Exploring the Need for Additional Nutritional Support in Adolescent Pregnancies

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Collaborating Organisations:
Born in Bradford
NIHR Collaboration for Leadership in Applied Health Research and Care
Yorkshire and Humber
University of Leeds

Candidate's 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 40,000 plus approximately 20,000 additional words in included articles

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Date	*January 2019*
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I appreciate the contributions of all of the participants, both in the Born in Bradford study and those who consented to be interviewed for this PhD.

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Abstract

There is significant evidence to suggest that pregnancy outcomes among adolescent pregnant women may be less favourable compared to those of adult women. Incidence of preterm delivery, low birthweight and babies who are small for their gestational age have been identified as outcomes of particular concern for this population. One school of thought regarding this issue suggests that nutrition in adolescent pregnancies may have a role to play in reducing these differences and improving outcomes for adolescent mothers and their babies, however this area is in need of further research. The primary aim of this thesis therefore is to address the research question "*Is there a need for additional nutritional support in adolescent pregnancies?"*

This is a mixed methods study following a sequential explanatory design in which priority is given to the quantitative research phase. Following a systematic review of the academic literature, the program of research is carried out in two distinct phases and the findings from each integrated.

The quantitative research phase utilises secondary data from the Born in Bradford cohort study to investigate differences in maternal and neonatal outcomes and dietary patterns between adolescents (age ≤19 years) and an adult control group (age 20-34 years). Differences in outcomes were assessed using logistic regression models and differences in dietary pattern assessed using a combination of principle component analysis and regression models.

The qualitative research phase was informed by the results of the quantitative phase and sought the perspectives of youth support professionals on supporting healthy eating in adolescent pregnancies through semi-structured interviews. Interviews were transcribed and analysed thematically. Findings from the program of research as a whole were then integrated narratively.

The results of the systematic literature review confirmed that the nutritional status of pregnant adolescents is likely to be poor. The quantitative analyses identified significant differences in outcomes between adolescent and adult women, particularly a higher odds of delivering babies who were very (<32 weeks gestation) or extremely (<28 weeks gestation) pre-term (aOR 2.12, 95% CI 1.06 to 4.25 and aOR 5.06, 95% CI 1.23 to 20.78, respectively), or at an extremely low birthweight (<1000g, aOR 4.13, 95% CI 1.41 to 12.11).

Results from the quantitative phase were used to inform the development of the qualitative interview guide following which the integration of findings from the program of research as a whole identified three overarching themes; social context, dietary pattern and need for support. Adolescent pregnant women were found to live in areas with higher levels of socio-economic deprivation, were more likely to be single parents and have unstable family backgrounds and housing insecurity. Adolescents were also found to consume higher levels of snack and processed foods, less fruit and vegetables, were likely to eat less regularly than older women and took fewer nutritional supplements. The need for additional social support, both in terms of the provision of services and facilitating young women to access existing services was also a key theme from the qualitative data.

The overarching themes identified in this program of work suggest that there are differences in diet quality between pregnant adolescents and adult pregnant women and that this may impact upon the health of the pregnancy. This research highlights that while additional support for eating healthily during pregnancy is important for this population, a more holistic approach which encompasses the range of complex issues faced by adolescent pregnant women is likely to have a greater impact on overall pregnancy health.

This work makes an original contribution to knowledge by investigating an important large British cohort with unique characteristics to answer questions which have not previously been investigated in this data set. It has identified issues for pregnant adolescents which have not previously been documented and included the perspectives of a key professional group whose views have not previously been included in this debate.

Contents

0.1 Article based thesis

The research in this thesis is presented in an article-based format which is somewhat different to the traditional monograph Ph.D. presentation; however the regulations and assessment criteria for the award remain the same. The guidance produced by Sheffield Hallam University on article-based theses describes the approach as a thesis format in which a number of articles (between three and five) are produced by the Ph.D. candidate during their period of candidature. These articles will either already be published or will be accepted for publication in peer reviewed journals at the time of submission. An article-based thesis will usually comprise an introduction including an explanation of the research question(s), the research subject, relevant literature and methodology and a concluding chapter in which the results of the research are summarised and discussed.

This article-based thesis includes three papers which have been published in peer-reviewed journals and a fourth which is currently under review for publication. The articles report on the four studies which together comprise this program of research and are included within the thesis with an accompanying narrative.

0.2 Outputs, contribution statements and permissions

Article A

Title	Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries
Authors	Katie Marvin-Dowle, Dr Victoria Burley, Prof. Hora Soltani
Full Reference	Marvin-Dowle K, Burley VJ, Soltani H. Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries. BMC pregnancy and childbirth. 2016 Dec;16(1):268.
Contribution Statement	This piece of work was led by Katie Marvin-Dowle who oversaw and was actively involved in all of the research processes at each stage
Permissions	The open access articles published in BMC's journals are made 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 (which, in an academic context, usually means citation).

Article B

Title	Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort
Authors	Katie Marvin-Dowle, Dr Karen Kilner, Dr Victoria Burley, Prof. Hora Soltani
Full Reference	Marvin-Dowle K, Kilner K, Burley VJ, Soltani H. Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort. BMJ open. 2018 Mar 1;8(3):e016258.
Contribution Statement	This piece of work was led by Katie Marvin-Dowle who oversaw and was actively involved in all of the research processes at each stage
Permissions	The BMJ Author License allows authors to use their articles for their own non-commercial purposes without seeking permission from the BMJ – the only condition being that a full reference or link to the original is included.

Article C

Title	Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis.
Authors	Katie Marvin-Dowle, Dr Karen Kilner, Dr Victoria Burley, Prof. Hora Soltani
Full Reference	Marvin-Dowle K, Kilner K, Burley V, Soltani H (2018) Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis. PLoS ONE 13(12): e0208879.
Contribution Statement	This piece of work was led by Katie Marvin-Dowle who oversaw and was actively involved in all of the research processes at each stage
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0.3 Abbreviations

ACE	Adverse Childhood Experience
AOAC	Association of Official Analytical Chemists
APGAR	Appearance, Pulse, Grimace, Activity, Respiration
BIB	Born in Bradford
BMI	Body Mass Index
CASP	Critical Appraisal Skills Programme
CLAHRC	Collaboration for Leadership in Applied Health Research and Care
COMA	Committee on Medical Aspects of Food and Nutrition
DLW	Doubly Labelled Water
DQI	Diet Quality Index
DRV	Dietary Reference Value
EAR	Estimated Average Requirement
FFQ	Food Frequency Questionnaire
FNP	Family Nurse Practitioner/Family Nurse Partnership
HCP	Health Care Professional
HSE	Health Survey for England
IUGR	Intra-Uterine Growth Restriction
LRNI	Lower Reference Nutrient Intake
MFA	Maternal-Foetal Attachment
NATSAL	National Sexual Attitudes and Lifestyles Survey
NDNS	National Diet and Nutrition Survey
NHS	National Health Service
NICU	Neonatal Intensive Care Unit
NIHR	National Institute for Health Research
PCA	Principal Component Analysis
RDA	Recommended Daily Allowance
RNI	Reference Nutrient Intake
SACN	Scientific Advisory Committee on Nutrition
SCBU	Special Care Baby Unit
SES	Socio-Economic Status
TEE	Total Energy Expenditure

UK	United Kingdom
US	United States
WHO	World Health Organisation

0.4 List of tables

0.5 List of figures

Chapter 1 - Introduction

1.1 Introduction

Pregnancