completed |
|---|---|---|
| Preliminary searches | Yes | No |
| Piloting of the study selection process | Yes | No |
| Formal screening of search results against eligibility criteria | No | No |
| Data extraction | No | No |
| Risk of bias (quality) assessment | No | No |
| Data analysis | No | No |

## Versions
06 December 2019

# Appendix C: Supplementary information for the overview of reviews

**Table S1. Search strategy in CINAHL search VIA EBSCO host**

1. pregnan*
2. antenatal
3. perinatal
4. prenatal
5. gestatio*
6. matern*
7. mother*
8. gravid*
9. (MH "Expectant Mothers")
10. (MH "Prenatal Care")
11. (MH "Pregnancy")
12. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11
13. weight management
14. weight gain
15. diet*
16. physical activity
17. exercise
18. behavio#r change
19. lifestyle
20. (MH "Gestational weight gain")
21. (MH "Weight Control")
22. (MH "Weight Reduction Programs")
23. 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22
24. obes*
25. overweight
26. raised BMI
27. raised body mass index
28. high BMI
29. high body mass index
30. high body mass
31. raised body mass
32. (MH "Obesity")
33. (MH "Body Mass Index")
34. 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33
35. systematic review
36. meta-analysis
37. meta analysis
38. (MH "Meta Analysis")
39. (MH "Systematic Review")
40. 35 OR 36 OR 37 OR 38 OR 39
41. 12 AND 23 AND 34 AND 40

**Table S2. AMSTAR Quality appraisal tool**

Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358:j4008.

**1. Did the research questions and inclusion criteria for the review include the components of PICO?**
□ Population
□ Intervention
□ Comparator group
□ Outcome GWG

**All included:** □ **Yes** □ **No**

---

**2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?**

<u>For Partial Yes</u>: The authors state that they had a written protocol or guide that included ALL the following:
□ review question(s)
□ a search strategy
□ inclusion/exclusion criteria
□ a risk of bias assessment

<u>For Yes</u>: As for partial yes, plus the protocol should be registered and should also have specified:
□ a meta-analysis/synthesis plan, if appropriate,
□ a plan for investigating causes of heterogeneity
□ justification for any deviations from the protocol

□ **Yes** □ **Partial Yes** □ **No**

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**3. Did the review authors explain their selection of the study designs for inclusion in the review?**

<u>For Yes</u>, the review should provide:
□ Explanation for including only RCTs

□ **Yes** □ **No**

| |
|---|
| **4. Did the review authors use a comprehensive literature search strategy?**<br><br>For Partial Yes (all the following):<br> searched at least 2 databases (relevant to research question)<br> provided key word and/or search strategy<br> justified publication restrictions (e.g. language)<br><br>For Yes, should also have (all the following):<br> searched the reference lists / bibliographies of included studies (<br> searched trial/study registries<br> included/consulted content experts in the field<br> where relevant, searched for grey literature<br> conducted search within 24 months of completion of the review<br><br> **Yes**  **Partial Yes**  **No** |
| **5. Did the review authors perform study selection in duplicate?**<br><br>For Yes, either ONE of the following:<br> at least two reviewers independently agreed on selection of eligible studies and achieved consensus on which studies to include<br> OR two reviewers selected a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder selected by one reviewer.<br><br> **Yes**  **No** |
| **6. Did the review authors perform data extraction in duplicate?**<br><br>For Yes, either ONE of the following:<br> at least two reviewers achieved consensus on which data to extract from included studies<br> OR two reviewers extracted data from a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder extracted by one reviewer.<br><br> **Yes**  **No** |
| **7. Did the review authors provide a list of excluded studies and justify the exclusions?**<br><br>For Partial Yes:<br> provided a list of all potentially relevant studies that were read in full-text form but excluded from the review<br><br>For Yes, must also have:<br> Justified the exclusion from the review of each potentially relevant study<br><br> **Yes**  **Partial Yes**  **No** |

**8. Did the review authors describe the included studies in adequate detail?**

For Partial Yes (ALL the following):
□ described populations
□ described interventions
□ described comparators
□ described outcomes
□ described research designs

For Yes, should also have ALL the following:
□ described population in detail
□ described intervention in detail (including doses where relevant)
□ described comparator in detail (including doses where relevant)
□ described study's setting
□ timeframe for follow-up

□ **Yes** □ **Partial Yes** □ **No**

**9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?**

For Partial Yes, must have assessed RoB from
□ unconcealed allocation
□ lack of blinding of patients and assessors when assessing outcomes (unnecessary for objective outcomes such as all cause mortality)

For Yes, must also have assessed RoB from:
□ allocation sequence that was not truly random,
□ selection bias

□ **Yes** □ **Partial Yes** □ **No**

**10. Did the review authors report on the sources of funding for the studies included in the review?**

For Yes
□ Must have reported on the sources of funding for individual studies included in the review. Note: Reporting that the reviewers looked for this information but it was not reported by study authors also qualifies

□ **Yes** □ **No**

**11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?**

For Yes:
□ The authors justified combining the data in a meta-analysis
□ AND they used an appropriate weighted technique to combine study results and adjusted for heterogeneity if present.
□ AND investigated the causes of any heterogeneity

□ **Yes** □ **No** □ **No meta-analysis conducted**

| |
|---|
| **12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?**<br><br><u>For Yes:</u><br> included only low risk of bias RCTs<br> OR, if the pooled estimate was based on RCTs at variable RoB, the authors performed analyses to investigate possible impact of RoB on summary estimates of effect.<br><br> **Yes**  **No**  **No meta-analysis conducted** |
| **13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?**<br><br><u>For Yes</u>:<br> included only low risk of bias RCTs<br> OR, if RCTs with moderate or high RoB were included the review provided a discussion of the likely impact of RoB on the results<br><br> **Yes**  **No** |
| **14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?**<br><br><u>For Yes:</u><br> There was no significant heterogeneity in the results<br> OR if heterogeneity was present the authors performed an investigation of sources of any heterogeneity in the results and discussed the impact of this on the results of the review<br><br> **Yes**  **No** |
| **15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?**<br><br><u>For Yes:</u><br> performed graphical or statistical tests for publication bias and discussed the likelihood and magnitude of impact of publication bias<br><br> **Yes**  **No**  **No meta-analysis conducted** |
| **16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?**<br><br><u>For Yes</u>:<br> The authors reported no competing interests<br>OR  The authors described their funding sources and how they managed potential conflicts of interest<br><br> **Yes**  **No** |

**Table S3. Reasons for excluding articles at full text**

| | Reference | Reason for exclusion |
|---|---|---|
| 1 | The International Weight Management in Pregnancy (i-WIP) Collaborative Group[2] | Research overview commentary on included study International Weight in Pregnancy Group 2017[1] |
| 2 | Allen et al 2014[3] | GWG not reported as an outcome |
| 3 | Behnam et al 2018[4] | Published in German – unable to find English version other than abstract |
| 4 | Bennett et al 2018[5] | GWG not reported as an outcome |
| 5 | Bennett et al 2019[6] | GWG not reported as an outcome |
| 6 | Boerger et al 2014[7] | Poster abstract – unable to obtain full text |
| 7 | Brown et al 2017[8] | No overweight/obese subgroup |
| 8 | Carolan-Olah 2016[9] | Included non-RCT studies (eg cohort, quasi-experimental, comparative). No overweight / obese subgroup |
| 9 | Craemer et al 2019[10] | Included non-RCT studies (eg controlled studies, cross-sectional studies) |
| 10 | Dodd et al 2008[11] | GWG not reported as an outcome |
| 11 | Domenjoz et al 2014[12] | No overweight/ obese subgroup |
| 12 | Elliott-Sale et al 2014[13] | Conference abstract for Elliott-Sale et al 2015[14] |
| 13 | Elliott-Sale et al 2014[14] | No overweight /obese subgroup |
| 14 | Farpour-Lambert et al 2018[15] | Overview of systematic reviews, not systematic review |
| 15 | Fealy et al 2017[16] | Weighing intervention rather than lifestyle intervention |
| 16 | Gardner et al 2011[17] | Included non-RCT studies (eg cohort studies, time series studies) |
| 17 | Gresham et al 2014[18] | GWG not reported as an outcome |
| 18 | Gresham et al 2016[19] | GWG not reported as an outcome |
| 19 | Guo et al 2019[20] | GWG not reported as an outcome – it was used as a measure of intervention intensity. No overweight /obese subgroup |
| 20 | Han, Crowther et al 2012[21] | Includes BMI subgroups, however GWG not a primary outcome so subgroup analysis for BMI not done on GWG outcome |
| 21 | Han, Middleton et al 2012[22] | No overweight /obese subgroup |
| 22 | Heslehurst et al 2014[23] | Planned to include not RCT studies (studies of any design), GWG not an outcome |
| 23 | Hill et al 2013[24] | Included non-RCT studies (eg case control, historical controls, cohort). No overweight /obese subgroup |
| 24 | Hutchesson et al 2020[25] | Not exclusively focussed during pregnancy (pre and post pregnancy as well) and no overweight/ obese subgroup |
| 25 | Kramer & McDonald 2006[26] | Included non-RCT studies (quasi-experimental studies). GWG not reported as an outcome. No overweight /obese subgroup |
| 26 | Lamina & Agbanusi 2013[27] | No overweight /obese subgroup |

| | | |
|---|---|---|
| 27 | Lassi & Bhutta 2013[28] | Included non-RCT studies (quasi and observational). GWG not reported as an outcome |
| 28 | Liu et al 2005[29] | Included non-RCT studies (controlled studies including pre and post-test design). No overweight/obese subgroup |
| 29 | Margo-Malosso et al 2017a[30] | GWG not reported as an outcome |
| 30 | Margo-Malosso et al 2017b[31] | GWG not reported as an outcome. No overweight/obese subgroup |
| 31 | Margo-Malosso et al 2017c[32] | Research overview commentary on Margo-Malosso et al 2017a[30] |
| 32 | Mehdi Hazavehie et al 2016[33] | Included non-RCT studies (any study with a comparison group), GWG not reported as an outcome, no overweight/obese subgroup |
| 33 | Mitanchez et al 2020[34] | Overview of systematic reviews, not systematic review |
| 34 | Mohsenzadeh-Ledari et al 2019[35] | No exclusively overweight/obese subgroup |
| 35 | Morisset et al 2010[36] | Included non-RCT studies (eg cross-sectional, retrospective, cohort and case-control studies). Review rather than systematic review |
| 36 | Muhammad et al 2020[37] | Protocol only |
| 37 | Muktabhant et al 2015[38] | No overweight/ obese subgroup (women with overweight or obesity were combined with GDM to form a 'high risk group' for analysis) |
| 38 | Muktabhant et al 2012[39] | Cochrane review updated by Muktabhant et al 2015[38] |
| 39 | Nascimento et al 2012[40] | No overweight/obese subgroup |
| 40 | Nasiri-Amiri et al 2019[41] | GWG not reported as an outcome |
| 41 | National Institute for Health and Clinical Excellence 2010[42] | Included non-RCT studies |
| 42 | Olander et al 2019[43] | Prospero protocol – review not yet published |
| 43 | Peaceman et al 2018[44] | Not a Systematic review - individual RCTs re-analysed together from a consortium |
| 44 | Perales et al 2016[45] | No overweight/obese subgroup |
| 45 | Ruifrok et al 2014[46] | No overweight/ obese subgroup. GWG not reported as an outcome (analysed as a causal factor) |
| 46 | Sanabria-Martinez et al 2015[47] | No overweight/obese subgroup |
| 47 | Sanabria-Martinez et al 2016[48] | No overweight/obese subgroup. GWG not reported as an outcome |
| 48 | Schlüssel et al 2008[49] | Included non-RCT studies (cross-sectional, case-control, cohort). No overweight/obese subgroup |
| 49 | Sebert Kuhlmann et al 2008[50] | GWG not reported (just according to IOM). No overweight/obese subgroup |
| 50 | Shepherd et al 2017[51] | Includes BMI subgroups, however GWG not a primary outcome so subgroup analysis for BMI not done on GWG outcome |
| 51 | Skouteris et al 2014[52] | Included non-RCT studies (eg prospective matched control). GWG not reported as separate outcome. No overweight/ obese subgroup |
| 52 | Streuling et al 2011[53] | No overweight/obese subgroup |

| | | |
|---|---|---|
| 53 | Sui et al 2012[54] | Included non-RCT studies (quasi-randomised) |
| 54 | Syngelaki et al 2018[55] | Protocol only |
| 55 | Tanentsapf et al 2011[56] | Included non-RCT studies (quasi-randomised) |
| 56 | Vincze et al 2019[57] | No overweight/ obese subgroup |
| 57 | Walker et al 2018[58] | No overweight/ obese subgroup reported |
| 58 | Wang et al 2016[59] | RCT not a systematic review |
| 59 | Wang et al 2019[60] | No overweight/ obese subgroup |

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**Table S4. Overall risk of bias scoring criteria for individual RCTs**

| **Risk of bias score** | **Criteria** |
|---|---|
| Low | All the reviews that included the trial had rated the domain of bias as low risk |
| Unclear | All the reviews that included the trial had rated the domain of bias as either low risk or unclear risk |
| High | All the reviews that included the trial had rated the domain of bias as high risk |
| Mixed | Risk of bias for that domain varied widely in the different reviews that included the trial including at least one trial rating it as high risk and others rating it as low and/or unclear risk |

**Table S5. Summary of effects of lifestyle interventions during pregnancy for women with pre-pregnancy overweight or obesity**

**Table S5a. Maternal outcomes**

| **Systematic review** | **AMSTAR confidence in results** | **Maternal outcomes** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Gestational weight gain** | **IOM adherence** | **Gestational diabetes** | **Pre-eclampsia** | **Caesarean Section** | **Preterm birth** |
| **Dietary interventions only** | | | | | | | |
| Quinlivan et al (2011) | Critically low | 4 trials in outcome – all reported in Thangaratinam et al (2012) | | | | | |
| **Physical activity only** | | | | | | | |
| Du et al (2019) | Low | **WMD -1.16 [(95%CI -1.69, -0.62)**, 12 trials, n=1158, $I^2$=18%] 3 unique trials^, SSE=no, EST O<E | | **OR 0.68 [(95%CI 0.50, 0.92**), 10 trials, n=1159, $I^2$=18%] 10 unique trials, SSE=no, EST=O<E | OR 1.42 [(95%CI 0.65,3.10), 4 trials, n=596, $I^2$=0%] 2 unique trials^, SSE=too few trials, EST=NSS | OR 1.04 [(95% CI 0.79, 1.35), 10 trials, n=982, $I^2$=0%] 8 unique trials, SSE=no, EST=NSS | OR 1.25 [(95%CI 0.62, 2.52), 6 trials, n=757, $I^2$=0%] 6 unique trials, SSE=no, EST=NSS |
| Wiebe et al (2015) | Moderate | WMD -0.34 [(95%CI -1.18, 0.51), 3 trials, n=439, $I^2$=0%] all trials overlapped with at least one other review, SSE=too few trials, EST= NSS | | | | OR 0.82 [(95% CI 0.53,1.29), 3 trials, n=417, $I^2$=0%] 1 unique trial, SSE=too few trials, EST=NSS | |
| **Mixture of diet and/or PA** | | | | | | | |
| Bain et al (2015) | High | 3 trials in outcome – all reported in Syngelaki et al (2019) | | OR 0.89 [(95% CI 0.57, 1.38), 7 trials, n=3113, $I^2$= 58%] 5 unique trials, SSE=no, EST=no p>0.10 | | OR 0.90 [(95% CI 0.77, 1.06), 4 trials, n=2662, $I^2$=19%] 2 unique trials, SSE=too few trials, EST=NSS | |
| Choi et al (2013) | Critically low | **WMD -0.95 [(95%CI -1.72, -0.19)**, 7 trials, n=721, $I^2$=8%] all trials overlapped with at least one other review., SSE= no, EST=O<E | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dodd et al (2010) | Critically low | 4 trials in outcome – all reported in Syngelaki et al (2019) | | OR 0.54 [(95% CI 0.26, 1.10), 3 trials, n=334, $I^2$=0%] 2 unique trials, SSE=too few trials, EST=NSS | 5 trials in outcome – all reported in Syngelaki et al (2019) | OR 1.24 [(95% CI 0.83, 1.84), 5 trials, n=533, $I^2$=21%] 4 unique trials, SSE=too few trials, EST=NSS | OR 0.56 [(95%CI 0.18, 1.77), 2 trials, n=281, $I^2$=0%] 2 unique trials, SSE=too few trials, EST=NSS |
| Flannery et al (2019) | High | Out of the 19 trials in the review, GWG was lower in three trials∫. All three studies included in other meta-analyses | | The incidence of GDM was lower in 2 out of 19 included trials. Both trials not included in other meta-analyses∫ | | | |
| Flynn et al (2016) | High | Out of the 13 included trials, GWG was lower in 9 trials. One trial not included in other meta-analyses | | | | | |
| Ho et al (2012) | Low | Out of the 6 included trials, GWG was lower in 2 trials. All trials included in at least one of the meta-analyses | | | 6 trials in outcome, no trial effective at reducing pre-eclampsia when analysing by ITT – 1 unique trial† | | |
| I-WIP (2017) | Moderate | Overweight subgroup ‡<br>**WMD -0.75 [(95%CI -1.22, -0.27)**, 28 trials, n=2574, $I^2$=33%]<br>Obese subgroup ‡<br>**WMD -0.85 [(95%CI -1.41, -0.29)**, 31 trials, n=3335, $I^2$=44%]<br><br>Not able to determine overlap of studies, SSE or EST<br>Authors report SSE possible | Overweight subgroup:<br>Below recommendations 19%<br>Adherent 29%<br>Over recommendations 51% (NR trials, n=1245)<br>Obese subgroup:<br>Below recommendations 26%<br>Adherent 30%<br>Over recommendations 44% (NR trials, n=1562) | Overweight subgroup<br>OR 1.13 [(95%CI 0.74, 1.72), 14 trials, n=6303, $I^2$=3%]<br>Obese subgroup<br>OR 1.05 [(95% CI 0.87, 1.28), 16 trials, n=7540, $I^2$= 0%]<br><br>Not able to determine overlap, SSE or EST | Overweight subgroup<br>OR 0.91 [(95%CI 0.62, 1.32), 10 trials, n=6181, $I^2$=0%]<br>Obese subgroup<br>OR 1.14 [(95% CI 0.91, 1.42), 12 trials, n=7749, $I^2$=0%]<br><br>Not able to determine overlap, SSE or EST | Overweight subgroup<br>OR 0.99 [(95%CI 0.82, 1.20), 24 trials, n=9064, $I^2$=0%]<br>Obese subgroup<br>OR 0.92 [(95% CI 0.81, 1.05), 26 trials, n=10,643, $I^2$=0%]<br><br>Not able to determine overlap, SSE or EST | Overweight subgroup<br>OR 1.03 [(95%CI 0.67, 1.56), 12 trials, n=6932, $I^2$=0%]<br>Obese subgroup<br>OR 0.91 [(95% CI 0.61, 1.36), 14 trials, n=8511, $I^2$= 0%]<br><br>Not able to determine overlap, SSE or EST |
| Lau et al (2017) | Low | **WMD -0.63 [(95%CI -1.07, -0.2)**, 7 trials, n=1636, $I^2$=14%] 3 unique trials*, SSE=no, EST=yes p=0.078 | | OR 0.99 [(95%CI 0.77, 1.26), 2 trials, n=1447, $I^2$=29%] 1 unique trial, SSE=too few trials, EST=NSS | 2 trials in outcome – both reported in Syngelaki et al (2019) | OR 0.94[(95% CI 0.77, 1.14), 2 trials, n=1689, $I^2$=0%] 1 unique trial, SSE=too few trials, EST=NSS | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shieh et al (2018) | Critically low | **WMD -1.75 [(95%CI -2.51, -0.98)**, 21 trials, n=6473, $I^2$=88%] 1 unique trial, SSE=yes, EST=no p>0.10 | | | | | |
| Syngelaki et al (2019) | Critically low | **WMD -1.57 [(95%CI -2.52, -0.62)**, 18 trials, n=5177, $I^2$=87%] 4 unique trials₸, SSE=no, EST=yes p=0.000 | | | OR 1.04 [(95% CI 0.81, 1.32) 14 trials, n=5385, $I^2$=0%] 6 unique trials^, SSE=no, EST=NSS | | |
| Thangaratinam et al (2012) | Moderate | **WMD -2.41 [(95%CI -4.04, -0.77)**, 11 trials, n=2149, $I^2$=91%] 1 unique trialʃ, SSE=no, EST=O<E | | Diet only subgroup: **OR 0.31 [(95% CI 0.13, 0.77),** 3 trials, n=406, $I^2$=33%] 1 unique trial, SSE=too few trials, EST=no p>0.10 | OR 0.79 [(95%CI 0.54, 1.16), 7 trials, n=1635, $I^2$=25%] 1 unique trialʃ, SSE=no, EST=no p>0.10 | | |
| Yeo et al (2017) | Low | **WMD -1.7 [(95%CI -2.39, -1.01)**, 32 trials, n=5418, $I^2$=83%] 8 unique trialsʃ, SSE=yes, EST=no p>0.10 | | | | | |

Figures may vary slightly from those reported in the systematic reviews due to corrections being made for errors such as using standard error not standard deviation, incorrect number of participants or using received treatment data not intention to treat within the original analyses.

I-WIP = The International Weight Management in Pregnancy Collaborative Group

IOM = Institute of Medicine (2009) weight gain in pregnancy recommendations

WMD = weighted mean difference

OR = odds ratio

95% CI =- 95% confidence interval

NR = not reported

SSE = small study effects (taken as Egger test p<0.10 alongside a more conservative effect size in largest trial than the overall random effects model summary)

EST = excess significance test

O<E = fewer observed studies than expected, therefore no excess significance

NSS = no studies had statistically significant results

ITT = intention to treat

^ compares different arms of Renault et al (2014) to other reviews

‡ adjusted for baseline weight and clustering effect

* this review was noted to include 2 RCTs that incorporated women of normal BMI, despite review inclusion criteria being exclusively women with overweight/ obesity

₸ compares different arms in Bogarts et al (2013) to other reviews

ʃ this review was noted to include 1 RCT in their overweight/obese meta-analysis that did not exclusively recruit participants with overweight/obesity

ϯ the authors of the review noted that in this unique trial pre-eclampsia results were reported for all women, not the overweight/obese subgroup

**Table S5b. Infant outcomes**

| Systematic review | AMSTAR confidence in results | Infant outcomes | | | | |
|---|---|---|---|---|---|---|
| | | **Birthweight** | **Macrosomia (>4000g)** | **LGA** | **Low birth weight (<2500g)** | **SGA** |
| **Dietary interventions only** | | | | | | |
| Quinlivan et al (2011) | Critically low | 4 trials in outcome – all reported in Thangaratinam et al (2012) | | | | |
| **Physical activity only** | | | | | | |
| Du et al (2019) | Low | WMD -39.62 [(95%CI -97.8, 18.57), 11 trials, n=1214, $I^2$=11%] 9 unique trials, SSE=no, EST=O<E | OR 0.91 [(95% CI 0.61, 1.36), 4 trials, n=595, $I^2$=22%] 4 unique trials, SSE=too few trials, EST=NSS | OR 0.88 [(95% CI 0.60, 1.30), 7 trials, n=961, $I^2$=3%]] 7 unique trials, SSE=no, EST=NSS | | OR 1.02 [(95%CI 0.52, 1.99) 6 trials, n=863 $I^2$=14%] 6 unique trials, SSE=no, EST=NSS |
| Wiebe et al (2015) | Moderate | WMD 9.67 [(95%CI -85.96, 105.3), 3 trials, n=460, $I^2$=24%] 1 unique trial, SSE=too few trials, EST=NSS | | 3 trials in outcome - 2 trials within Du et al (2015), one reported macrosomia not LGA# | | 2 trials in outcome - 1 trial within Du et al (2015), one reported birthweight<2500g not SGA# |
| **Mixture of diet and/or PA** | | | | | | |
| Bain et al (2015) | High | 1 trial in outcome – reported in Lau et al (2017) | | OR 0.92 [(95%CI 0.75, 1.12), 3 trials, n=2616, $I^2$=0%]ꟷ 2 unique trials, SSE=too few trials, EST=NSS | | |
| Choi et al (2013) | Critically low | | | | | |
| Dodd et al (2010) | Critically low | 3 trials in outcome – all reported in Thangaratinam et al (2019) | OR 2.13 [(95%CI 0.83, 5.43), 3 trials, n=366, $I^2$=0%] θϒ 3 unique trials, SSE=too few trials, EST=NSS | | OR 0.38 [(95% CI 0.03, 4.55), 1 trial, n=49, $I^2$=N/A] 1 unique trial, SSE=too few trials, EST=NSS | |
| Flannery et al (2019) | High | | The incidence of birthweight >4000g was lower in 1 of the 19 included trials. 1 trial not included in other meta-analyses | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Flynn et al (2016) | High | Out of the 13 included trials, birthweight increased in the intervention group in 2 trials, with no significant differences in the other trials. Nine trials not included in other meta-analyses^ | | | | |
| Ho et al (2012) | Low | | | | | |
| I WIP (2017) | Moderate | | | Overweight subgroup<br>OR 0.92 [(95%CI 0.68, 1.25), 20 trials, n=8715, $I^2$=26.5%]<br>Obese subgroup<br>OR 0.96 [(95% CI 0.71, 1.32), 22 trials, n=10328, $I^2$= 32.6%]<br><br>Not able to determine overlap, SSE or EST | | Overweight subgroup<br>OR 1.13 [(95%CI 0.81, 1.57), 21 trials, n=8812, $I^2$=5.9%]<br>Obese subgroup<br>OR 0.96 [(95% CI 0.74, 1.24), 23 trials, n=10391, $I^2$= 0%]<br><br>Not able to determine overlap, SSE or EST |
| Lau et al (2017) | Low | WMD -11.3 [(95%CI -62.21, 39.61), 5 trials, n=1967, $I^2$=0%] 4 unique trials*, SSE=too few trials, EST=NSS | OR 0.99 [(95% CI 0.76, 1.31), 2 trials, n=1679, $I^2$=0%] 2 unique trials, SSE=too few trials, EST=NSS | | | |
| Shieh et al (2018) | Critically low | | | | | |
| Syngelaki et al (2019) | Critically low | | | | | |
| Thangaratinam et al (2012) | Moderate | WMD -20 [(95%CI -90, 50), 9 trials, n=1882, $I^2$=27%] 8 unique trials∫, SSE=no, EST=O<E | | OR 1.07 [(95% CI 0.64, 1.79), 7 trials, n=1904, $I^2$=60%] 6 unique trials§∫, SSE=no, EST=O<E | | OR 1.19 [(95% CI 0.75, 1.87), 4 trials, n=1220, $I^2$= 0%] 4 unique trials⸸∫<br>SSE=too few trials, EST=NSS |
| Yeo et al (2017) | Low | | | | | |

Figures may vary from those reported in the systematic reviews due to corrections being made for errors such as using standard error not standard deviation, incorrect number of participants or using received treatment data not intention to treat within the original analyses.

I-WIP = The International Weight Management in Pregnancy Collaborative Group

LGA = large for gestational age

SGA = small for gestational age

WMD = weighted mean difference

OR = odds ratio
95% CI =- 95% confidence interval
NR = not reported
N/A – not applicable
SSE = small study effects (taken as Egger test p<0.10 alongside a more conservative effect size in largest trial than the overall random effects model summary)
EST = excess significance test
O<E therefore not pertinent
NSS = no studies had statistically significant results
^ Included different arms of Renault et al (2014) and Guelinckx et al (2010) to those included within the meta-analyses
θ Combined LGA and macrosomia into one outcome of LGA, however all included trials report macrosomia so reported here under macrosomia heading
ϒ 1 included trial reported Birthweight>4500g not >4000g
ꟸ 1 included trial reported birthweight>4000g not LGA
§ 3 included trials actually report birthweight >4000g and 1 included trial reports birthweight >4500g
# Composite outcome reported for both 'small at birth' of SGA and birthweight <2500g and for 'large at birth' of LGA and macrosomia
ɨ 3 of the included trials report birthweight < 2500g
ʃ this review was noted to include 1 RCT in their overweight/obese meta-analysis that did not exclusively recruit participants with overweight/obesity
* this review was noted to include 2 RCTs that incorporated women of normal BMI, despite review inclusion criteria being exclusively women with overweight/ obesity

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## Table S6. Subgroup analysis of gestational weight gain by type of intervention

| Systematic reviews | **AMSTAR confidence in results** | **Outcome (calculated)** |
|---|---|---|
| **Physical activity only** | | |
| Choi et al (2013) | Critically low | WMD -1.73 [(95% CI -3.67, 0.20), 2 studies, n=52, $I^2$=0%] 1 unique study |
| Du et al (2019) | Low | **WMD -1.16 [(95% CI -1.69, -0.62), 12 studies, n=1158, $I^2$=18%]** 6 unique studies |
| Shieh et al (2018) | Critically low | All 6 included studies were reported in Du et al (2019) |
| Syngelaki et al (2019) | Critically low | **WMD -1.14 [(95% CI -2.22, -0.06), 4 studies, n=623, $I^2$=52%]** 0 unique studies - 3 included in Du et al (2019), 1 in Wiebe et al (2015) |
| Wiebe et al (2015) | Moderate | WMD -0.34 [(95% CI -1.18, 0.51) 3 studies, n=439, $I^2$=0%] 0 unique studies – 2 included in Du et al (2019), 1 in Syngelaki et al (2019) |
| **Dietary only** | | |
| Dodd et al (2010) | Critically low | All 4 included studies were reported in Syngelaki et al (2019) |
| Flynn et al (2016) | High | All 3 included studies reported in Shieh et al (2018) |
| Quinlivan et al (2011) | Critically low | **WMD -5.99 [(95% CI -9.15, -2.84) 4 studies, n=491, $I^2$ = 85%]** 0 unique studies – 3 in Syngelaki et al (2019) and 1 (+2 of the others) in Shieh et al (2018) |
| Shieh et al (2018) | Critically low | **WMD -5.84 [(95% CI -10.12, -1.56) 4 studies, n=719, $I^2$ = 95%]** 1 unique study |
| Syngelaki et al (2019) ‡ | Critically low | **WMD -1.73 [(95% CI -2.95, -0.50) 14 studies, n=4554, $I^2$=89%]** 11 unique studies (7 of which others attributed to mixed interventions) |
| **Combined interventions- physical activity and dietary components** | | |
| Bain et al (2015) | High | WMD 0.28 [(95% CI -1.13, 1.69) 3 studies, n=1980, $I^2$=43%] 0 unique studies – 2 in Choi et al (2013) and 1 in Shieh et al (2018) |
| Choi et al (2013) | Critically low | WMD -0.56 [(95% CI -1.76, 0.64), 5 studies, n=669, $I^2$=30%] 2 unique studies (one of these was different arms of an RCT included in another systematic review and therefore taken as separate and the other was attributed to physical activity only within the other systematic reviews) |
| Flynn et al (2016) | High | All 10 included studies reported in Shieh et al (2018) |
| Shieh et al (2017) | Critically low | **WMD -0.82 [(95% CI -1.29, -0.35) 11 studies, n=5408, $I^2$=65%]** 9 unique studies |

‡ This review included interventions that only included advice on increasing walking or physical activity within the dietary only subgroup

## References


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Shieh C, Cullen DL, Pike C, Pressler SJ. Intervention strategies for preventing excessive gestational weight gain: Systematic review and meta-analysis. *Obes Rev*. 2018;19(8):1093-1109.

Syngelaki A, Sequeira Campos M, Roberge S, Andrade W, Nicolaides KH. Diet and exercise for preeclampsia prevention in overweight and obese pregnant women: Systematic review and meta-analysis. *J Matern Fetal Neonat Med*. 2019;32(20):3495-3501.

Wiebe HW, Boulé NG, Chari R, Davenport MH. The effect of supervised prenatal exercise on fetal growth. *Obstet Gynecol*. 2015;125(5):1185-1194.

# Appendix D: Ethical approval for the quantitative research component

Health Research Authority

East of England - Cambridge East Research Ethics Committee

[redacted]

**Please note: This is the favourable opinion of the REC only and does not allow you to start your study at NHS sites in England until you receive HRA Approval**

15 July 2016

Prof Hora Soltani
Professor of Maternal and Infant Health
Sheffield Hallam University
Mundella House
34 Collegiate Crescent
Sheffield
S10 2BP

Dear Prof Soltani

| | |
|---|---|
| **Study title:** | **An evaluation of the impact of a midwife-led maternal obesity service on pregnancy outcomes and childhood obesity.** |
| **REC reference:** | **16/EE/0280** |
| **Protocol number:** | **2015-16/HWB-HSC-33** |
| **IRAS project ID:** | **207998** |

Thank you for your letter of 13 July 2016 responding to the Proportionate Review Sub-Committee's request for changes to the documentation for the above study.

The revised documentation has been reviewed and approved by the sub-committee.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this favourable opinion letter. The expectation is that this information will be published for all studies that receive an ethical opinion but should you wish to provide a substitute contact point, wish to make a request to defer, or require further information, please contact the REC Assistant Mrs Joanne O'Neil, [redacted]. Under very limited circumstances (e.g. for student research which has received an unfavourable opinion), it may be possible to grant an exemption to the publication of the study.

**Confirmation of ethical opinion**

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

**Conditions of the favourable opinion**

The REC favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission must be obtained from each host organisation prior to the start of the study at the site concerned.</u>

*Management permission should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements. Each NHS organisation must confirm through the signing of agreements and/or other documents that it has given permission for the research to proceed (except where explicitly specified otherwise).*

*Guidance on applying for HRA Approval (England)/ NHS permission for research is available in the Integrated Research Application System, [www.hra.nhs.uk](www.hra.nhs.uk) or at [http://www.rdforum.nhs.uk](http://www.rdforum.nhs.uk).*

*Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.*

*For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.*

*Sponsors are not required to notify the Committee of management permissions from host organisations.*

<u>Registration of Clinical Trials</u>

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database. This should be before the first participant is recruited but no later than 6 weeks after recruitment of the first participant.

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g. when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non-clinical trials this is not currently mandatory.

If a sponsor wishes to request a deferral for study registration within the required timeframe, they should contact [redacted] The expectation is that all clinical trials will be registered, however, in exceptional circumstances non registration may be permissible with prior agreement from the HRA. Guidance on where to register is provided on the HRA website.

**It is the responsibility of the sponsor to ensure that all the conditions are complied with**

**before the start of the study or its initiation at a particular site (as applicable).**

**Ethical review of research sites**

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" above).

**Approved documents**

The documents reviewed and approved by the Committee are:

| *Document* | *Version* | *Date* |
|---|---|---|
| IRAS Application Form [IRAS_Form_13072016] | | 13 July 2016 |
| IRAS Checklist XML [Checklist_16062016] | | 16 June 2016 |
| Letter from sponsor [PI Confirmation of Cover] | 1 | 15 June 2016 |
| Other [Burdett Approval Letter] | 1 | 04 November 2015 |
| Other [Cover letter-Clarifications] | 1 | 12 July 2016 |
| Research protocol or project proposal [Protocol-Final-V1] | 1 | 15 June 2016 |
| Summary CV for Chief Investigator (CI) [CV-Short] | 1 | 15 June 2016 |

**Statement of compliance**

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

**After ethical review**

Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website: http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance

We are pleased to welcome researchers and R & D staff at our NRES committee members' training days – see details at http://www.hra.nhs.uk/hra-training/

With the Committee's best wishes for the success of this project.

Yours sincerely

pp. [redacted]

**Dr Rebecca Harmston**
**Chair**

[redacted]

*Copy to:* *Mr Brian Littlejohn*

*Mrs Amy Bell, NHS Doncaster CCG and NHS Bassetlaw CCG*

# Appendix E: Ethical approval for the qualitative interviews

NHS
Health Research Authority

East of England - Essex Research Ethics Committee

[redacted]

**<u>Please note</u>: This is an acknowledgement letter from the REC only and does not allow you to start your study at NHS sites in England until you receive HRA Approval**

13 October 2017

Prof Hora Soltani
Professor of Maternal, Infant and Reproductive Health
Sheffield Hallam University
Mundella House, 34 Collegiate Cres
Collegiate Campus
Sheffield Hallam University
S10 2BP

Dear Prof Soltani

| | |
|---|---|
| **Study title:** | **Women's experiences of a maternal obesity service** |
| **REC reference:** | **17/EE/0378** |
| **Protocol number:** | **2015-16/HWB-HSC-33** |
| **IRAS project ID:** | **231105** |

Thank you for your letter of 11 October 2017. I can confirm the REC has received the documents listed below and that these comply with the approval conditions detailed in our letter dated 05 September 2017

**Documents received**

The documents received were as follows:

| *Document* | *Version* | *Date* |
|---|---|---|
| Interview schedules or topic guides for participants [Interview | V2 | 26 September 2017 |

| | | |
|---|---|---|
| shedules or topic guides for participants] | | |
| Participant consent form [Participant consent form] | V2 | 26 September 2017 |
| Participant information sheet (PIS) [Participant infomration sheet] | V2 | 26 September 2017 |

**Approved documents**

The final list of approved documentation for the study is therefore as follows:

| *Document* | *Version* | *Date* |
|---|---|---|
| Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Sponsor Insurance] | V1 | 31 July 2017 |
| Interview schedules or topic guides for participants [Interview shedules or topic guides for participants] | V2 | 26 September 2017 |
| IRAS Application Form [IRAS_Form_21082017] | | 21 August 2017 |
| IRAS Checklist XML [Checklist_11102017] | | 11 October 2017 |
| Letter from funder [Burdett approval letter] | v1 | 04 November 2015 |
| Letters of invitation to participant [Invitation letter] | v1 | 20 June 2017 |
| Other [Indemnity] | V1 | 31 July 2017 |
| Participant consent form [Participant consent form] | V2 | 26 September 2017 |
| Participant information sheet (PIS) [Participant infomration sheet] | V2 | 26 September 2017 |
| Research protocol or project proposal [Protocol] | v1 | 15 June 2016 |
| Summary CV for Chief Investigator (CI) [SHort CV] | V1 | 17 August 2017 |

You should ensure that the sponsor has a copy of the final documentation for the study. It is the sponsor's responsibility to ensure that the documentation is made available to R&D offices at all participating sites.

| | |
|---|---|
| **17/EE/0378** | **Please quote this number on all correspondence** |

Yours sincerely

[redacted]

**Ellen Swainston**
**REC Manager**

E-mail: [redacted]

*Copy to:* *Mr Keith Fildes*
*Mrs Emma Hannaford, NHS Doncaster CCG and NHS Bassetlaw CCG*

# Appendix F: Participant information sheet for the qualitative interviews

Version 5 07/09/2018

Sheffield Hallam University

Doncaster and Bassetlaw Hospitals NHS Foundation Trust

# Participant information sheet

| | |
|---|---|
| Study title: | An evaluation of maternal weight management service provision |
| Lead Investigator | Professor Hora Soltani |
| Telephone number | [redacted] |
| IRAS project number | 231105 |

Study Sponsor: Sheffield Hallam University

We would like to invite you to take part in our research study. Before you decide we would like you to understand why the research is being done and what it would involve for you. Talk to others about the study if you wish. Ask us if there is anything that is not clear.

This study is has been approved by the East of England - Essex Ethics Service Committee

Participant name:

You will be given a copy of this information sheet to keep

## 1. What is the purpose of this study?

The purpose of this study is to understand women's experiences of maternal healthy weight service provision in Doncaster. This includes finding out what things you found useful about the service and what you think could be improved.

## 2. Why have I been invited?

You have been invited to take part in this study as you are having your antenatal care in Doncaster and you had a BMI ≥40kg/m² when you booked for antenatal care.

## 3. Do I have to take part?

Your decision to take part in this study is entirely voluntary. You may refuse to participate or you can withdraw from the study at any time. Your refusal to participate or wishing to withdraw would not influence in any way current or potential future medical care.

## 4. What will happen to me if I take part?

If you take part in this study you will be asked to participate in a group discussion about your experiences of maternal weight management services. This will include questions such as whether anyone providing care during this pregnancy (or any previous pregnancies you may have had) has discussed healthy weight gain during pregnancy, how this information was provided and how you/other women might like this to be approached in the future. The group will include other women who have also received antenatal care at Doncaster and have a BMI ≥40kg/m². This group discussion will be informal and will be tape recorded with your consent. Alternatively if more convenient you could talk about your experiences with a researcher in a telephone interview.

If you wish to do so you, you will be offered the opportunity to read the findings of the study and make comments on them, to ensure the findings truly capture women's experiences of maternal weight management services.

## 5. Expenses and payments

You will be given a £10 gift voucher when you take part in the focus group /telephone interview to thank you for your time.

## 6. What are the possible disadvantages of taking part?

We do not anticipate any risks of taking part in this study.

## 7. What are the possible benefits of taking part?

It is hoped that the results of this study will help to improve the care provided to women during pregnancy in Doncaster. It is hoped that learning what works well about current service provision and what women would like to see improved will help to improve maternity services.

## 8. What if there is a problem or I want to complain?

If you have any queries or questions please contact:

Prof Hora Soltani
Professor of Maternal and Infant Health
Faculty of Health and Wellbeing
Sheffield Hallam University
34 Collegiate Crescent
Sheffield
S10 2BP
Telephone: [redacted]
email:h.soltani@shu.ac.uk

If you would rather contact an independent organisation, you can do this using the normal Doncaster Hospitals procedure and contact the Patient Advice and Liaison Service (PALS)on: [redacted]

### 9. Will my taking part in this study be kept confidential?

All reasonable steps will be taken to ensure your confidentiality.

The focus group /telephone interview will be recorded and then written up word-for-word. Each participant will be given a pseudonym (code name). The transcript will be kept on a computer. All computers used as part of this study will be password protected. Audio files will be deleted at the end of the project. Written transcripts will then be kept for as long as they might be useful in future research. No identifying details will be in any final report or any publication, meaning people reading these will not be able to identify you.

All study documents relating to the administration of this research, such as the consent form you sign to take part, will be kept in a folder called a site file or project file. This is locked away securely. The folder might be checked by people in authority who want to make sure that researchers are following the correct procedures.

These people will not pass on your details to anyone else.

In the event of a revelation during the course of the focus group /telephone interview of a risk of harm or unacceptable professional conduct, participant confidentiality may be limited to ensure safety of others. If any issues were raised throughout the study, the researcher will consult with her university research support office and then discuss the issues with the mangers and relevant health care professionals in the maternity unit in order to take an appropriate action in accordance with their professional Code of Conduct.

### 10. What will happen to the results of the research study?

The results from this study will be used to inform effective maternity care. The results will be presented locally to the Maternal and Infant Health Research Group, as well as being written up for publication in peer reviewed journals and presented at conferences.

### 11. Who is sponsoring the study?

The sponsor of the study has the duty to ensure that it runs properly and that it is insured. This study's sponsor is Sheffield Hallam University.

### 12. Who has reviewed this study?

All research in the NHS is looked at by an independent group of people called a Research Ethics Committee, to protect your safety, rights, wellbeing and dignity. This research has been approved by the East of England - Essex Ethics Committee.

## 13. What about data protection?

Sheffield Hallam University is the sponsor for this study based in the United Kingdom. We will be using information from you in order to undertake this study and will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. Sheffield Hallam University will keep identifiable information about you for 4 months after the study has finished.
Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained. To safeguard your rights, we will use the minimum personally-identifiable information possible.
You can find out more about how we use your information at:
https://www.shu.ac.uk/about-this-website/privacy-policy/privacy-notices/privacy-notice-for-research

## 14. Will I get to know the results of the study?

Yes, the results of the study when published will be available and can be posted out to you, if you wish. If you were interested to know about the results before publication we can provide a summary of the results for you as well. You can obtain these results by contacting Hora Soltani.

## 15. Further information and contact details

If you have any queries or would like to have more information, please contact:

Prof Hora Soltani
Professor of Maternal and Infant Health
Faculty of Health and Wellbeing
Centre for Health and Social Care Research
Sheffield Hallam University
34 Collegiate Crescent
Sheffield
S10 2BP
Telephone: [redacted]
email: h.soltani@shu.ac.uk

# Appendix G: Participant consent form for the qualitative interviews

Version 6 07/09/2018

Sheffield Hallam University

Doncaster and Bassetlaw Hospitals NHS Foundation Trust NHS

# Participant consent form

| | |
|---|---|
| Study title: | An evaluation of maternal weight management service provision |
| Lead investigator | Professor Hora Soltani |
| Telephone number | [redacted] |
| Approving ethics committee | East of England - Essex |
| IRAS project number | 231105 |

Participant name

| | **Please read the following statements and put your initials in the box to show that you have read and understood them and that you agree with them** | **Please initial each box** |
|---|---|---|
| 1 | I confirm that I have read and understood the information sheet version 5 dated September 2018 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. | |
| 2 | I understand that my involvement in this study is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. | |
| 3 | I agree to the focus group/telephone interview being audio recorded. | |
| 4 | I agree to anonymised direct quotations from the focus group /telephone interview being used in published material. | |
| 5 | I agree to take part in this study | |

| | | |
|---|---|---|
| | I would like to receive a copy of the initial study results to read and comment on to ensure they truly reflect women's experiences (If yes please provide contact details on attached sheet) | Yes / No |
| | I would like to receive a copy of the study results once they are available (If yes please provide contact details on attached sheet) | Yes / No |

**To be filled in by the participant**

I agree to take part in the above study

| Your name | Date | Signature |
|---|---|---|
| | | |

**To be filled in by the person obtaining consent**

I confirm that I have explained the nature, purposes and possible effects of this research study to the person whose name is printed above.

| Name of investigator | Date | Signature |
|---|---|---|
| | | |

Filing instructions

1 copy to the participant
1 original in the Project or Site file
1 copy in the medical notes (if applicable)

# Contact details (if yes to receiving study results)

Email address ________________________________________

Postal address ________________________________________

______________________________________________________

______________________________________________________

______________________________________________________

# Appendix H: Supplementary material for the antenatal healthy lifestyle service intensity article

## Supplementary Material: Appendix S1. Maternal and neonatal outcomes according to service intensity for primiparous women

| Outcome | Low intensity 2009-2011 (n=81) | Enhanced service 2012-2015 (n=125) | Crude Mean difference (MD) or Odds ratio (OR) (95% CI) | Adjusted MD/OR (95% CI) [a] |
|---|---|---|---|---|
| **Number of antenatal healthy lifestyle service appointments, mean (SD)** | 1.6 (1.6) | 2.5 (1.0) | MD 0.9 (0.5-1.3)*** | aMD 0.9 (0.5-1.1)*** |
| **Number of antenatal healthy lifestyle service appointments, n (%)** | | | | |
| 0 | 8 (9.9%) | 1 (0.8%) | REF | REF |
| 1 | 42 (51.9%) | 19 (15.4%) | OR 3.62 (0.42-31.02) | aOR 3.04 (0.34-27.10) |
| 2 | 21 (25.9%) | 36 (29.3%) | OR 13.71 (1.60-117.4)* | aOR 12.06 (1.35-107.5)* |
| 3 or more | 10 (12.3%) | 67 (54.5%) | OR 53.6 (6.04-475.3)*** | aOR 51.2 (5.48-478.3)** |
| **Gestation at first antenatal healthy lifestyle appointment, mean (SD), wk** | 16.1 (3.7) | 17.3 (4.9) | MD 1.2 (-0.1 to 2.5) | aMD 1.1 (-0.3 to 2.4) |
| **Gestational weight gain, mean (SD), kg** | 8.8 (7.9) | 7.6 (7.0) | MD -1.2 (-3.4 to 1.0) | aMD -1.1 (-3.3 to 1.1) |
| **Weight gain according to Institute of Medicine recommendations, n (%)** | | | | |
| Too little | 19 (26.8%) | 33 (32.4%) | OR 1.08 (0.48-2.44) | aOR 1.05 (0.45-2.45) |
| Recommended | 18 (25.4%) | 29 (28.4%) | REF | REF |
| Too much | 34 (47.9%) | 40 (39.2%) | OR 0.73 (0.35-1.54) | aOR 0.73 (0.33-1.60) |
| **Gestation at final weight, mean (SD), wk** | 38.6 (2.0) | 37.3 (1.8) | MD -1.3 (-1.9 to -0.7)*** | aMD -1.3 (-1.8 to -0.7)*** |
| **Weekly weight gain, mean (SD), kg/week** | 0.31 (0.28) | 0.28 (0.25) | MD -0.03 (-0.11 to 0.05) | aMD -0.03 (-0.11 to 0.05) |
| **Birthweight, mean (SD), g** | 3467 (696) | 3402 (619) | MD -65 (-252 to 122) | aMD -59 (-249 to 130) |
| **Gestation at birth, mean (SD), wk** | 39.9 (2.2) | 39.5 (2.0) | MD -0.35 (-0.96 to 0.25) | aMD -0.33 (-0.94 to 0.29) |
| **Low birthweight (<2500g), n (%)** | 5/79 (6.3%) | 7/117 (6.0%) | OR 0.94 (0.29-3.08) | aOR 1.03 (0.31-3.44) |
| **Macrosomia (>4000g), n (%)** | 11/79 (13.9%) | 16/117 (13.7%) | OR 0.98 (0.43-2.24) | aOR 1.02 (0.44-2.36) |
| **Small for gestational age (<10th centile), n (%)** | 16/79 (20.3%) | 25/117 (21.4%) | OR 1.07 (0.53-2.17) | aOR 1.04 (0.50-2.14) |
| **Large for gestational age (>90th centile), n (%)** | 10/79 (12.7%) | 9/117 (7.7%) | OR 0.58 (0.22-1.49) | aOR 0.55 (0.21-1.46) |
| **Preterm (<37+0 weeks), n (%)** | 6/79 (7.6%) | 9/118 (7.6%) | OR 1.01 (0.34-2.94) | aOR 0.89 (0.29-2.72) |
| **Postdates (>41+6 weeks), n (%)** | 2/79 (2.5%) | 5/118 (4.2%) | OR 1.70 (0.32-9.01) | aOR 1.67 (0.31-9.08) |
| **Vaginal birth, n (%)** | 34/79 (43.0%) | 56/117 (47.9%) | OR 1.22 (0.68-2.16) | aOR 1.17 (0.65-2.11) |
| **Caesarean birth, n (%)** | 38/79 (48.1%) | 50/117 (42.7%) | OR 0.81 (0.45-1.43) | aOR 0.83 (0.46-1.50) |
| **Induction of labour (excluding Caesarean birth prior to labour), n (%)** | 49/66 (74.2%) | 71/109 (65.1%) | OR 0.65 (0.33-1.28) | aOR 0.65 (0.33-1.28) |
| **Postpartum haemorrhage (estimated blood loss ≥500ml), n (%)** | 45/79 (57.0%) | 53/105 (50.5%)[b] | OR 0.77 (0.43-1.39) | aOR 0.80 (0.44-1.46) |
| **Perineal laceration sustained (excluding women with a Caesarean birth), n (%)** | 38/41 (92.7%) | 53/65 (81.5%) | OR 0.35 (0.09-1.32) | aOR 0.33 (0.08-1.39) |
| **Epidural analgesia (attempted or achieved), n (%)** | 59/79 (74.7%) | 71/113 (62.8%) | OR 0.57 (0.30-1.08) | aOR 0.52 (0.27-1.01) |
| **General anaesthetic, n (%)** | 7/79 (8.9%) | 9/113 (8.0%) | OR 0.89 (0.32-2.50) | aOR 0.99 (0.34-2.82) |

| | | | | |
|---|---|---|---|---|
| **Shoulder dystocia (excluding women with a Caesarean birth), n (%)** | 3/40 (7.5%) | 0/66 (0.0%) | - | - |
| **Apgar score at 1 minute <7, n (%)** | 12/78 (15.4%) | 14/113 (12.4%) | OR 0.78 (0.34-1.79) | aOR 0.83 (0.36-1.95) |
| **Apgar score at 5 minutes <7, n (%)** | 2/78 (2.6%) | 3/133 (2.7%) | OR 1.04 (0.17-6.35) | aOR 1.26 (0.20-8.08) |
| **Neonatal unit admission, n (%)** | 5/78 (6.4%) | 9/111 (8.1%) | OR 1.29 (0.42-4.00) | aOR 1.41 (0.44-4.48) |
| **Breastfeeding initiation, n (%)** | 56/78 (71.8%) | 71/114 (62.3%) | OR 0.65 (0.35-1.21) | aOR 0.57 (0.30-1.10) |
| **Breastfeeding at discharge from hospital, n (%)** | 44/77 (57.1%) | 44/111 (39.6%) | OR 0.49 (0.27-0.89)* | aOR 0.43 (0.23-0.80)** |
| **Day of discharge from hospital, n (%)** | | | | |
| Day of birth | 6 (7.6%) | 12 (10.3%) | REF | REF |
| Day 1 | 15 (19.0%) | 39 (33.6%) | OR 1.30 (0.41-4.09) | aOR 1.11 (0.34-3.67) |
| Day 2 | 39 (49.4%) | 35 (30.2%) | OR 0.45 (0.15-1.32) | aOR 0.39 (0.12-1.24) |
| Day 3+ | 19 (24.0%) | 30 (25.9%) | OR 0.79 (0.25-2.46) | aOR 0.71 (0.22-2.30) |
| **Sex of infant, n (%)** | | | | |
| Male | 36 (45.6%) | 63 (53.8%) | OR 1.39 (0.79-2.47) | aOR 1.42 (0.79-2.56) |
| Female | 43 (54.4%) | 54 (46.2%) | REF | REF |
| **Haemoglobin <110g/l at booking, n (%)** | 1/81 (1.2%) | 2/119 (1.7%) | OR 1.37 (0.12-15.34) | aOR 1.21 (0.11-13.87) |
| **Haemoglobin<105 g/l at 28 weeks, n (%)** | 4/77 (5.2%) | 2/111 (1.8%) | OR 0.34 (0.06-1.88) | aOR 0.42 (0.07-2.48) |
| **Haemoglobin<105g/l at 36 weeks, n (%)** | 2/55 (3.6%) | 2/81 (2.5%) | OR 0.67 (0.09-4.91) | aOR 0.74 (0.10-5.52) |
| **Gestational diabetes mellitus (excluding those with gastric surgery), n (%)** | 12/71 (16.9%) | 24/112 (21.4%) | OR 1.34 (0.62-2.89) | aOR 1.29 (0.58-2.86) |
| **Additional monitoring for raised blood pressure, n (%)** [c] | 20/73 (27.4%) | 24/104 (23.1%) | OR 0.80 (0.40-1.58) | aOR 0.75 (0.37-1.52) |

[a] Adjusted for deprivation (REF= most deprived quintile) and smoking (REF=non smoker)

[b] The new electronic health notes for recording intrapartum care from 2015 made it difficult to obtain estimated blood loss for many women who gave birth in 2015

[c] Additional monitoring for raised blood pressure - women receiving monitoring over and above routine care due to raised blood pressure, including those who went on to be diagnosed with Pregnancy Induced hypertension, pre-eclampsia or HELLP syndrome

* significant at p<0.05 level, ** significant at p<0.01 level, *** significant at p<0.01 level

## Supplementary Material: Appendix S2. Maternal and neonatal outcomes according to service intensity for multiparous women

| Outcome | Low intensity 2009-2011 (n=233) | Enhanced service 2012-2015 (n=241) | Crude Mean difference (MD) or Odds ratio (OR) (95% CI) | Adjusted MD/OR (95% CI)[a] |
|---|---|---|---|---|
| **Number of antenatal healthy lifestyle service appointments, mean (SD)** | 1.0 (1.1) | 2.1 (1.3) | MD 1.0 (0.8-1.3)*** | aMD 1.0 (0.8-1.2)*** |
| **Number of antenatal healthy lifestyle service appointments, n (%)** | | | | |
| 0 | 78 (33.5%) | 30 (12.5%) | REF | REF |
| 1 | 101 (43.3%) | 50 (20.8%) | OR 1.23 (0.72-2.10) | aOR 1.24 (0.71-2.15) |
| 2 | 37 (15.9%) | 62 (25.8%) | OR 4.16 (2.32-7.45)*** | aOR 4.20 (2.30-7.64)*** |
| 3 or more | 17 (7.3%) | 98 (40.9%) | OR 14.32 (7.38-27.78)*** | aOR 14.41 (7.27-28.59)*** |
| **Gestation at first antenatal healthy lifestyle appointment, mean (SD), wk** | 17.9 (5.9) | 17.3 (4.7) | MD -0.6 (-1.7 to 0.5) | aMD -0.6 (-1.7 to 0.5) |
| **Gestational weight gain, mean (SD), kg** | 5.8 (7.1) | 4.7 (6.6) | MD -1.2 (-2.5 to 0.2) | aMD -1.3 (-2.7 to 0.1) |
| **Weight gain according to Institute of Medicine recommendations, n (%)** | | | | |
| Too little | 85 (44.0%) | 100 (51.6%) | OR 0.92 (0.56-1.50) | aOR 0.92 (0.56-1.53) |
| Recommended | 43 (22.3%) | 53 (27.3%) | REF | REF |
| Too much | 65 (33.7%) | 41 (21.1%) | OR 0.49 (0.28-0.86)* | aOR 0.47 (0.27-0.84)* |
| **Gestation at final weight, mean (SD), wk** | 37.9 (1.8) | 36.6 (1.4) | MD -1.3 (-1.6 to -0.9)*** | aMD -1.3 (-1.6 to -1.0)*** |
| **Weekly weight gain, mean (SD), kg/week** | 0.22 (0.28) | 0.17 (0.25) | MD -0.05 (-0.11 to 0.00)*[b] | aMD -0.06 (-0.11 to -0.01)*[c] |
| **Birthweight, mean (SD), g** | 3465 (603) | 3546 (599) | MD 81 (-30 to 192) | aMD 70 (-41 to 183) |
| **Gestation at birth, mean (SD), wk** | 39.2 (1.8) | 39.1 (1.9) | MD -0.1 (-0.4 to 0.3) | aMD -0.1 (-0.4 to 0.3) |
| **Low birthweight (<2500g), n (%)** | 10/222 (4.5%) | 8/230 (3.5%) | OR 0.76 (0.30-1.97) | aOR 0.82 (0.31-2.17) |
| **Macrosomia (>4000g), n (%)** | 34/222 (15.3%) | 49/230 (21.3%) | OR 1.50 (0.92-2.43) | aOR 1.39 (0.85-2.28) |
| **Small for gestational age (<10$^{th}$ centile), n (%)** | 49/222 (22.1%) | 29/230 (12.6%) | OR 0.51 (0.31-0.84)** | aOR 0.52 (0.31-0.87)* |
| **Large for gestational age (>90$^{th}$ centile), n (%)** | 19/222 (8.6%) | 29/230 (12.6%) | OR 1.54 (0.84-2.84) | aOR 1.51 (0.81-2.81) |
| **Preterm (<37+0 weeks), n (%)** | 24/223 (10.8%) | 22/230 (9.6%) | OR 0.88 (0.48-1.62) | aOR 0.83 (0.44-1.54) |
| **Postdates (>41+6 weeks), n (%)** | 1/223 (0.4%) | 5/230 (2.2%) | OR 4.93 (0.57-42.57) | aOR 6.21 (0.71-54.08) |
| **Vaginal birth, n (%)** | 132/223 (59.2%) | 124/230 (53.9%) | OR 0.81 (0.56-1.17) | aOR 0.79 (0.54-1.16) |
| **Caesarean birth, n (%)** | 88/223 (39.5%) | 100/230 (43.5%) | OR 1.18 (0.81-1.72) | aOR 1.20 (0.82-1.76) |
| **Induction of labour (excluding Caesarean birth prior to labour), n (%)** | 63/162 (38.9%) | 99/164 (60.4%) | OR 2.39 (1.53-3.73)*** | aOR 2.40 (1.53-3.78)*** |
| **Postpartum haemorrhage (estimated blood loss ≥500ml), n (%)** | 81/222 (36.5%) | 84/197 (42.6%)[d] | OR 1.29 (0.87-1.92) | aOR 1.35 (0.90-2.01) |
| **Perineal laceration sustained (excluding women with a Caesarean birth), n (%)** | 68/135 (50.4%) | 70/127 (55.1%) | OR 1.21 (0.74-1.97) | aOR 1.17 (0.70-1.95) |
| **Epidural analgesia (attempted or achieved), n (%)** | 82/222 (36.9%) | 99/218 (45.4%) | OR 1.42 (0.97-2.08) | aOR 1.47 (0.99-2.17) |
| **General anaesthetic, n (%)** | 22/224 (9.8%) | 14/219 (6.4%) | OR 0.63 (0.31-1.26) | aOR 0.61 (0.30-1.24) |

| | | | | |
|---|---|---|---|---|
| **Shoulder dystocia (excluding women with a Caesarean birth), n (%)** | 5/134 (3.7%) | 3/127 (2.4%) | OR 0.62 (0.15-2.67) | aOR 0.54 (0.12-2.37) |
| **Apgar score at 1 minute <7, n (%)** | 30/221 (13.6%) | 26/218 (11.9%) | OR 0.86 (0.49-1.51) | aOR 0.85 (0.47-1.52) |
| **Apgar score at 5 minutes <7, n (%)** | 3/221 (1.4%) | 2/217 (0.9%) | OR 0.68 (0.11-4.09) | aOR 0.64 (0.10-4.01) |
| **Neonatal unit admission, n (%)** | 15/221 (6.8%) | 16/227 (7.0%) | OR 1.04 (0.50-2.16) | aOR 1.04 (0.49-2.17) |
| **Breastfeeding initiation, n (%)** | 103/217 (47.5%) | 110/223 (49.3%) | OR 1.08 (0.74-1.57) | aOR 1.03 (0.70-1.50) |
| **Breastfeeding at discharge from hospital, n (%)** | 87/215 (40.5%) | 91/217 (41.9%) | OR 1.06 (0.72-1.56) | aOR 0.99 (0.67-1.46) |
| **Day of discharge from hospital, n (%)** | | | | |
| Day of birth | 40 (17.8%) | 23 (10.2%) | REF | REF |
| Day 1 | 73 (32.5%) | 107 (47.3%) | OR 2.61 (1.44-4.72)** | aOR 2.57 (1.41-4.70)** |
| Day 2 | 75 (33.3%) | 64 (28.3%) | OR 1.48 (0.81-2.74) | aOR 1.47 (0.79-2.75) |
| Day 3+ | 37 (16.4%) | 32 (14.2%) | OR 1.50 (0.75-3.02) | aOR 1.40 (0.69-2.85) |
| **Sex of infant, n (%)** | | | | |
| Male | 105 (46.7%) | 117 (50.6%) | OR 1.17 (0.81-1.69) | aOR 1.18 (0.81-1.73) |
| Female | 120 (53.3%) | 114 (49.4%) | REF | REF |
| **Haemoglobin <110g/l at booking, n (%)** | 5/222 (2.3%) | 4/230 (1.7%) | OR 0.77 (0.20-2.90) | aOR 0.89 (0.23-3.46) |
| **Haemoglobin<105 g/l at 28 weeks, n (%)** | 14/212 (6.6%) | 12/215 (5.6%) | OR 0.84 (0.38-1.85) | aOR 0.95 (0.42-2.12) |
| **Haemoglobin<105g/l at 36 weeks, n (%)** | 14/140 (10.0%) | 21/160 (13.1%) | OR 1.36 (0.66-2.79) | aOR 1.53 (0.74-3.19) |
| **Gestational diabetes mellitus (excluding those with gastric surgery), n (%)** | 33/191 (17.3%) | 51/202 (25.2%) | OR 1.62 (0.99-2.64) | aOR 1.64 (0.99-2.70) |
| **Additional monitoring for raised blood pressure, n (%)** [e] | 34/209 (16.3%) | 35/201 (17.4%) | OR 1.09 (0.65-1.82) | aOR 1.08 (0.63-1.83) |

[a] Adjusted for deprivation (REF= most deprived quintile) and smoking (REF=non smoker)
[b] no longer significant after removing outlier (MD -0.05, 95% CI -0.10, 0.01)
[c] remained significant after removing outlier (aMD -0.05, 95% CI -0.10, -0.001)
[d] the new electronic health notes for recording intrapartum care from 2015 made it difficult to obtain estimated blood loss for many women who gave birth in 2015
[e] Additional monitoring for raised blood pressure - women receiving monitoring over and above routine care due to raised blood pressure, including those who went on to be diagnosed with Pregnancy Induced hypertension, pre -eclampsia or HELLP syndrome
* significant at *P*<0.05 level, ** significant at *P*<0.01 level, *** significant at *P*<0.01 level

# Appendix I: Supplementary information for the qualitative interviews article: the interview schedule

## Supplementary Information File 1: Interview schedule

Today I want to concentrate on how you feel about the maternal healthy weight service you received. There are no right or wrong opinions; I would like you to feel comfortable saying what you really think and how you really feel.

Has anyone discussed weight management with you during your pregnancy?

- who has discussed it?
- what has been discussed?
- were they supportive in the way they discussed it?
- was the information you were given useful/ or helpful?
- was the information you got from different people consistent?
- did you follow any of the advice you were given during pregnancy?
    - if yes - what?
    - how?
    - what did you find easy to do?
    - what was difficult to do?

    - if no - why not?
    - what did you find particularly difficult?
    - could anything have been done to make it easier?

*(prompt with any further discussions around:*

- *appropriate gestational weight gain*
- *healthy eating*
- *physical activity)*

- Have you been weighed at any point in pregnancy?
    - how did you feel about being weighed during pregnancy?
    - how often were you weighed?
    - and by who?

- Have you accessed any community based weight management services during pregnancy? ( eg exercise groups, Slimming world. weight watchers etc)
- Are you aware of any that you could access but didn't?

For anyone who has had a previous pregnancy:

- How did service provision in this pregnancy differ from service provision in previous pregnancies?

*If previous weight management service is mentioned:*

- *What were your initial thoughts about the service and being referred to it?*
- *Did you attend the service?*
- *Could you tell me about any parts you particularly liked?*
    - *why did you like them?*

    - *did you feel it was beneficial and helped you in any way?*
    - *could you share an example?*
- *Were there any aspects you didn't like?*
    - *why not?*
    - *what specifically didn't you like about it?*

So thinking of service provision in the future:

- Who would you feel most comfortable getting advice on weight management from?
- What, if anything, do you think could be improved in the services that you have received?
- What barriers do you think women face if following weight management advice during pregnancy?
    - Is there any way health professionals could help women to overcome these?
- What things do you think help following weight management advice during pregnancy?
    - Is there any way health professionals could help women to take advantage of these?

- Do you have any further comments you would like to make about the services provided or how best to support pregnant women to live healthy lifestyles?

Thank you again for taking part, we really appreciate it.

# Abstracts published during PhD

**F Fair**, H Soltani (2020) Evaluating the long-term impact of an antenatal healthy lifestyle service: retrospective cohort study. *European Journal of Public Health,* 30(Supplement_5):v267. Accepted as oral presentation at the 16th World Congress on Public Health – Rome (rearranged to virtual) 12th-17th October 2020.

[redacted]

[redacted]

## Evaluating the long-term impact of an antenatal healthy lifestyle service: retrospective cohort study

**Frankie Fair**

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**Introduction:**
Maternal obesity is associated with increased odds of obesity in the offspring. The antenatal period is considered a good opportunity to promote lifestyle improvements. The long-term impact of maternal characteristics and attending a maternal healthy lifestyle service (MHLS) on childhood risk of overweight was evaluated.

**Methods:**
Women with a body mass index (BMI) $\geq$35kg/m$^2$ referred to one MHLS in England from 2009 were included in a retrospective cohort study. Pseudo-anonymised data from the National Child Measurement Programme were matched to data from women referred to this service. Children were classified as 'overweight' if their weight centile was $\geq$95th centile at 6-8 weeks or 9-12 months or their BMI was $\geq$95th centile at school entry (4-5 years). Univariate logistic regression determined the odds ratios (OR) and 95% confidence intervals (CI) of childhood overweight according to uptake of the MHLS, gestational weight gain (GWG) and other characteristics.

**Results:**
The proportion of infants classified as overweight increased over time [2.8% at 6-8 weeks (20/713), 13.8% at 9-12 months (89/647) and 30.4% at school entry (206/677)]. The odds of overweight increased with each unit increase in birthweight (OR 39.9 95%CI 13.4-119.1 at 6-8 weeks, OR 3.7 95%CI 2.4-5.7 at 9-12 months and OR 1.9 95%CI 1.4-2.5 at school entry). GWG above Institute of Medicine recommendations increased the odds of overweight at 6-8 weeks (OR 2.9 95%CI 1.1-7.4). Women living in the most deprived quartile (OR 1.6 95%CI 1.1-2.2) or who smoked when booking for antenatal care (OR 1.5 95%CI 1.0-2.2) had increased odds of infant with BMI $\geq$95th centile at school entry. Attendance at a MHLS and maternal BMI did not significantly impact on child overweight at any time; however the sample only included women with a raised BMI.

**Conclusions:**
Lifestyle during pregnancy, GWG and other wider health determinants such as deprivation have long lasting effects on infant health and childhood obesity.

**Key messages:**
- Overweight at school entry is high (>30%) for women with a raised BMI when booking for antenatal care.
- Addressing maternal socioeconomic conditions, gestational weight gain and smoking during pregnancy are key priorities for the long-term health of children.

[redacted]

**F Fair**, H Soltani (2020) Experiences of maternal weight management services among women with a raised body mass index. *European Journal of Public Health,* 30(Supplement_5):v851. Accepted as poster presentation at the 16th World Congress on Public Health – Rome (rearranged to virtual) 12th-17th October 2020.

## Experiences of maternal weight management services among women with a raised body mass index

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**Background:**
Obesity is associated with increased maternal morbidity and mortality. Maternal weight management services (MWMS) are a good opportunity to influence lifestyle behaviours of mothers. To understand what constitutes the most suitable service, women's views on MWMS are paramount.

**Methods:**
A purposive sample of 13 women with a BMI$\geq$40kg/m$^2$ were interviewed at 36 weeks gestation. A semi-structured interview schedule explored their experiences of MWMS provision and advice, awareness of services and the barriers and facilitators to antenatal weight management. Interviews were recorded and transcribed verbatim. Inductive thematic analysis was undertaken.

**Results:**
Four themes emerged. 'Understanding where I am at' showed women's readiness and motivation varied, from being avoidant or unaware of weight as an issue to already making changes. 'Getting information' revealed while a few women felt that they received good information during pregnancy most reported a lack of information or minimal information provided in a 'tick-box' fashion. Women particularly wanted practical advice. 'Difficulties I face' identified physical, emotional and financial barriers and the strategies some women used to overcome these. 'Encountering professionals - a mixed experience' demonstrated women wanted to be treated with respect and sensitivity and that how weight management information was addressed was more important than who provided it. The fine line professionals need to tread was evidenced by women thinking they had received inadequate information and yet that there was too much focus on their weight and its related risks during pregnancy.

**Conclusions:**
MWMS should not be seen as a 'tick box' exercise but should be woman-centred to assist women to move forward in their weight management journey, no matter what their starting point. Women desired practical advice provided in a sensitive, respectful manner not just the continual repetition of the risks of being obese during pregnancy.

**Key messages:**
- Maternal weight management services require a woman-centred approach to enable women to move forward on their weight management journey.
- Women want practical, sensitive advice not just the continual repetition of the risks of being obese during pregnancy.

# Other articles co-authored by the candidate referred to within this body of work

## Factors associated with gestational weight gain in women with morbid obesity

**Fair FJ, Soltani H (2023) Factors associated with gestational weight gain in women with morbid obesity. *Journal of Obstetrics and Gynaecology*, 43(2):2288228 doi: 10.1080/01443615.2023.2288228.**[336]

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# Factors associated with gestational weight gain in women with morbid obesity

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**ABSTRACT**

**Background:** Women with obesity are at increased risk of excessive gestational weight gain. Women with a body mass index (BMI) of 40 kg/m$^2$ or more are known to have different patterns of weight gain than women with lower levels of obesity. This study therefore aimed to determine the characteristics associated with gestational weight gain (GWG) among women with a BMI of 40 kg/m$^2$ or more.
**Methods:** Secondary analysis was undertaken on a retrospective cohort of women with a BMI of 40 kg/m$^2$ or more, with a singleton pregnancy referred to an antenatal healthy lifestyle service between 2009 and 2015 (n = 735). GWG was calculated by subtracting weight at the first antenatal appointment from final recorded weight in pregnancy provided the final weight was recorded from at least 34 + 0 weeks gestation. Univariable and multiple linear regression analyses were employed to determine the association between GWG and different maternal and infant characteristics.
**Results:** Average GWG among women with a BMI of 40 kg/m$^2$ or more was 6.0 (±7.1)kg. Multiple regression showed GWG decreased with increasing BMI and increasing parity. Other socio-demographic factors were also significantly associated with GWG, with higher GWG seen among those with high levels of deprivation, where the highest household occupation was of a manual nature, in older women and women of non-White British ethnicity.
**Conclusion:** GWG in this cohort of women with a BMI of 40 kg/m$^2$ or more was within Institute of Medicine recommendations. Using a systems approach to GWG management that incorporates biological, psychological and socio-ecological factors is important.

**PLAIN ENGLISH SUMMARY**

Women with the highest levels of obesity are known to have different patterns of weight gain during pregnancy than other women. This study looked at what factors were linked to pregnancy weight gain in women with the highest levels of obesity. Pregnancy weight gain was calculated by subtracting the woman's weight at her first pregnancy appointment from her weight at the end of pregnancy, providing she was at least 34 weeks pregnant when she was weighed.

The higher the woman's body mass index above 40 kg/m$^2$ at the start of pregnancy, the less weight they gained in pregnancy. Women gained less weight during pregnancy if they already had one or more children rather than were having their first baby or if they lived in households where no one worked. Weight gain was also linked to whether the woman lived in a deprived area and weight gain was higher in women from an ethnic minority. In the future any interventions during pregnancy to help women gain the correct amount of weight need to consider multiple things including how many children they already have, as well as the influence of the woman's family and friends and where the woman lives.

**ARTICLE HISTORY**
Received 4 July 2023
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**KEYWORDS**
Maternal obesity; raised BMI; gestational weight gain; prenatal care

## Introduction

A body mass index (BMI) of 25.0–29.9 kg/m$^2$ is classified as overweight and a BMI $\geq$30kg/m$^2$ as obese, with obesity subdivided into three classes, class I (BMI 30.00–34.99 kg/m$^2$), class II (BMI 35.00–39.99 kg/m$^2$) and class III (BMI $\geq$40.00 kg/m$^2$) (WHO 2000). Across most of the globe overweight and obesity during pregnancy has increased over recent decades (Devlieger *et al.* 2016). In England rates of obesity during pregnancy have approximately tripled from 7.6% in 1989 (Heslehurst *et al.* 2010) to 22.2% in 2018–2019 (National Health Service (NHS) Digital 2019). Individuals with the highest levels of obesity (BMI $\geq$40kg/m$^2$) were rare several decades ago. However, recently the incidence of women with a BMI $\geq$40kg/m$^2$ in early pregnancy has been found to vary being 1.6% in Spain (Williamson *et al.* 2020), 3.3% in England (Public Health England (PHE)), 2019a) and 9.7% in the United States (Williamson *et al.* 2020).

Numerous adverse risks are associated with maternal obesity during pregnancy for both the woman and neonate (Lutsiv *et al.* 2015; Santos *et al.* 2019). Maternal overweight or

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obesity are estimated to be linked to 23.9% of pregnancy complications, with the highest risk of complications occurring in women with a BMI $\geq$40kg/m$^2$ (Santos *et al*. 2019). Additionally, women with obesity prior to pregnancy are at increased risk of excessive gestational weight gain (GWG) (Samura *et al*. 2016). The Institute of Medicine (IOM) recommends a GWG between 5 and 9 kg for women with obesity (Rasmussen & Yaktin 2009). However, 44% of women with obesity gain more than this recommended weight (Rogozińska *et al*. 2017). Increased GWG is itself associated with many adverse outcomes such as increased risk of caesarean birth (Goldstein *et al*. 2017), labour induction (Xu *et al*. 2021), large for gestational age infants (Santos *et al*. 2019; Goldstein *et al*. 2017), long term maternal weight retention (Samura *et al*. 2016), and childhood obesity (Voerman *et al*. 2019).

Several studies have explored whether factors such as maternal age, ethnicity, parity, socio-economic status, marital status, education, and smoking status are associated with GWG (Lindberg *et al*. 2016; Samura *et al*. 2016; Garmendia *et al*. 2017; Emery *et al*. 2021; Cheng *et al*. 2021). Women with a BMI $\geq$40kg/m$^2$ are at the highest risk of many adverse pregnancy outcomes (Lutsiv *et al*. 2015; Santos *et al*. 2019; D'Souza *et al*. 2019) and are known to have different GWG patterns to other women with lower levels of obesity (Lindberg *et al*. 2016). However, women with a BMI $\geq$40kg/m$^2$ are underrepresented in current research, with no studies specifically looking at factors associated with GWG among this subgroup of women. Given the increasing prevalence of women with a BMI $\geq$40kg/m$^2$ attending for perinatal care (Devlieger *et al*. 2016), better understanding of the factors associated with GWG in this group of women is particularly pertinent.

The objective of this study was therefore to determine the characteristics associated with GWG among women with a BMI of 40 kg/m$^2$ or more.

## Methods

### Participants and procedures

Secondary analysis of a retrospective cohort study was undertaken of women who booked for antenatal care from July 2009 to 2015 in a National Health Service Trust in the Yorkshire and Humber region of England. This Trust had high rates of maternal obesity and deprivation compared to the rest of England (Public Health England (PHE) 2019b). Women were eligible for inclusion if they had a BMI $\geq$40kg/m$^2$ when first attending for antenatal care and had a singleton pregnancy that remained viable at 24 weeks gestation. Maternal and neonatal data were obtained from routinely collected pregnancy and birth health records.

At the NHS Trust during this time women with a BMI $\geq$40kg/m$^2$ were offered access to a midwife-led antenatal healthy lifestyle service. This has been described in full elsewhere (West 2010; Fair and Soltani 2023). At this service women were routinely offered either one (July 2009–2011) or three visits (2012–2015), with women also able to access the service for additional appointments if they desired. Women were offered support and advice at this service covering four key aspects: minimising GWG, healthy eating, undertaking physical activity, and breastfeeding.

### Measures

#### Sociodemographic data

At the first antenatal appointment women self-reported educational level, smoking status, marital status and ethnicity, as well as the occupation of herself and her partner. The highest occupation category for each household (either the woman or her partner) was calculated using the three category National Statistics Socio-Economic Classification (NS-SEC) system (Office for National Statistics (ONS), 2010). Furthermore, postcode was used to determine an Index of Multiple Deprivation (IMD) score. This is the official measure of relative deprivation in England, combining information from seven domains (income, employment, education, health, crime, housing and living environment) to give an overall score from 1 (most deprived) to 32844 (least deprived) (Smith *et al*. 2015). These scores were designated into quintiles.

#### Maternal BMI

BMI was calculated using weight and height measured at the first antenatal appointment. In a small minority of cases ($n = 9$) BMI was obtained from the medical records as weight or height were not recorded to calculate BMI independently.

#### Pregnancy and intrapartum data

Women self-reported parity. Other pregnancy and intrapartum related data were documented by healthcare providers such as, birthweight and infant sex, as well as expected date of birth on ultrasound from which gestation at appointments and birth were calculated.

#### Gestational weight gain

The final recorded weight in pregnancy was used, providing the gestation of this weight was at least the middle of the third trimester (34 + 0 weeks gestation). If a weight was not recorded from 34 + 0 weeks gestation onwards the woman was classified as not having GWG recorded. GWG was determined by subtracting weight at the first antenatal appointment from final weight. Given variation in GWG timings, gestation at the first and last recorded weight in pregnancy were adjusted for within the multiple regression analysis.

### Statistical analysis

Logical checks and data cleaning were carried out and inconsistencies returned to the field for clarification. Characteristics were compared between women who had GWG recorded ($n = 618$) and those who did not ($n = 117$) using student's t-test or Chi-square test. For women who had a recorded GWG, the independent relationship between GWG and maternal socio-demographic characteristics, pregnancy characteristics and infant characteristics were explored using linear regression with GWG as the dependent variable.

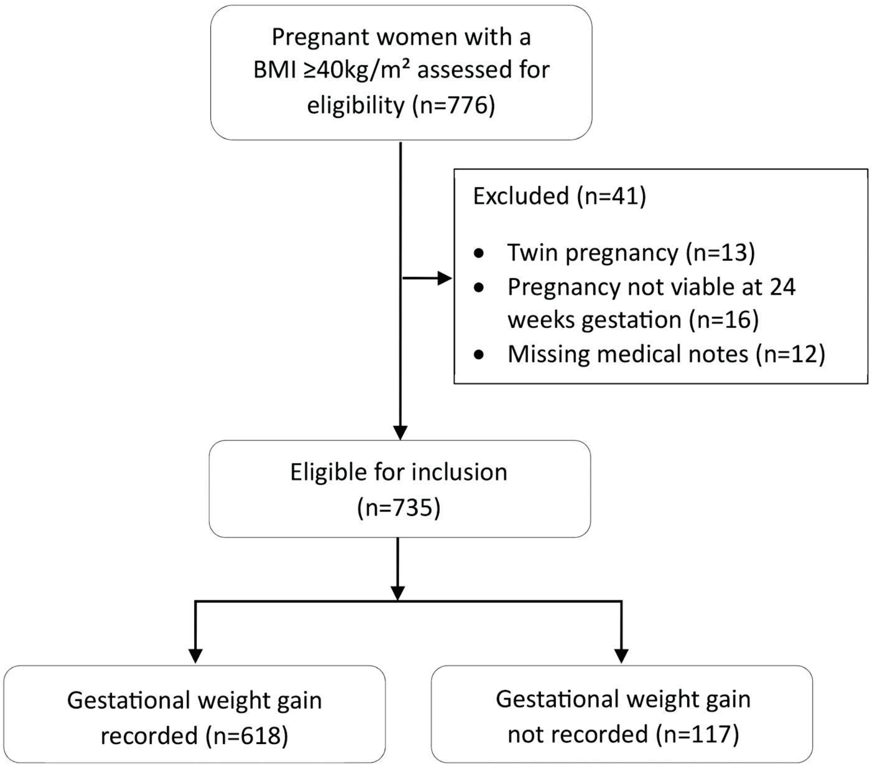


**Figure 1.** STROBE flow chart of study participant selection.

Variables were chosen by consulting previous literature on the topic (Lindberg *et al.* 2016; Samura *et al.* 2016; Garmendia *et al.* 2017; Emery *et al.* 2021; Cheng *et al.* 2021). Factors were then entered into a multiple regression main effects linear model to determine the significance of each variable on GWG once controlling for other factors. The multiple regression model was adjusted for birthweight, gestation at the first antenatal weight, gestation at the final recorded weight and gestation at birth. Education was omitted from the multiple regression model due to the large number of missing cases. Additionally marital status was omitted from the multiple regression model as this factor had high variance inflation factors leading to concerns over multi-collinearity. A separate model was constructed for women whose pregnancies were not complicated by either diabetes (type 1, type 2 or gestational) or hypertension (pre-existing or pregnancy induced). For each linear regression model, assumptions were checked using standard regression diagnostics for linearity, normality, leverage and influence. Where outliers or points of potentially high leverage were identified, data analysis was rerun after removal of these points to determine any impact on the significance or direction of the effect size. Where differences in the magnitude or direction of the effect size were noted, both effect sizes have been presented. For all models the unstandardised $\beta$ co-efficient alongside its 95% confidence interval (CI) are presented. $p < 0.05$ was regarded as statistically significant. All analyses were undertaken in SPSS 26.0.

### *Ethical approvals*

This study was approved by the East England - Cambridge East Research Ethics Committee (IRAS: project number 207998). The need for informed consent was waived by the ethics committee due to the retrospective nature of this study.

## Results

Figure 1 provides a flowchart of study participant selection. Of the 735 eligible women, 618 had their GWG recorded. Women with and without the primary outcome GWG were compared (Table 1). Women who already had two or more children or who gave birth prematurely were significantly less likely to have GWG recorded. Women whose highest household occupation was classified as either ‘routine or manual’ or ‘housewife/unemployed/student’ also tended to be less likely to have GWG recorded. Of women who gave birth prematurely, 64.8% ($n = 46$) did not have GWG recorded. These women and those who moved away from the area ($n = 18$) accounted for 55% of those lacking the outcome of GWG.

Mean GWG was 6.0 kg (±7.1) and ranged from a weight loss of 17.6 kg to weight gain of 27.6 kg. The average gestation of the final weight was 37.4 (±1.8) weeks, with a median final weight to birth interval of 1.9 weeks (interquartile range 0.9–3.1 weeks). GWG decreased with increasing maternal BMI at the first antenatal appointment and parity (Table 2). GWG increased with ethnicity other than white British and in households with someone in employment. Compared to those in the most deprived quintile, women in the second most deprived quintile had a significantly higher weight gain during pregnancy. Compared to attending no antenatal healthy lifestyle service appointments, attending one, two or three or more appointments had no impact on GWG.

Within the multiple regression main effects linear model (Table 3), maternal BMI, parity, ethnicity, deprivation and highest household occupation remained significantly independently associated with GWG. However, within the multiple regression model only women whose highest household occupation was a manual occupation had higher GWG. Furthermore, maternal age became significant within the multiple regression model. This multiple regression model accounted for 21.1% of the total variance in GWG. After removing the thirteen outliers/points of high leverage (Table S1), factors significantly associated with GWG remained the same except that maternal age was no longer significant and smoking status when booking for antenatal care was associated with increased GWG. When only looking at pregnancies that were not complicated by diabetes or hypertension, the factors associated with GWG remained the same except for maternal age which was no longer significantly associated with GWG (Table S2).

## Discussion

Average weight gain within this cohort was 6.0 kg which is within the 5–9kg range recommended for women with obesity (Rasmussen & Yaktin 2009). The present study showed wide variability in GWG among women with a BMI $\geq$40kg/m$^2$. The multiple regression model showed that GWG decreased with increasing BMI and increasing parity. Higher GWG was seen among those with high levels of deprivation, where the highest household occupation was of a manual nature, in older women and women of non-White British ethnicity.

Previous studies and reviews of women of all BMI categories have similarly noted maternal BMI (Kirchengast and Hartmann 2013; Cheney *et al*. 2017), and parity (Deputy *et al.* 2015; Heery *et al*. 2015; Pawlak *et al*. 2015; Garmendia *et al.* 2017; Rogozińska *et al.* 2017; Nunnery *et al*. 2018; Cheng *et al*. 2021) to be factors associated with GWG or excessive GWG, although these factors were not always significant when adjusting for covariates. Parity has also previously been associated with GWG when specifically looking at women with obesity (Raymond *et al*. 2014; Deputy *et al*. 2015). In all instances nulliparous women had higher GWG or were at increased risk of excessive GWG.

The literature regarding deprivation is inconsistent. Low socio-economic status or proxy measures of socioeconomic status such as education, employment or housing type have been found to increase the odds of GWG below guidelines (Lindberg *et al*. 2016), increase risk of excessive GWG in early pregnancy (Cheney *et al*. 2017) and to have no significant impact on GWG (Garmendia *et al*. 2017; Cheng *et al*. 2021) even though all of the studies were undertaken in high income countries. A complicated interaction between deprivation and GWG was noted within this study. Once controlling for other factors GWG was higher in women in the second most deprived quintile compared to those in the most deprived quintile, and higher in those from a manual occupation than in those who were unemployed or a housewife. The reasons for this are unclear but may be due to women in the most deprived quintile being less able to afford a healthy lifestyle, particularly an adequate quantity of food during pregnancy. Within this cohort after controlling for confounders such as deprivation there was a trend for those who smoked to have a higher GWG, which became significant after removing outliers. Other studies have similarly shown current and previous history of smoking to be significantly associated with GWG outside of the recommended range (Kirchengast and Hartmann 2013; Pawlak *et al*. 2015; Lindberg *et al*. 2016), although women with a BMI $\geq$40kg/m$^2$ were a small minority of these samples.

Maternal age has been noted to be associated with GWG in previous studies, with women with excessive GWG noted to be younger on average than those with inadequate or adequate GWG (Kirchengast and Hartmann 2013; Cheng *et al*. 2021). Others have also found women over 35 years of age to have significantly lower GWG than younger women (Heery *et al*. 2015) and for GWG to decrease with increasing maternal age (Rogozińska *et al.* 2017). This previously noted effect may in part be explained by nulliparous women having higher GWG, as only one study adjusted for parity (Rogozińska *et al.* 2017). Additionally, BMI increases with maternal age (National Health Service (NHS) Digital 2019) and as there is a trend for GWG to decrease with increasing BMI (Siega-Riz *et al*. 2020) this may also partly explain the lower GWG with advancing maternal age. Within our multiple regression analysis that adjusted for parity and maternal BMI there was a trend towards higher GWG with advancing maternal age after the removal of outliers.

Women of ethnicity other than white British had higher GWG within this study, despite their mean BMI being higher at the start of pregnancy. However, given the limited number of women on non-white ethnicity these results should be treated with caution. The literature regarding the impact of ethnicity on GWG provides a complex picture. One study noted that women of non-Irish nationality had increased GWG (Heery *et al*. 2015), and another that being of African American ethnicity was associated with increased odds of excess GWG (Nunnery *et al*. 2018). Others have however noted non-White ethnicity to decrease mean GWG (Rogozińska *et al.* 2017) or the odds of GWG above recommendations (Pawlak *et al*. 2015; Lindberg *et al*. 2016). These differences may be explained by the ethnic composition within the studies, as a further study found some ethnicities to be associated with inadequate GWG and others with excess GWG among women with obesity (Deputy *et al*. 2015).

Attendance at the antenatal healthy lifestyle service was not significantly associated with GWG in either the univariate or multiple regression analysis. No data was collected by the service regarding whether service attendance led to any improvements in diet or physical activity. When women with access to the antenatal healthy lifestyle service have previously been compared to women in a separate NHS Trust who did not have access to such a service, the only clinical outcome that favoured the lifestyle service was breastfeeding at discharge from the hospital (Fair and Soltani 2023). No

**Table 1.** Maternal characteristics of women with and without gestational weight gain outcome recorded.

| Variable | Category | With GWG (n = 618) | Without GWG (n = 117) | *p*-value |
|---|---|---|---|---|
| Body mass index | | 44.0 (±3.7) | 44.0 (±3.7) | 0.719 ∫ |
| Gestation at first antenatal weight (weeks) | | 9.1 (±3.3) | 8.9 (±3.2) (n = 116) | 0.515 |
| Maternal age (years) | | 28.3 (±5.4) | 29.1 (±5.3) | 0.171 |
| Smoking status at first antenatal appointment | | | | 0.109 |
| | Smoker | 129 (20.9%) | 32 (27.6%) | |
| | Non-smoker | 489 (79.1%) | 84 (72.4%) | |
| Parity | | | | 0.004** |
| | 0 | 190 (30.8%) | 30 (25.6%) | |
| | 1 | 219 (35.4%) | 29 (24.8%) | |
| | 2 or more | 209 (33.8%) | 58 (49.6%) | |
| Ethnicity | | | | 0.952 |
| | White British | 587 (95.6%) | 112 (95.7%) | |
| | All other ethnicities | 27 (4.4%) | 5 (4.3%) | |
| Deprivation quintile | | | | 0.123 |
| | Quintile 1: Most deprived | 339 (54.9%) | 78 (66.7%) | |
| | Quintile 2 | 127 (20.5%) | 21 (17.9%) | |
| | Quintile 3 | 78 (12.6%) | 9 (7.7%) | |
| | Quintile 4 | 53 (8.6%) | 8 (6.8%) | |
| | Quintile 5: Least deprived | 21 (3.4%) | 1 (0.9%) | |
| Highest household occupation | | | | 0.077 |
| | Professional or higher occupations | 107 (17.8%) | 15 (13.3%) | |
| | Intermediate occupations | 141 (23.5%) | 17 (15.0%) | |
| | Routine and manual occupations | 197 (32.8%) | 46 (40.7%) | |
| | Housewife/ Unemployed/ student | 156 (25.9%) | 35 (31.0%) | |
| Education | | | | 0.589 |
| | GCSE/ equivalent or lower | 102 (43.4%) | 17 (44.7%) | |
| | AS/A level or equivalent | 60 (25.5%) | 12 (31.6%) | |
| | Degree, postgraduate or equivalent | 73 (31.1%) | 9 (23.7%) | |
| Marital status | | | | 0.508 |
| | Married/civil partnership | 210 (34.2%) | 46 (39.3%) | |
| | Partner | 334 (54.4%) | 57 (48.7%) | |
| | Single ‡ | 70 (11.4%) | 14 (12.0%) | |
| Preterm birth (<37 + 0 weeks gestation) | | | | 0.000*** |
| | No | 592 (95.9%) | 54 (54.0%) | |
| | Yes | 25 (4.1%) | 46 (46.0%) | |

Data are mean ± standard deviation or n (%). Abbreviations GWG: gestational weight gain; IMD: Index of Multiple Deprivation.
∫Mann Whitney U test used as data not normally distributed.
‡- The single category included 10 women who were divorced/ separated/widowed.
** statistically significant at $p < 0.01$ level,.
*** statistically significant at $p < 0.01$ level.

impact on other outcomes such as vaginal birth, birthweight or preterm birth were noted (Fair and Soltani 2023).

Given the higher GWG among nulliparous women and the complex inter-ethnic variability noted within this and previous studies, the importance of adapting interventions to the needs of nulliparas and specific ethnic groups is highlighted. This is especially important given that women themselves report wanting more information in their first pregnancy (Fair *et al*. 2022). Additionally, current interventions are believed to inadequately consider culture and ethnic differences (Byrd *et al*. 2018) despite known ethnic health disparities (Jardine *et al*. 2021). Furthermore, the multifaceted interaction between GWG and ethnicity, socioeconomic status and other maternal and infant outcomes, emphasise the need to consider obesity and GWG management not just at an individual level, but through a wider lens that incorporates social, environmental, political and economic responsibilities and implications (Devlieger *et al*. 2016). A systems approach to obesity has therefore been recommended (Lee *et al*. 2017). This approach addresses all interconnected factors that contribute to obesity including the individual biological variables such as genetics and physiological aspects, psychological effects and socio-ecological factors (Lee *et al*. 2017). Incorporating socio-ecological factors moves from an exclusively individual focus to also tackle the influences on women from their family and home, work and peers, community, industry, government, culture and society (Hill 2021).

## *Strengths and limitations of the study*

This study explored the factors associated with GWG within a large sample of women with a BMI ≥40kg/m$^2$, a category often lacking in previous studies. Some limitations however need to be acknowledged. Women within this cohort had been invited to an antenatal healthy lifestyle service, however attendance at this service had no impact on GWG suggesting the results are still generalisable to a wider population. Retrospective data collection is known for its limitations around data completeness (Hasson *et al*. 2015). Poor documentation of maternal education was particularly evident within this study. Additionally, women of high parity and those whose highest household occupation was classified as housewife, unemployed or student were significantly less likely to have a final weight within the medical notes. This may have influenced the impact of these factors within the multiple regression model. The retrospective nature of the study also limited the availability of some factors previously noted in the literature to be associated with GWG such as psychosocial factors and maternal diet. Women were routinely weighed at booking and at 36 weeks gestation within

**Table 2.** Crude regression coefficients and 95% confidence intervals for each variable with gestational weight gain.

| Variable | Category | n | β (95% CI) | *p*-value |
|---|---|---|---|---|
| Number of healthy lifestyle clinic appointments attended | 0 | 618 | REF | |
| | 1 | | 0.02 (-1.75, 1.80) | 0.979 |
| | 2 | | 0.49 (-1.32, 2.30) | 0.596 |
| | 3+ | | 0.78 (-0.97, 2.53) | 0.380 |
| Body mass index | | 618 | −0.18 (-0.33, −0.03) | 0.021* |
| Maternal age (years) | | 618 | 0.05 (-0.05, 0.16) | 0.328 |
| Smoking status at first antenatal appointment | Non-smoker | 618 | REF | |
| | Smoker | | −0.22 (-1.60, 1.16) | 0.754 |
| Parity | 0 | 618 | REF | |
| | 1 | | −2.50 (-3.86, −1.14) | 0.000*** |
| | 2 or more | | −3.23 (-4.61, −1.86) | 0.000*** |
| Ethnicity | White British | 614 | REF | |
| | All other ethnicities | | 4.24 (1.52, 6.97) | 0.002** |
| Deprivation quintile | Quintile 1: Most deprived | 618 | REF | |
| | Quintile 2 | | 1.98 (0.53, 3.43) | 0.007** |
| | Quintile 3 | | 0.58 (-1.16, 2.33) | 0.512 |
| | Quintile 4 | | 0.89 (-1.16, 2.95) | 0.395 |
| | Quintile 5: Least deprived | | 0.64 (-2.49, 3.77) | 0.688 |
| Highest household occupation | Professional or higher occupations | 601 | 2.62 (0.87, 4.36) | 0.003** |
| | Intermediate occupations | | 1.95 (0.34, 3.57) | 0.018* |
| | Routine and manual occupations | | 2.33 (0.84, 3.82) | 0.002** |
| | Housewife/ Unemployed/ student | | REF | |
| Education | GCSE/ equivalent or lower | 235 | REF | |
| | AS/A level or equivalent | | 2.13 (-0.16, 4.41) | 0.068 |
| | Degree, postgraduate or equivalent | | 1.35 (-0.81, 3.50) | 0.220 |
| Marital status | Married/civil partnership | 614 | 0.44 (-1.49, 2.36) | 0.657 |
| | Partner | | −0.66 (-2.48, 1.17) | 0.482 |
| | Single ‡ | | REF | |
| Infant sex | Female | 617 | REF | |
| | Male | | 0.97 (-0.15, 2.09) | 0.090 § |

Abbreviations: β: regression coefficient; 95% CI: = 95% confidence interval; REF: referent;.
Removing the outlier(s) and / or point(s) of high leverage, did not change the direction of the effect or the significance except in the case detailed below:.
§Further away from reaching significance when removing the 2 cases with large standardised residuals [0.826, 95% CI -0.281, 1.933) $p = 0.143$, $n = 615$].
‡- The single category included 9 women who were divorced/ separated/widowed.
* statistically significant at $p < 0.05$ level,.
** statistically significant at $p < 0.01$ level,.
*** statistically significant at $p < 0.01$ level.

**Table 3.** Multiple regression model of factors associated with gestational weight gain in women with a BMI ≥ 40kg/m$^2$ ($n = 596$).

| Variable | Category | β (95% CI)‡ | *p*-value |
|---|---|---|---|
| Constant | | 14.71 (-2.62, 32.04) | 0.096 |
| Body mass index | | −0.22 (-0.36, −0.07) | 0.003** |
| Maternal age | | 0.12 (0.005, 0.24) | 0.041* |
| Smoking status at first antenatal appointment | Non-smoker | REF | |
| | Smoker | 1.33 (-0.07, 2.73) | 0.062 |
| Parity | 0 | REF | |
| | 1 | −3.10 (-4.44, −1.76) | <0.001*** |
| | 2 or more | −3.96 (-5.47, −2.44) | <0.001*** |
| Ethnicity | White British | REF | |
| | All other ethnicities | 3.07 (0.47, 5.67) | 0.021* |
| Deprivation quintile | Quintile 1: Most deprived | REF | |
| | Quintile 2 | 2.00 (0.63, 3.37) | 0.004** |
| | Quintile 3 | 0.21 (-1.46, 1.89) | 0.803 |
| | Quintile 4 | 0.13 (-1.91, 2.17) | 0.899 |
| | Quintile 5: Least deprived | 0.16 (-2.84, 3.16) | 0.915 |
| Highest household occupation | Professional or higher occupations | 1.41 (-0.35, 3.18) | 0.117 |
| | Intermediate occupations | 1.17 (-0.42, 2.76) | 0.149 |
| | Routine and manual occupations | 1.56 (0.14, 2.98) | 0.032* |
| | Housewife/ Unemployed/ student | REF | |
| Number of healthy lifestyle clinic appointments attended | 0 | REF | |
| | 1 | −0.54 (-2.26, 1.18) | 0.537 |
| | 2 | −0.12 (-1.86, 1.62) | 0.890 |
| | 3+ | −0.02 (-1.74, 1.70) | 0.982 |
| Infant sex | Female | REF | |
| | Male | 0.39 (-0.68, 1.45) | 0.478 |

‡Adjusted for birthweight, gestation at first antenatal weight, gestation at final recorded weight and gestation at birth.
$R2 = 0.211$ $F = 7.328$ $p < 0.001$, $n = 596$ df = 21.
Within the final model, normality of the residuals was checked graphically. Durbin Watson = 1.981. Collinearity tolerance ranged from 0.426 to 0.953 and variance inflation factors ranged from 1.05 to 2.35, therefore no concerns with multicollinearity were indicated within this model.
No cases with extreme Cook's values were identified, 3 cases had standardised residuals > ± 3 and 10 cases had Mahalanobis distances where $p < 0.001$. For analysis removing these outliers/ points of leverage please see Table S1.

the Trust with the antenatal healthy lifestyle service. To capture as many women as possible we included anyone who had a final weight recorded from 34 weeks gestation onwards. However, a large proportion of women who gave birth prematurely did not have a final weight recorded, so this study is largely applicable to women with a term or late preterm birth. Given the multiple tests undertaken within the univariate and multiple regression model the probability of a type 1 error increases; it is therefore possible that some of the findings within this study were chance findings and did not actually represent observed differences. Additionally, outliers within the multiple regression model suggested the model fitted less well for the few cases where BMI was 60 or more and when women attended for their first antenatal care appointment after 26 weeks gestation.

## Conclusions

Among women with a BMI $\geq$40kg/m$^2$, higher GWG was seen among those who were nulliparous, with high levels of deprivation and where the highest household occupation was of a manual nature. While there were too few cases within this analysis to make generalisations, the requirement for further understanding around GWG according to ethnicity among women with a high BMI has been demonstrated. Furthermore, the study has highlighted the need to specifically focus on the effectiveness of any interventions developed among nulliparous women and those from more deprived backgrounds.

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## Authors' contributions

FF and HS developed the protocol; FF assisted with data collection; FF analysed and interpreted the data; HS supervised analysis and interpretation of the data; FF wrote the manuscript; HS revised the manuscript; FF and HS agreed the final manuscript.

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## Data availability statement

The datasets used and/or analysed during the current study are not publicly available within a repository as they belong to the Hospital Trust, but the data is available from the corresponding author on reasonable request.

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# Healthy weight services in England before, during and after pregnancy: A mixed methods approach

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# Healthy weight services in England before, during and after pregnancy: a mixed methods approach

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## Abstract

**Background:** Maternal overweight and obesity are associated with numerous adverse outcomes including higher rates of maternal and infant mortality and morbidity. Overweight and obesity before, during and after pregnancy are therefore a significant public health priority in England. This project explored and mapped healthy weight service availability at different stages of the childbearing cycle.

**Methods:** A mixed methods approach included a questionnaire-based survey disseminated through Local Maternity Systems and semi-structured interviews or focus groups with providers and commissioners. Current maternal weight service provision was explored along with some of the barriers and facilitators for providing, delivering and accessing healthy weight services. Descriptive statistics were reported for quantitative data and content analysis was used for thematic reporting of qualitative data.

**Results:** A total of 88 participants responded to the survey. All services were offered most frequently during pregnancy; with healthy eating and/or weight management services offered more often than physical activity services. Few services were targeted specifically at women with a raised body mass index. There was a high degree of inconsistency of service provision in different geographical areas.
Several themes were identified from qualitative data including "equity and variation in service provision", "need for rigorous evaluation", "facilitators" to encourage better access or more effective service provision, including prioritisation, a change in focus and co-design of services, "barriers" encountered including financial and time obstacles, poor communication and insufficiently clear strategic national guidance and "the need for additional support".

**Conclusions:** There is a need to reduce geographical variation in services and the potential health inequalities that this may cause. Improving services for women with a raised body mass index as well as services which encourage physical activity require additional emphasis. There is a need for more robust evaluation of services to ensure they are fit for purpose. An urgent need for clear national guidance so that healthcare providers can more effectively assist mothers achieve a healthy weight gain was identified. Commissioners should consider implementing strategies to reduce the barriers of access identified such as childcare, transport, location and making services free at the point of use.

**Keywords:** Healthy weight, Gestational weight gain, Maternal obesity, Service provision

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## Background

Obesity and overweight (Body Mass Index (BMI) ≥25 $kg/m^2$) affect more than 60% of the adult population [1]; with data from 37 maternity units showing the rate of first trimester maternal obesity has more than doubled over the previous 2 decades [2]. Managing the consequences of obesity is estimated to cost the National Health Service (NHS) £27 billion per year [3]. Childbearing contributes to the rise of overweight and obesity in women [4]. Raised BMI is associated with increased short-and long-term adverse outcomes for mothers such as increased risk of maternal mortality, pregnancy induced hypertension, gestational diabetes, primary postpartum haemorrhage and interventional birth [5]. For babies, there are additional risks of stillbirth, large for gestational age, admission to neonatal units and neonatal mortality [6–11].

The promotion of healthy lifestyle and healthy weight before, during and after pregnancy have been suggested to reduce the risk of pregnancy and birth complications as well as to minimise the risk of obesity development and metabolic diseases such as type 2 diabetes in the long term [12–14]. Implementing preventative strategies that provide opportunities to enhance lifestyle choices throughout preconception, pregnancy and the postpartum with the aim of reducing the burden of maternal obesity and its associated complications have been identified as top priorities [15]. However, little is known about the pattern of service provision to support women and families to enhance their lifestyle and promote healthy weight gain at such an important life stage.

In 2015 the United Kingdom (UK) government announced its ambition to halve rates of stillbirth, neonatal death and maternal death by 2030 [16]. In 2016 'Better Births' set out the vision for safer, more personalised, kinder, professional, and more family-friendly maternity services [16]. While NHS England lead the overall programme, Public Health England (PHE) leads the implementation of Workstream 9 'Improving prevention and population health' within the Better Births recommendations [15]. Local Maternity Systems (LMS) have been established to drive this transformation and are responsible for developing and implementing a local vision for transforming maternity services by 2020/2021. In total forty-four LMS have been established across England which include both providers and commissioners operating together to ensure that women and families are able to access the services they need in a timely manner.

This study aimed to explore current service provision of maternal healthy weight services in England through a survey of LMS representatives and to determine the perspectives of key stakeholders on variation in service provision and related barriers and facilitators locally.

## Method

A mixed methods approach was undertaken. It is recognised that combining different research methodologies in mixed methods research can provide better understanding of research questions through triangulation of results collected from different sources [17]. An online questionnaire was distributed and analysed. The results of this were utilised to develop a semi-structured interview schedule which was used to gather further data from key stakeholders.

### Online survey

Using an online Survey Monkey questionnaire, we explored commissioners' and providers of healthcare services' views to establish the various range and type of services available to support women in achieving a healthy weight and lifestyle prior to pregnancy, during pregnancy or up to 1 year postpartum (see Additional file 1). The survey included fixed response and open-ended questions around services available for all women with regards to healthy eating (services specifically aimed at promoting a healthy diet), physical activity (services aimed at encouraging exercise) and weight management (services aimed at weight management which could address diet, exercise or psychosocial issues). The survey also asked about any services available for women with a raised BMI (≥25 $kg/m^2$). Where services were provided, respondents were asked if the service had been evaluated in any way, this could include local audit or formal external evaluation. Respondents were also asked if the services provided, were for the women only or incorporated other family members into the service and whether service users had been involved when developing the service.

The survey was disseminated through the national maternity transformation programme network to all 44 LMS. The questionnaire was initially sent out on 12th March 2018, followed by a reminder on 24th April 2018. Further requests were sent to LMS Chairs within regions where no initial responses were received.

### Semi-structured interviews

Individual interviews or focus groups were undertaken with a purposive sample of key stakeholders within one region of England. These stakeholders included providers and commissioners of maternity, public health, sexual health, contraceptive and health visiting services. A semi-structured interview schedule informed by the survey results was developed (see Additional file 2). This covered services currently provided, services that respondents would like to see provided and factors interviewees felt were facilitators or barriers to service provision or access.

### Data analysis

Descriptive statistics were reported for the quantitative component of the survey and simple content analysis undertaken on the open-ended responses within the survey.

All interviews and focus groups were audio recorded and transcribed verbatim. Themes within responses were identified using a simple content analysis. Transcripts were initially read to ensure familiarity with the data. Interviewees' responses were then coded inductively by two researchers to enhance trustworthiness of the findings. Similar and disparate codes were developed into themes. Two researchers undertook the analysis with the final themes agreed through discussion.

## Results - online questionnaire

### Characteristics of respondents

Responses were received from 88 people of whom 39 (44.3%) were commissioners, 43 (48.9%) were providers, 1 (1.1%) was a specialist, 1 (1.1%) worked as both a commissioner and provider and four (4.5%) did not answer.

Figure 1 shows the LMS distribution of respondents. A response was received from 23 of the 44 LMS (52.3%) within England. Of the fourteen respondents who did not report which LMS they were from, 11 took no further part in the survey.

### Service provision for women before, during or after pregnancy

A total of 68 participants answered questions about service availability for all women promoting healthy eating and/or weight management and 44 responded to questions about physical activity. Both types of services were offered most frequently during pregnancy and the time that services were reported to be offered least was prior to pregnancy. Healthy eating and/or weight management services were offered more often than physical activity services at all stages of the childbearing cycle (See Fig. 2).

Additional service provision for women with a BMI ≥ 25 kg/m$^2$ was low at all stages of the childbearing cycle (Fig. 2); with very few respondents reporting additional services (only 7 healthy eating and/or weight management services and 3 physical activity services). Similarly to services for all women, most services were provided during pregnancy.

### Geographical distribution of services

Service availability varied between different LMSs, with some LMSs reporting no services during the childbearing cycle, some reporting provision across all stages and some at one or two of the different stages only - prior to pregnancy, during pregnancy or postpartum.

In all LMS where there were multiple respondents it was noted that the services reported varied between respondents. This could be from no service availability to availability across all stages of the childbearing cycle. It was unclear within our survey whether this was due to service availability awareness differing between respondents or whether there were differences in service availability in different NHS Trusts/ clinical commissioning groups within each LMS.

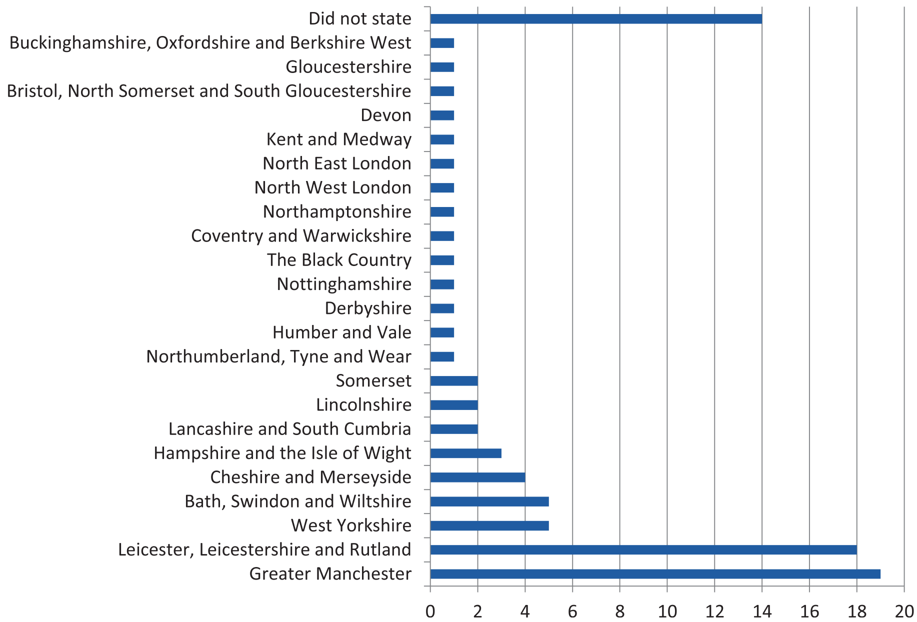


**Fig. 1** Survey responses from the different Local Maternity Systems (LMSs) ($n = 88$)

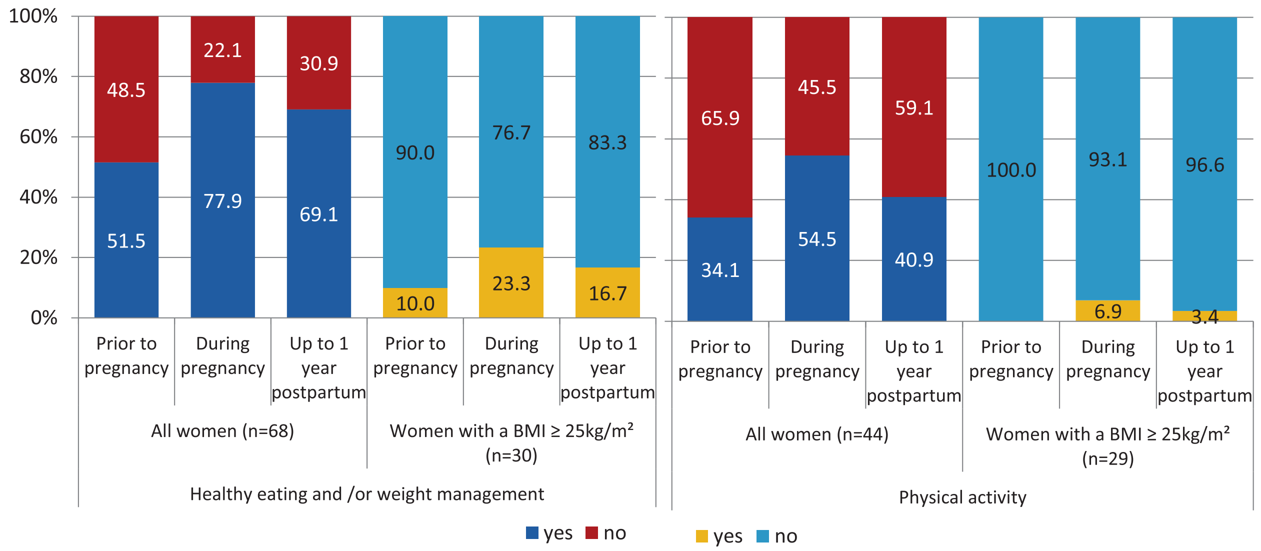


**Fig. 2** Service availability to all women and women with a raised BMI at different childbearing stages

**Service components**

Services provided varied. They could include basic information provision such as the Eat Well Plate [18], safe exercise in pregnancy guidelines or the physical activity in pregnancy infographic [19] given by professionals such as midwives or health visitors. Some areas provided information about bespoke programmes that women could access such as aquanatal classes, Cook it Programmes, leisure centre partnerships or park walks. A few respondents reported the availability of dietician referral or could refer women to specific services such as HENRY (Health, Exercise and Nutrition for the Really Young) [20].

***Family approach to the services***

A family approach was reported to be taken in 74.4% of healthy eating / weight management services and in 57.7% of physical activity services (Fig. 3). Family approaches included other family members being incorporated into the service, whole family activities for example cookery courses or proactive onward referral for family members. Some respondents also felt that changing the mothers' lifestyle would impact the long-term health of all family members.

***Evaluation of the services***

Only 35.9% of services encouraging healthy eating or weight management and 32.0% promoting physical activity reported to have been evaluated (Fig. 3). Evaluation was mainly through service user feedback or internal audit. Only four services had been independently evaluated, either by an independent University or national evaluation of services such as Slimming World. None of the services for women with a raised BMI reported they had been formally evaluated.

***Service user involvement in services***

Over a third of respondents reported service user involvement (Fig. 3). This included co-creation of the

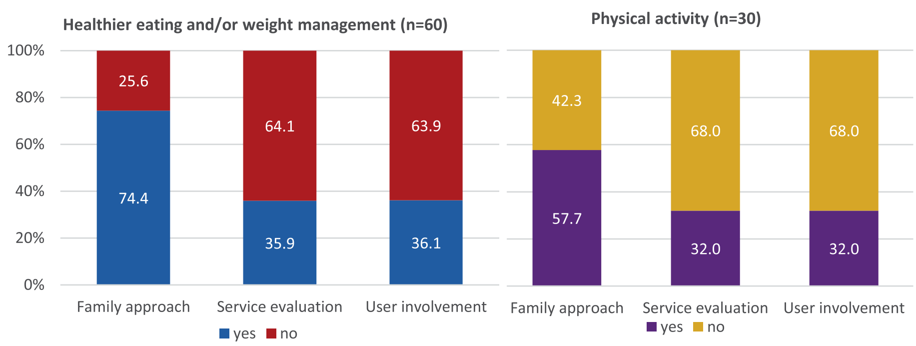


**Fig. 3** Services reporting that they had been evaluated, used a family approach or had involved service users

service, service development through user feedback or service user involvement on research steering groups.

Results of the survey are also summarised on the info-graphic in Additional file 3.

## Results - semi-structured interviews

### Characteristics of participants

Thirteen participants undertook semi-structured individual interviews ($n = 6$) or focus groups (two focus groups with 2 and 5 participants respectively). Participants had a wide geographical distribution within two LMS and varied professional roles including council public health workers ($n = 7$), specialist or consultant midwives whose role included public health ($n = 4$), a health visitor ($n = 1$) and a council-sports partnership worker ($n = 1$).

### Service provision description from interview participants' perspectives

#### *Services provided for all women*

Services provided for all women were similar to those described within survey responses, including information provision by midwives or health visitors ($n = 8$), HENRY and it's follow on initiatives ($n = 5$) or other initiatives to promote healthy eating and physical activity ($n = 2$), exercise groups such as aquanatal or buggy fit ($n = 6$) and referral to local leisure centres ($n = 5$). Some interviewees also discussed additional provision not mentioned by survey respondents including links with schools and colleges to provide pre-conception education ($n = 1$), achieving Baby Friendly Initiative [21] accreditation or providing breastfeeding support ($n = 2$), 'Fitmums and Friends' and 'This Girl Can' - campaigns to promote women to exercise ($n = 1$), initiatives targeting healthy food provision options in vending machine ($n = 2$) and the Promotional Guide Tool [22] used by health visitors to promote conversations with women regarding lifestyle ($n = 1$).

#### *Service provision for women with a raised body mass index*

Similarly to the survey, there were few services specifically for women with a raised BMI. Some had consciously move away from targeted services to avoid stigmatisation, while others had experienced decommissioning of services due to funding issues ($n = 3$).

### Thematic representation of the interview findings

The themes and subthemes identified from qualitative data are presented in Fig. 4 and discussed in detail below.

### Equity and variation in service provision

In line with survey results, geographical variation in service provision was noted both between areas and within areas. In one area women within the same NHS Trust for maternity care could have access to different services dependent on where they lived, due to councils which commissioned services having different boundaries to NHS Trusts.

> *"I see women on a Wednesday morning and I can only say you can go to Slimming World if you want but you'll have to pay for it yourself and then I see ladies on a Thursday morning and I say this is the lovely XXXX [*who runs the free local maternity programme for women with a raised BMI*]. It's just unequal"* Participant 2.

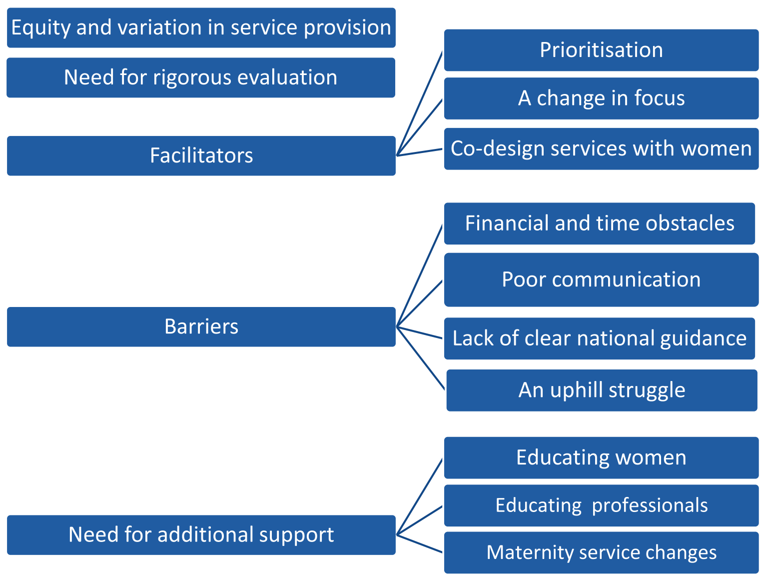


**Fig. 4** Thematic representation of key stakeholders' views on maternal weight management service provision

### Need for rigorous evaluation

Evaluation of services was universally poor. The exception was the national HENRY programme which had been independently evaluated [23]. Any local evaluation described was by monitoring attendance or asking women for feedback, with changes incorporated into the service in response to any issues raised.

Respondents felt limited specific guidance on acceptable weight gain during pregnancy as standards to measure services against hindered evaluation. One service however used the Centre for Maternal and Child Enquires maternal obesity report [7] as a UK baseline for outcomes such as Caesarean delivery, induction of labour and preterm birth, with which to compare their service outcomes.

> *"I think it's very difficult in pregnancy to evaluate it properly because we don't have a true reference range for what is a healthy weight gain."* Participant 7.

### Facilitators for weight management service provision and access

Suggestions made by interviewees to encourage better access or more effective service provision, included prioritisation, a change in focus and co-design of services.

#### *Prioritisation*

Prioritisation of the first 1000 days by one council had allowed additional funding to be attained for high priority areas, to commission additional services. The high-level initiative Healthy Weight Declaration was also seen to support local government to develop and implement policies around healthy weight for example changing food provision at community cafes or parenting groups [24].

> *"So there's things like the healthy weight declaration … that's something that we're trying to take on board here and it's very much about changing the culture around food, activity and the environment essentially. So you know the food that's provided in hospital vending machines or gym vending machines, so that's been challenged so that healthier food is provided"* Participant 1.

#### *A change in focus*

There was a shift from focussing exclusively on weight onto healthy eating and activity. The importance of establishing the individual's current understanding of weight management and encouraging women to identify their own goals was also considered to be important, rather than imposing the provider's ideas.

> *"on a general level I think the focus needs to move away from weight and more onto health of eating well and moving more and shifting the culture in that way"* Participant 1.

#### *Co-design of services with women*

Clear communication with service users to ensure appropriate services are commissioned was considered key to ensure access. Providing free services, in places with good transport links, on-site childcare, high visibility through good marketing and de-centralised services to reduce the distances women have to travel were all considered vital to improve service accessibility.

> *"being commissioned appropriately with discussion with services and with women ... because sometimes I think when services are being commissioned they don't think about the people who're actually using them, so it's so important asking the right women"* Participant 5.

Providing services for all women was felt to increase service uptake, by preventing mothers with a raised BMI feeling stigmatised. This also made sense to providers given the increasing population levels of overweight and poor diet and the lower cost associated with embedding a universal service into existing provision, rather than paying for an additional service.

> *"Regardless of people's weight, we know that people have poor diets. I think whenever we talk about targeted interventions, we always just come back to we might as well do it universally"* Participant 13.

### Barriers to weight management service provision and access

Numerous barriers that inhibited provision, promotion and access to healthy lifestyle services were identified.

#### *Financial and time obstacles*

Lack of money was the biggest obstacle reported. It prevented services being commissioned, prevented investment in services and inhibited service delivery. Rural areas were especially hard hit as running services in areas where pregnant women were very dispersed was not cost effective. Money restrictions also equated to time restrictions within appointments, meaning discussions around healthy eating or referral to available services were always a low priority for midwives needing to address many other topics. The proper evaluation of services was also impeded by lack of money.

> *"It's a difficult one because the council don't have the budget anymore."* Participant 4.

The constant cycle of commissioning, decommissioning, revamping and re-commissioning of services as funding was available made it difficult for practitioners to stay informed with service availability.

*"I know staff find it so frustrating when things are coming and going because they say you know it's fantastic this and the next minute you're putting a message saying actually the services have stopped."* Participant 5.

***Poor communication***

Commissioners reported difficulties in evaluating services as they were unable to assess the quality of front-line staff conversations. They also reported frustration at not receiving information such as attendance when it was requested from providers, so did not know whether further promotion of services was required.

*"They [midwives] tend to record that a discussion has to take place, but the quality of the discussion could vary so I could say, well you know you are pregnant, now you must eat well and exercise and then tick my box, or ... it could be a bit more of an open discussion with a bit more quality to it"* Participant 11.

***Lack of clear strategic national guidance***

Limited evidence on interventions that positively impact on pregnancy or neonatal outcomes, coupled with no national guidelines on weight gain in pregnancy and National Institute of Health and Care Excellence (NICE) guidance that was seen to be out-of-date, made it difficult for providers to know what services to commission and how to effectively evaluate current services.

*"Our NICE guidelines for weight monitoring, if you want the truth they are so woolly you could never evaluate it, because it doesn't specifically say who to do what ... It is not a proactive guide in my opinion." Participant 4.*

*"It would help if current NICE guidelines were appropriate … we were so looking forward to them coming out and … when they did they were very meek and all they were talking about was about myth-busting … These guidelines are totally out of date … they need updating and they need more teeth as well." Participant 7.*

One respondent felt it also led to NHS trusts all developing their own thing, when a lot of time and effort could be saved with national level input.

***An uphill struggle***

Participants felt the public viewed being overweight as 'normal', due to increasing population prevalence. The media propagated image of healthy eating and physical activity being middle-class and too expensive for women from deprived communities also needs addressing to reduce inequitable access.

*"there is a perception I think that healthy eating and being physically active is quite a middle-class thing and I think that's a real issue ... and that's not helped by the media ... I know from experience when I've delivered sessions and it was about sugar and our children having sugar and she* [a mother] *was like I don't want my child to be an effing snob by not having sugar."* Participant 1.

Work commitments and employers not facilitating access to healthy lifestyle appointments also made it difficult for women to benefit from services. Finally, women wanting to lose weight often undertake it themselves rather than going to a healthcare professional for support to achieve their goal. Group interventions were especially felt to inhibit access for some women.

**Need for additional support**

***Educating women***

There was a call for more pre-conception education, either through schools or a national campaign highlighting the risks to mother and child of being overweight at conception, to reduce the number of women with a raised BMI prior to pregnancy. Incorporating aspects such as weight maintenance and cooking skills into antenatal classes was also suggested.

*"ideally you don't want them to go into pregnancy overweight … I think you start at school because they are potentially your mothers of the future." Participant 4.*

*"ideally with women who are overweight it would be nice if they lost some weight before they got pregnant, which some of them do, but not all of them because some of them are oblivious!" Participant 2.*

***Educating professionals***

Training all healthcare professionals prior to registration was felt to be essential, so healthy eating is an integral part of the job from the start.

*"Ideally we should be starting with the student midwives in university and then the newly qualified midwives, so that actually, that message is from the start of their midwifery training. ... No, it's not an extra, it's not something that they learn afterwards, it's part of their training."* Participant 4.

Healthcare professionals who themselves were obese or struggled with their weight were seen to lack confidence to raise the topic with women. Training staff to understand behaviour change theory, personal motivators and to initiate conversations, including those who traditionally don't have a public health role, was seen as crucial to achieve the ethos of Make Every Contact Count.

> *"We're looking at things like workforce development and … trying to train up parts of the workforce that perhaps wouldn't have traditionally been … and sometimes people from different services have better relationships with families, we know that a lot of our housing officers for example, have good relationships with families." Participant 13.*

Furthermore, service availability for pregnant women could be improved by training providers on the needs of pregnant women and how to incorporate them into existing adult services.

#### *Maternity service changes*

Many respondents wanted further maternal obesity services, either bespoke or the commissioning of programmes such as Slimming World for all pregnant women. Continuity of carer during pregnancy was also desired to assist with conversations and follow-up regarding healthy lifestyle. A desire for personalised trajectories for monitoring weight during pregnancy was also voiced, however this would require services in place for onward referral if women's weight gain exceeded expectations. Better liaison between midwives and health visitors for women with a raised BMI to prevent weight gain between pregnancies was also called for.

> *"I think, if we had a secure evidence base that enabled us to say, 'this is a good trajectory for you', … similar to ... customised growth charts for plotting a foetus, ... we could follow them ... But, also we'd need to know what to say if somebody's growth exceeds; what to do, what to offer, where to refer them, how to help them"* Participant 7.

## Discussion

Healthy eating, weight management and physical activity services for all women were varied in nature from nothing or the provision of very basic information to structured weight management or physical activity programmes. Service provision for women with a BMI ≥ 25 kg/m$^2$ was found to be minimal, particularly for physical activity interventions. The results regarding availability of services was consistent between the semi-structured interviews and the survey.

This study showed clear variation in maternal obesity service provision across England with a complete lack of accessible services in a number of areas, especially for women with a high BMI. Multiple respondents within a single LMS had differing awareness of service provision. Participants in the semi-structured interviews suggested this could have been due both to service inequity between different areas and also due to the constant commissioning and decommissioning of services making it difficult for practitioners to stay informed of service provision. It is essential therefore that healthcare professionals who have contact with women prior to pregnancy, during pregnancy and postpartum are informed of up-to-date local service provisions. Clearer national leadership is also required on the commissioning requirements around maternal healthy weight to help reduce geographical variation and the potential health inequalities that this may cause.

While numerous services had worked hard to involve service users in the development or update of services, very few reported being evaluated. The majority of those that had been evaluated had done so through internal audit. More needs to be done to formally evaluate services. This needs to include evaluation of the effective behaviour change components of the service through frameworks such as Michie et al. [25] who developed a taxonomy of behaviour change techniques used within interventions. This is in line with Public Health England who have recommended the application of an evidence based framework to ensure the embedding of appropriate behaviour change techniques into interventions [26] and have provided a list of the most effective behaviour change techniques to use in future weight management interventions [27]. A recent review of behaviour change techniques used in gestational weight management trials has found these techniques are currently poorly reported [28]. Future services need to more clearly elaborate on the behaviour change techniques incorporated within specific interventions, so that active components of interventions can be identified and more readily reproduced. There should also be a focus on the extent to which services are delivering evidence-based interventions as intended. Research has consistently shown that evidence translation is problematic [29] and calls have been made to utilise appropriate behaviour change techniques for health professional behaviour change [30]. More concise, clearer and directive national guidance would also enable existing services to be better evaluated for effectiveness. This could prevent local areas 'reinventing the wheel' with a limited budget. NICE should therefore consider urgently reviewing the maternal obesity guidelines [13] so that they reflect up to date evidence.

The main barrier identified by participants to providing and commissioning healthy weight services for the childbearing population was the lack of, or inconsistency in, funding. Funding to public health budgets has seen significant cuts over recent years which has had significant effects on public health services across the board [31]. To tackle the increasing problem of maternal obesity it is therefore important that good practice is shared effectively when services have been evaluated robustly and found to improve maternal health outcomes. This is required to meet the vision of workstream 9 'improving prevention and population health' within the maternity transformation programme to improve health by preventing poor outcomes and improve woman's health before, during and after pregnancy [32].

Commissioners should consider implementing strategies to reduce the barriers identified through the interviews especially as these are likely to affect women living in deprived areas disproportionately to their more affluent counterparts. Initiatives such as de-centralising services into local areas with good transport links and childcare provision may help to facilitate women's access, particularly for women from deprived areas. Making all services free at the point of use needs to be considered, alongside a proper economic evaluation to determine the cost effectiveness of such a strategy. These facilitators were also identified in a recent study addressing how lifestyle interventions could be tailored to improve access and ultimately outcomes for low socio-economic populations [33]. The importance of consulting the target population to better understand their service needs and to ensure services developed are relevant and appropriate cannot be overlooked [26].

National educational resources should be developed to educate women and healthcare providers around healthy maternal weight prior to pregnancy, during pregnancy and in the postpartum period. This is necessary both to maximise the use of available services and to ensure consistent reliable messaging around maternal healthy weight.

Previous research has shown regional differences in the rate of maternal obesity and clear evidence of health inequalities in relation to a higher incidence of maternal obesity and its complications among women from Black and Ethnic Minority (BME) backgrounds and those who are socially deprived [2, 5, 34]. It is therefore important to consider sociodemographic predictors of maternal obesity and its complications in any future research to ensure equitable service provision.

### Limitations of this study

This research was enhanced by the participants in both phases of the study representing a wide variety of occupations and including both commissioners and providers. Survey respondents were also geographically well dispersed across England and the interviewees covered numerous councils and NHS trusts. However, like any other survey this represents a self-selected sample of respondents. The fact that only 23 of the 44 LMSs provided a response to the survey was also a limitation of the project. However complementary approaches in this research present findings which indicate discrepancies in service provision from various key stakeholders' perspectives. It also highlighted the need for rigorous evaluation of existing services and equitable provision of services particularly before and after pregnancy.

## Conclusion

Healthy weight service provision varies in different geographical areas across England. It is therefore important to ensure all healthcare workers are aware of related service provisions. More maternity healthy weight services are needed with an emphasis on physical activity. Service provision and access also needs to be encouraged prior to pregnancy and in the postnatal period, particularly for those with a raised BMI. To ensure these services are fit for purpose more robust evaluation is required. Finally, healthcare providers should be aware of the existing services to encourage their uses. They also require clear guidance and training to support pregnant women achieve a healthy weight gain.

## Supplementary information

**Supplementary information** accompanies this paper at https://doi.org/10.1186/s12913-020-05440-x.

**Additional file 1.** Provision of maternal healthy weight services survey.

**Additional file 2.** Stakeholder interview schedule.

**Additional file 3.** Maternal Healthy Weight Service Provision in England Infographic.

#### Abbreviations

BMI: Body Mass Index; LMS: Local Maternity Systems; NHS: National Health Service; UK: United Kingdom; PHE: Public Health England; HENRY: Health, Exercise and Nutrition for the Really Young; NICE: National Institute of Health and Care Excellence; WS9: Workstream 9

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#### Authors' contributions

FF – Survey development and analysis, interview schedule development and analysis, writing the methods, results and discussion sections, drafting the full article. KMD -Undertaking interviews, input into analysis, writing initial drafts of the introduction and discussion. MA – Input regarding behaviour change, survey development and interview schedule development. HS – Development and oversight of the project, assisting with survey development and analysis, interview schedule development and analysis, commented on the drafted article. All authors have read and approved the final manuscript

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**Availability of data and materials**
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**
Ethical approval was obtained prior to commencing data collection (Sheffield Hallam University Converis Number ER6157422).
Information was provided at the start of the survey and consent was assumed inherent for the participants who completed the online survey voluntarily. Written participant information was provided to those participating in the interviews and focus groups and written informed consent obtained.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare that they have no competing interests.

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## Publisher's Note

# An analysis of behaviour change techniques used in a sample of gestational weight management trials

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*Review Article*

# An Analysis of Behaviour Change Techniques Used in a Sample of Gestational Weight Management Trials

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*Introduction*. Maternal obesity and excessive gestational weight gain are associated with multiple adverse outcomes. There is a lack of clarity on the specific components of effective interventions to support pregnant women with gestational weight management. *Method*. All 44 studies within a preexisting review of lifestyle interventions, with a potential to impact on maternal weight outcomes, were considered for content analysis. Interventions were classified using Behaviour Change Technique (BCT) taxonomy clusters to explore which categories of BCT were used in interventions and their effectiveness in managing gestational weight gain. *Results*. The most commonly used BCTs were within the categories of "feedback and monitoring," "shaping knowledge," "goals and planning," "repetition and substitution," "antecedents," and "comparison of behaviours." For diet and mixed interventions "feedback and monitoring," "shaping knowledge," and "goals and planning" appeared the most successful BCT categories. *Conclusions*. Poor reporting within studies in defining the BCTs used, in clarifying the differences in processes between intervention and control groups, and in differentiating between the intervention and research processes made BCT classification difficult. Future studies should elaborate more clearly on the behaviour change techniques used and report them accurately to allow a better understanding of the effective ingredients for lifestyle interventions during pregnancy.

## 1. Introduction

Maternal obesity and excessive gestational weight gain are associated with adverse outcomes (such as macrosomia, shoulder dystocia, and gestational diabetes [1, 2]) and are on the rise. Despite an urgent need for evidence based guidance to support pregnant women on gestational weight management, there is a lack of clarity about effective interventions and their specific components. Interventions developed to reduce excessive gestational weight gain and its associated outcomes generally fit into the broad categories of dietary only, physical activity only, and mixed approaches utilising both diet and physical activity components [3]. It is important to identify which components and specific behaviour change techniques within these complex interventions are most effective, since this is needed to inform the development of future interventions and guidance.

Michie et al. have reported a consensually agreed structured taxonomy of behaviour change techniques which provides a framework for a more precise reporting of complex interventions [4]. The Behaviour Change Technique (BCT) taxonomy [4] is a useful tool to extract the active components of interventions, allowing comparisons between the component parts of successful and unsuccessful behaviour change interventions. Several studies [5–7] have used the behaviour change technique taxonomy described by Michie et al. [8] to define gestational weight gain management interventions. However only Currie et al. [9] have used the most up-to-date clustered BCT taxonomy [4] to code lifestyle interventions during pregnancy or the postnatal period, in their systematic review of 14 studies aimed at reducing the decline in physical activity during pregnancy.

Gestational weight management strategies often rely on complex interventions involving various interacting components. Identification of active components of these interventions would help in better understanding and interpreting the results of the existing systematic reviews. It would also be helpful to inform the design of new interventions and their evaluations.

Numerous systematic reviews have evaluated the efficacy of interventions designed to improve weight outcomes for mothers [3, 5, 6, 10–14]. Of these most included 9 to 11 interventional studies [5, 10, 11, 13], with one review [14] only including 5 studies, two reviews including 19 studies [6, 12], and the final review by Thangaratinam et al. [3] of 44 studies. The reviews by Brown et al. [14], Thangaratinam et al. [3], and Choi et al. [13] focused exclusively on randomised controlled trials. Results across the reviews have varied. Streuling et al. [10] found that physical activity or diet alone interventions were not effective at reducing gestational weight gain but interventions based on physical activity and dietary counselling combined with weight monitoring appeared to be successful. In comparison Choi et al. [13] found that obese and overweight women allocated to physical activity or physical activity plus diet interventions in pregnancy had lower gestational weight gains, with supervised physical activity being especially effective. Thangaratinam et al. [3] showed some evidence of effectiveness across all interventions in reducing gestational weight gain (mean difference (MD) −1.42, 95% confidence interval (CI) −1.89 to −0.95). They also reported significant reductions in weight gain in pregnancy in subgroup analysis for dietary interventions (MD −3.84, 95% CI −5.22 to −2.45), physical activity interventions (MD −0.72, 95% CI −1.20 to −0.25), and interventions with a mixed approach (MD −1.06, 95% CI −1.67 to −0.46).

Due to the comprehensive approach in inclusivity and rigour in Thangaratinam et al.'s [3] review and due to it being the most highly accessed and cited article within the field of research of gestational weight management, this was selected as the source of literature for content analysis in our review. The aim of this study was therefore to evaluate the behaviour change techniques included in diet, physical activity, or mixed interventions with a potential to impact on maternal or fetal outcomes related to weight and to identify the categories of behaviour change technique of those interventions which were effective. To our knowledge, this is the first study to use the BCT taxonomy to identify techniques used in a wide range of gestational weight management lifestyle interventions.

*1.1. Objectives.* To explore the patterns of behaviour change techniques used in interventions with a potential to impact maternal and fetal outcomes related to gestational weight gain.

## 2. Methods

*2.1. Data Selection.* This study was based on the 44 randomised controlled trials of interventions with a potential to impact maternal or fetal outcomes related to weight which were included in the HTA commissioned systematic review [3]. The studies included in the review were focused on diet only ($n = 13$), physical activity only ($n = 18$), or mixed ($n = 13$) diet and physical activity interventions for a range of pregnant women, focussing specifically on overweight and or obese women in 11 studies. The study selection criteria and assessments of quality and bias have all been reported by Thangaratinam et al. [3]. They found that the quality of studies included in the analysis for gestational weight gain was moderate, but quality for other outcomes such as preterm delivery and hypertension was low, where there may have been a risk of publication bias.

*2.2. Data Extraction and Synthesis.* Michie et al.'s [4] health behaviour change technique taxonomy was used to identify the behavioural components of the intervention within each included study. This taxonomy contains 93 itemised health behaviour change techniques which are clustered into 16 groupings (see the following list), with each group containing between 3 and 11 clustered behaviour change techniques. For practicality of reporting the category groupings were used for the purpose of this review.

*Groupings within Michie et al.'s [4] Hierarchically Clustered Behaviour Change Technique Taxonomy.* Consider the following:

(1) Goals and planning.
(2) Feedback and monitoring.
(3) Social support.
(4) Shaping knowledge.
(5) Natural consequences.
(6) Comparison of behaviour.
(7) Associations.
(8) Repetition and substitution.
(9) Comparison of outcomes.
(10) Reward and threat.
(11) Regulation.
(12) Antecedents.
(13) Identity.
(14) Scheduled consequences.
(15) Self-belief.
(16) Covert learning.

Three researchers (H. Soltani, M. A. Arden, and A. M. S. Duxbury) independently extracted and coded the data, to improve reliability of the data categorisation. Where there were differences in coding, the research team had a discussion to reach consensus regarding the codes and categories.

Behaviour change technique categories were classified as successful or unsuccessful within each study dependent upon whether a significant difference was found between the intervention and control group on gestational weight gain. Due to the heterogeneity of the included studies data was synthesised narratively and presented in tables and graphs as statistical synthesis was not possible.

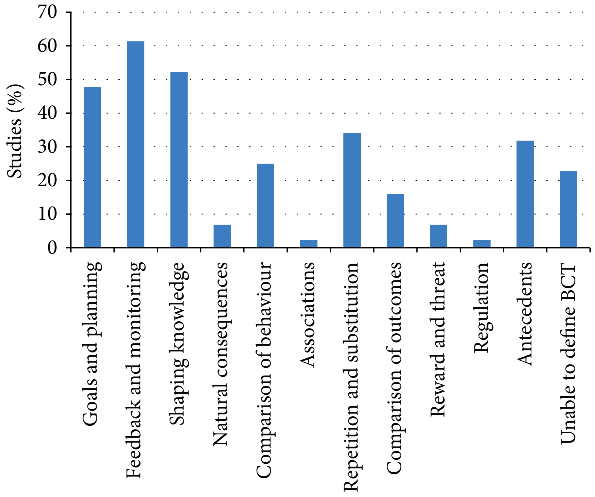


Figure 1: Behaviour change technique taxonomy categories of the interventions in included studies ($n = 44$ studies).

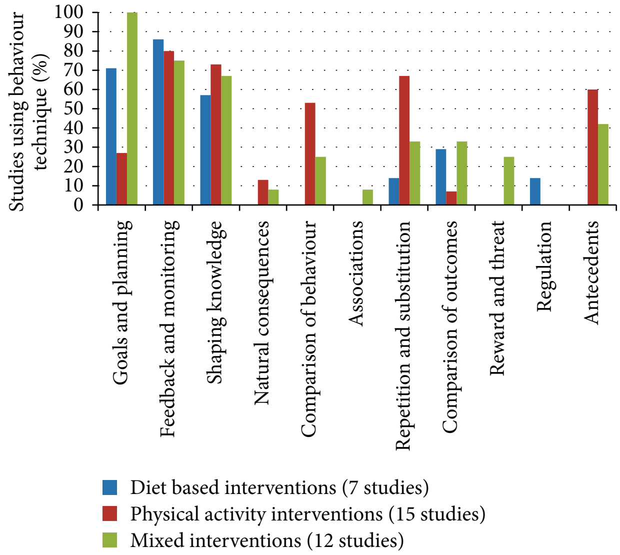


Figure 2: Behaviour change technique taxonomy categories according to intervention type ($n = 34$ studies).

## 3. Results

Of the original 44 papers included within the Thangaratinam et al. review [3], one study only consisted of a conference abstract [26]. Full-text versions of all of the other articles were obtained. The 44 trials included 7627 women who had been randomised. Healthcare professionals delivering the interventions varied across the studies and included dieticians, nutritionists, clinical psychologists, doctor, nurses, and midwives.

Table 1 contains study characteristics and the behaviour change technique categories agreed by the researchers for each of the included studies [15–59]. It was not possible to apply any behaviour change taxonomy code to 10 of the studies. Figure 1 shows the distribution of BCT categories within the studies. The most commonly used behaviour change technique clusters were "feedback and monitoring," "shaping knowledge," "goals and planning," "repetition and substitution," "antecedents," and "comparison of behaviours."

There were many studies where the authors could not agree on the behaviour change techniques involved within the intervention. The disputed techniques are shown in Table 2. Eight of the 10 studies for which no behaviour change technique code was recorded had potentially included BCTs but the research team could not reach agreement on them. Two studies [27, 56] included no discernible BCTs. The most common category where a disagreement occurred between the authors was "goals and planning," with 21 of the 22 studies with a disputed behaviour change technique being discrepant within this cluster. In only 2 of these 21 studies [21, 23] was the discrepancy not within the subcategory "goal setting (behaviour)."

For the studies where it was possible to categorise the type of behaviour change, BCT category according to type of intervention was plotted (Figure 2). While all types of intervention made use of "feedback and monitoring" and "shaping knowledge" techniques physical activity based interventions utilised "comparison of behaviours" and "repetition and substitution" more than dietary or mixed lifestyle interventions. In comparison dietary based and mixed interventions incorporated "goals and planning" more often.

Gestational weight gain was reported in 34 studies; however for 6 of these studies no agreement was obtained for applying a BCT code. The success of each behaviour change technique according to type of intervention in the resulting 28 studies is shown in Figure 3. In studies where a BCT classification could be applied a significant difference in gestational weight gain between the intervention groups and control groups was found more often for diet based ($n = 5$) or mixed interventions ($n = 6$) compared to physical activity based interventions ($n = 1$).

The prevalence of each BCT category in both successful and unsuccessful interventions for reducing gestational weight gain is shown in Table 3. The BCT categories present in 50% or over of the studies with successful interventions were "feedback and monitoring," "goals and planning," and "shaping knowledge."

## 4. Discussion

We have used the Thangaratinam et al. [3] review as an example of a report incorporating diet, physical activity, and mixed lifestyle interventions with the potential to impact on maternal or fetal weight outcomes. Of the 44 studies included within that review, 34 reported total gestational weight gain.

The most commonly used behaviour change technique categories were "feedback and monitoring," "shaping knowledge," "goals and planning," "repetition and substitution," "antecedents," and "comparison of behaviours." To our knowledge there is only one other study [9] in which lifestyle interventions in pregnancy or the postpartum have been classified according to Michie et al.'s BCT taxonomy [4]. The behaviour change technique components of interventions in pregnancy aimed at reducing the decline in physical activity were categorised within that study by Currie et al. [9], with

Table 1: Study characteristics and definite Behaviour Change Technique categories.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | GWG in kg Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Diet based interventions | | | | | | | |
| Clapp 1997 [15] | Not stated | — | 12 | 11.8 (5.6) | 19.7 (2.9) | $p < 0.01$ | — |
| Crowther et al. 2005 [16] | Dietician | 1000 | 1000 | 8.1 (0.3) | 9.8 (0.4) | Adjusted $p = 0.01$ | Feedback and monitoring, shaping knowledge, comparison of outcomes |
| Landon et al. 2009 [17] | Clinician | 958 | 931 | 2.8 (4.5) | 5 (3.3) | $p < 0.001$ | Feedback and monitoring |
| Ney et al. 1982 [18] | Not stated | 20 | 20 | 11.8 (4.5) | 15.9 (6.8) | $p < 0.05$ | — |
| Quinlivan et al. 2011 [19] | Food technologist, clinical psychologist | 132 | 124 | 7.0 (5.2) | 13.8 (5.2) | $p < 0.001$ | Goals and planning, feedback and monitoring, shaping knowledge, regulation |
| Thornton et al. 2009 [20] | Dietician, physician | 257 | 232 | 4.99 (6.79) | 14.06 (7.40) | $p < 0.001$ | Goals and planning, feedback and monitoring |
| Wolff et al. 2008 [21] | Dietician | 64 | 50 | 6.6 (5.5) | 13.3 (7.5) | $p = 0.002$ | Goals and planning, feedback and monitoring, comparison of outcomes |
| Bechtel-Blackwell 2002 [22] | Research nurse | 60 | 46 | 6.87 (NR) | 5.57 (NR) | NS | — |
| Briley et al. 2002 [23] | Nutritionist | 27 | 20 | 11.9 (6.3) | 15.2 (5.1) | NS | Goals and planning, feedback and monitoring, shaping knowledge |
| Khoury et al. 2005 [24] | Dietician | 290 | 290 | 8.9 (3.1) | 9.4 (3.0) | NS $p = 0.20$ | Goals and planning, shaping knowledge, repetition and substitution |
| Rae et al. 2000 [25] | Research dietician | 125 | 117 | 11.56 (10.48) | 9.68 (10.66) | NS $p = 0.338$ | — |
| Badrawi et al. 1992 [26] | Not stated | 100 | — | NR | NR | NR | — |
| Gomez et al. 1994 [27] | Not stated | 60 | | NR | NR | NR | — |

Table 1: Continued.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | GWG in kg Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Physical activity based interventions | | | | | | | |
| Sedaghati et al. 2007 [28] | Qualified instructor and midwife | 100 | 90 | 13.55 (1.131) | 15.1 (2.102) | $p < 0.000$ | Feedback and monitoring, shaping knowledge, antecedents |
| Baciuk et al. 2008 [29] Cavalcante et al. 2009 [30] | Qualified instructor | 71 | 70 | 14.3 (2.1) | 15.1 (1.6) | NS $p = 0.38$ | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |
| Barakat et al. 2009 [31] | Qualified fitness specialist | 160 | 142 | 11.5 (3.7) | 12.4 (3.4) | NS (but some difference in obese only group) | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |
| Barakat et al. 2012 [32] | Qualified instructor with obstetric assistance | 100 | 83 | 12.5 (3.2) | 13.8 (3.1) | NS $p > 0.05$ | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |
| Clapp et al. 2000 [33] | Not stated | 50 | 46 | 15.7 (4.7) | 16.3 (3.4) | NS | — |
| Erkkola 1976 [34] | Not stated | 76 | 62 | 11.8 (NR) | 11 (NR) | NS | Feedback and monitoring, shaping knowledge, natural consequences |
| Garshasbi and Faghih 2005 [35] | Midwife | 266 | 212 | 14.1 (3.8) | 13.8 (5.2) | NS $p = 0.63$ | Comparison of outcomes |

Table 1: Continued.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | GWG in kg Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Haakstad and Bo 2011 [36] | Qualified instructor | 105 | 105 | 13 (4) | 13.8 (3.8) | NS $p = 0.31$ | Goals and planning, feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution |
| Hopkins et al. 2010 [37] | Not stated | 98 | 84 | 8.2 (3.5) | 8 (3.7) | NS | Goals and planning, feedback and monitoring, antecedents |
| Marquez-Sterling et al. 2000 [38] | Qualified instructor | 20 | 15 | 16.2 (3.4) | 15.7 (4) | NS $p = 0.649$ | Goals and planning, comparison of behaviour, repetition and substitution |
| Ong et al. 2009 [39] | Supervised | 12 | 12 | 3.7 (3.4) | 5.2 (1.3) | NS $p = 0.155$ | Shaping knowledge, repetition and substitution, antecedents |
| Prevedel et al. 2003 [40] | Not stated | 60 | 41 | 15 (NR) | 12.7 (NR) | NS | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution |
| Santos et al. 2005 [41] | Not stated | 92 | 72 | 5.7 (NR) | 6.3 (NR) | NS $p = 0.62$ | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |

Table 1: Continued.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | GWG in kg Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Bell and Palma 2000 [42] | Not applicable | 61 | 61 | NR | NR | NR | — |
| Erkkola and Makela 1976 [43] | Not stated | 103 | 103 | NR | NR | NR | Feedback and monitoring, shaping knowledge, natural consequences |
| Khaledan et al. 2010 [44] | Not stated | 39 | — | NR | NR | NR | Goals and planning, feedback and monitoring, repetition and substitution, antecedents |
| Lee et al. 1996 [45] | Qualified instructor | 370 | 351 | NR | NR | NR | Feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |
| Yeo et al. 2000 [46] | Not stated | 17 | 16 | NR | NR | NR | — |
| Mixed interventions | | | | | | | |
| Asbee et al. 2009 [47] | Dietician, physician, nurse | 144 | 100 | 13.02 (5.67) | 16.15 (7.03) | $p = 0.01$ | Goals and planning, feedback and monitoring, comparison of outcomes, reward and threat |
| Huang et al. 2011 [48] | Nurse trained in nutrition and fitness | 240 | 189 | 14.02 (2.38) | 16.22 (3.26) | $p < 0.001$ | Goals and planning, feedback and monitoring, shaping knowledge, reward and threat |
| Jeffries et al. 2009 [49] | Medical student | 286 | 236 | 10.7 (4.21) | 11.5 (4.03) | $p = 0.01$ in overweight group but NS in underweight, normal weight or obese | Goals and planning, feedback and monitoring |
| Phelan et al. 2011 [50] | Research assistants, nurses, clinicians | 401 | 363 | Normal weight 16.2 (4.6) obese 15.1 (7.5) | Normal weight 15.3 (4.4) obese 14.7 (6.9) | significant increase in normal weight women exceeding IOM guidelines | Goals and planning, feedback and monitoring, shaping knowledge, associations, antecedents |

Table 1: Continued.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Polley et al. 2002 [51] | Nutritionist or clinical psychologist | 120 | 110 | Normal weight 15.4 (7.1) overweight 13.6 (7.2) | Normal weight 16.4 (4.8); overweight 10.1 (6.2) | significant increase in normal weight women exceeding IOM guidelines | Goals and planning, feedback and monitoring, repetition and substitution |
| Vinter et al. 2011 [52] | Dietician, physiotherapist | 360 | 304 | **median** {**range**} 7.0 (4.7–10.6) | **median** {**range**} 8.6 (5.7–11.5) | $p = 0.014$ | Goals and planning, shaping knowledge, comparison of behaviour, repetition and substitution, antecedents |
| Guelinckx et al. 2010 [53] | Nutritionist | 195 | 122 | Active group 9.8 (7.6) Passive group 10.9 (5.6) | 10.6 (6.9) | NS | Goals and planning, feedback and monitoring, shaping knowledge, reward and threat |
| Hui et al. 2011 [54] | Dietician and fitness trainer | 52 | 45 | 14.2 (5.3) | 14.2 (6.3) | NS $p = 1.00$ | Goals and planning, feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, comparison of outcomes, antecedents |
| Hui et al. 2006 [55] | Dietician and fitness trainer | 224 | 190 | 15.2 (5.9) | 14.1 (6.0) | NS $p = 0.28$ | Goals and planning, feedback and monitoring, shaping knowledge, comparison of behaviour, repetition and substitution, comparison of outcomes, antecedents |

Table 1: Continued.

| Study | Intervention delivery | Number of participants randomised | Number of participants analysed | GWG in kg Intervention group mean (SD) | GWG in kg Control group mean (SD) | Significant difference | Agreed BCT categories |
|---|---|---|---|---|---|---|---|
| Jackson et al. 2011 [56] | Video doctor simulating health care provider | 321 | 289 | 15.15 (NR) | 15.24 (NR) | NS $p = 0.95$ | — |
| Bung et al. 1991 [57] | Not stated | 41 | 34 | NR | NR | NR | Goals and planning, feedback and monitoring, shaping knowledge, antecedents |
| Ferrara et al. 2011 [58] | Trained dietician, lactation consultant | 197 | 197 | NR | NR | NR | Goals and planning, shaping knowledge, natural consequences, comparison of outcomes |
| Kulpa et al. 1987 [59] | Nutritionist, exercise physiologist and obstetrician | 141 | 85 | Primigravida 14.3 (NR) Multigravida 12.5 (NR) | Prigravida 14.2 (NR) Multigravida 15.4 (NR) | NR | Goals and planning |

GWG = gestational weight gain.
SD = standard deviation.
BCT = Behaviour Change Technique.
NR = not reported.
NS = not significant.
IOM = Institute of Medicine.

Table 2: Discrepant Behaviour Change Technique categorisation across the studies.

| Study | Discrepant BCT categorisation | Type of intervention (D = diet; P = physical activity; M = mixed) |
|---|---|---|
| Badrawi et al. 1992 [26] | Goals and planning | D |
| Barakat et al. 2009 [31] | Goals and planning | P |
| Barakat et al. 2012 [32] | Goals and planning | P |
| Bechtel-Blackwell 2002 [22] | Comparison of outcomes | D |
| Bell and Palma 2000 [42] | Goals and planning | P |
| Briley et al. 2002 [23] | Goals and planning | D |
| Baciuk et al. 2008 [29]<br>Cavalcante et al. 2009 [30] | Goals and planning | P |
| Clapp 1997 [15] | Goals and planning | D |
| Clapp et al. 2000 [33] | Goals and planning | P |
| Erkkola 1976 [34] | Goals and planning | P |
| Erkkola and Makela 1976 [43] | Goals and planning | P |
| Garshasbi and Faghih 2005 [35] | Goals and planning<br>Shaping knowledge | P |
| Lee et al. 1996 [45] | Goals and planning | P |
| Marquez-Sterling et al. 2000 [38] | Goals and planning<br>Shaping knowledge | P |
| Ney et al. 1982 [18] | Goals and planning | D |
| Ong et al. 2009 [39] | Goals and planning | P |
| Prevedel et al. 2003 [40] | Goals and planning | P |
| Rae et al. 2000 [25] | Goals and planning | D |
| Santos et al. 2005 [41] | Goals and planning | P |
| Sedaghati et al. 2007 [28] | Goals and planning | P |
| Wolff et al. 2008 [21] | Goals and planning | D |
| Yeo et al. 2000 [46] | Goals and planning<br>Feedback and monitoring<br>Shaping knowledge<br>Repetition and substitution | P |

the 6 most commonly used BCT categories being the same as those found within this study. Others have used Michie's previous taxonomy [8] to code pregnancy and postpartum lifestyle interventions. All of these found behaviour change techniques within the categories of "goals and planning" and "feedback and monitoring" were the most frequently used [5–7]. Hill et al. [6] and Gilinsky et al. [7] both also noted "instruction on how to perform the behavior" was often utilised which sits within the "shaping knowledge" cluster in the Michie et al. BCT taxonomy [4]. Gilinsky et al. [7] also identified "set graded tasks" which is often used in physical activity trials and is classified under the "repetition and substitution" cluster. Hill et al. [6] found studies often provided "information on the consequences of behavior" which corresponds with behaviours in the "natural consequences" cluster. With the exception of Hill et al.'s [6] "natural consequences" category, these behaviour change techniques correspond closely with those found in our study.

When assessing BCT taxonomy categories, there were disputes among the authors (Table 2), mostly around the "goal setting (behaviour)" technique. This categorisation was disagreed on for 15 out of the 18 physical activity interventional studies which could account for "goals and planning" appearing to be more often incorporated into dietary based and mixed interventions compared to physical activity interventions. In the majority of these disputed studies there was no explicit reference to goal setting within the descriptions of the intervention procedures provided according to the BCT taxonomy definition: "set or agree on a goal defined in terms of the behaviour to be achieved" [4]. Participants had been assigned to the intervention condition as part of the research protocol. Although the intervention description included exercise classes or similar, it was not clear whether or not a goal had been set or agreed to attend/engage in these classes, even though this seemed likely to have occurred. These disagreements may reflect health psychologists stricter

Table 3: Prevalence of BCT categories within successful and unsuccessful interventions at reducing gestational weight gain.

| | BCTs present in successful intervention (% of 12 studies) | BCTs present in unsuccessful intervention (% of 16 studies) |
|---|---|---|
| Goals and planning | 75.0 | 50.0 |
| Feedback and monitoring | 91.7 | 75.0 |
| Shaping knowledge | 50.0 | 81.3 |
| Natural consequences | 0 | 6.3 |
| Comparison of behaviour | 8.3 | 56.3 |
| Associations | 8.3 | 0 |
| Repetition and substitution | 16.7 | 68.8 |
| Comparison of outcomes | 25.0 | 18.8 |
| Reward and threat | 16.7 | 6.3 |
| Regulation | 8.3 | 0 |
| Antecedents | 25.0 | 50.0 |

BCT = Behaviour Change Technique.

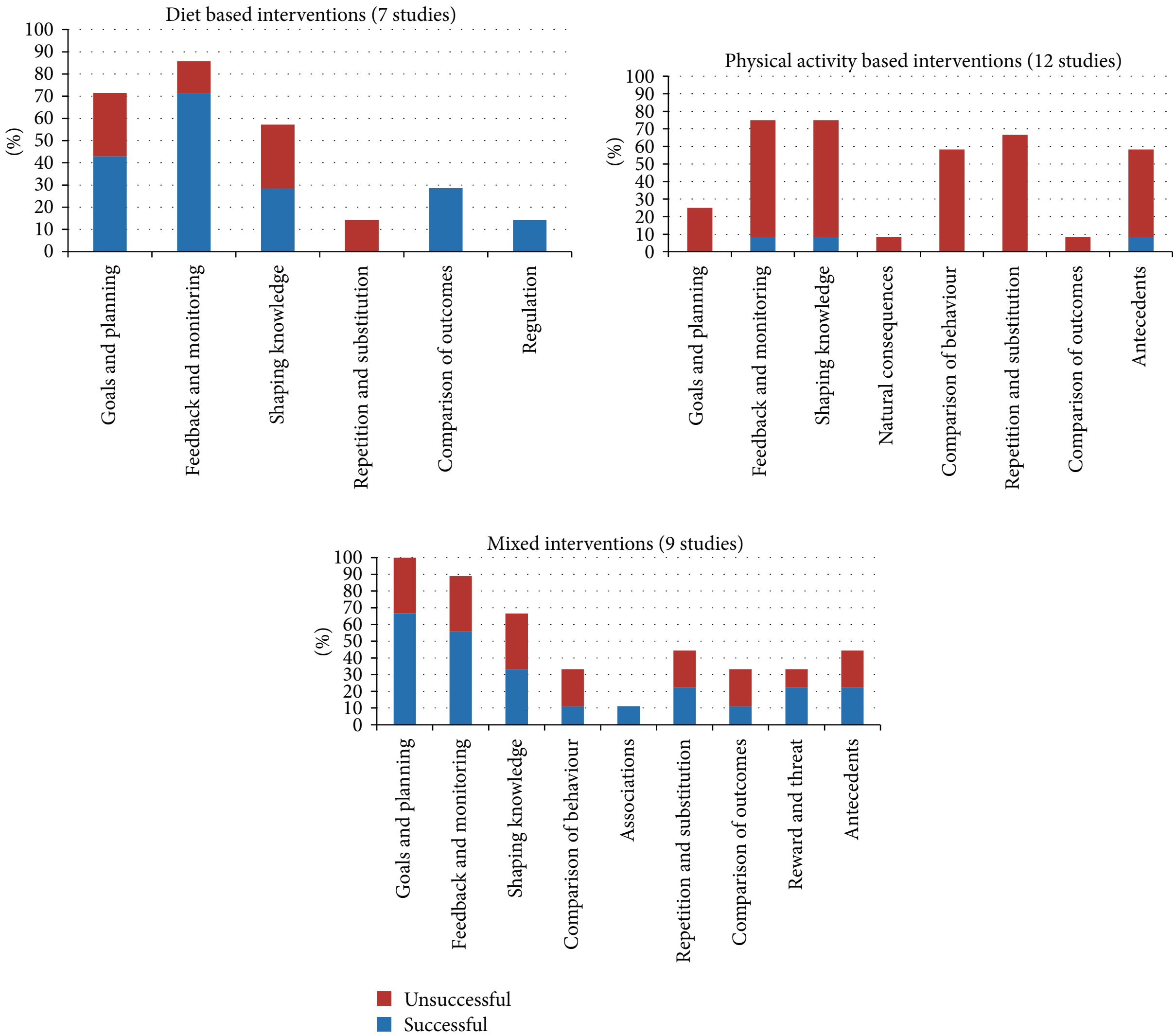


Figure 3: Success of intervention on gestational weight gain across intervention type.

understanding and interpretation of BCT coding, which does not necessarily match the understanding of clinicians and emphasises the potential difficulties of translating BCT's into practice. Clarification of these ambiguities is required to enhance the implementation and reporting of BCT's in research and practice.

Categories of behaviour change techniques were present in both effective and ineffective interventions, except for "regulation" which was only present in one successful diet based intervention and "association" which was within one successful mixed intervention. Others who have assessed behaviour change techniques utilised within interventions have similarly found behaviour change strategies to be present in both effective and ineffective studies [5]. Within this current study physical activity interventions were largely unsuccessful at managing gestational weight gain, whereas individual behaviour change techniques within diet based or mixed interventions were of varied success. However the success or failure of an intervention could be a result of a number of factors beyond the specific BCT's, for example, the study design, insufficiency of the sample size, or poor fidelity to intervention processes and attrition rates in the original studies.

The success or failure of the interventions may have been influenced by individual BCTs or by the specific combination of BCTs within the intervention. It was not possible to statistically analyse the individual effectiveness of BCTs or to assess the effectiveness of different combinations of behaviour techniques due to the number of different combinations of BCTs present within studies, which is a limitation of this review. However it was noted that successful interventions always included BCTs from one or both of "goals and planning" or "monitoring and feedback". This is in line with Michie et al.'s [60] findings with regard to healthy eating and physical activity interventions in the general population, with what Gilinsky et al. [7] found for interventions effective at increasing postnatal physical activity and with Harkin et al. [61] who found larger effect sizes in interventions incorporating monitoring of goal progress. When specifically looking at gestational weight gain studies utilising explicit goal setting Brown et al. [14] found a difference in the types of interventions which were effective at different body mass indexes (BMIs) with some interventions working best for women of normal weight and others for women who were overweight or obese. Future research into effective behaviour change techniques will need to take account of potential differential effects across various BMI categories.

The lack of clear and consistent reporting of which behaviour change techniques were undertaken within each intervention was a recurrent theme across this study. Poor reporting, making classification of BCTs difficult, was noted to occur within three main areas: lack of differentiation between the intervention processes and the research processes of the study; difficulties in determining which components were delivered only to the intervention group rather than to both the intervention and control groups; and finally poor or vague definitions of the behaviour change components used. Each of these areas will be discussed in turn.

Some studies were noted to lack clarity over whether the incorporated behaviours were part of the intervention or just part of the study design, for example, glucose monitoring, blood pressure measurements, and completing questionnaires. If these activities were purely for the researchers own benefit to determine clinical outcome measures for the study they would not be part of the intervention and therefore should not be part of the behaviour change technique classification; however if participants were given feedback on the results of blood pressure readings or their current weight in order to promote behaviour change then these procedures would be part of the intervention and their component techniques should be classified This lack of clarity across the studies made BCT classification difficult. The importance of clear reporting was also highlighted due to difficulties in determining which behavioural processes were solely applied to the intervention group. For example, statements such as "participants were weighed at each appointment" did not make it clear if everyone was weighed or just the intervention group.

Behaviour change technique coding was difficult as some studies used vague phrases such as "nutrition counselling" or "education" to describe their interventions and did not clearly specify what techniques these interventions included. Furthermore interventions such as water aerobics sessions or gym access where a fitness instructor was present would most likely include "how to perform the behavior" or "demonstrating the behaviour"; however when this was not explicitly stated it was difficult to identify the techniques and their effectiveness in a standardised and consistent manner. Others have also described the difficultly of applying behaviour change codes to intervention components due to a lack of specificity within reports [5].

One study noted by the authors to provide a clear description which allowed rigorous behaviour change technique codes to be applied was Jeffries et al. [49]. Codes included "goal setting the outcome" as intervention women were informed of their optimal weight gain based on their BMI and Institute of Medicine (IOM) guidelines and given personalised weight gain charts and "self-monitoring the outcome" as intervention group women were asked to weigh themselves every 4 weeks and record it on their chart. In contrast an example of reporting which made BCT classification difficult is Bechtel-Blackwell et al. [22]. They conducted an education based intervention where the intervention group had three 20 minute group sessions which covered: *"nutritional needs specific to the woman's stage of her pregnancy."* It was not clear whether these sessions just provided information or worked through problems to provide solutions (i.e., if you feel sick, then drink water or go for a walk). No code could therefore be applied.

When developing intervention studies researchers should "clearly define and provide a rationale for all behaviour change techniques that have been included" [62]. Future studies should use frameworks for intervention design such as the Behaviour Change Wheel [63] that guide developers through the process of developing a clear rationale based on evidence. Reporting behaviour change interventions stating what has been done using the standardised terms found in the behaviour taxonomy would enable other researchers to understand exactly what the intervention included and would allow statistical analysis to evaluate the effectiveness of specific study components. This would provide a more robust conclusion of the effectiveness of specific BCT categories at preventing excessive gestational weight gain, facilitating the replication of successful interventions or intervention components. The lack of standardised terms in the maternal obesity intervention literature, and the use of vague terms such as "nutrition counselling" means that we cannot understand what aspects of the intervention made it successful and that we cannot properly replicate it in future research. Without the ability to build on knowledge in this way researchers will not be able to improve intervention design in the future.

## 5. Conclusions

Coding interventions using the BCT taxonomy is valuable in the field of gestational weight management. However a better understanding of these techniques, clarity in their implementation, and reporting in a standard format are necessary to allow a robust and reliable evaluation of their efficacy.

## Disclaimer

The views and opinions expressed are those of the authors, and not necessarily those of the NHS, the NIHR, or the Department of Health.

## Conflict of Interests

The authors declare that there is no known conflict of interests.

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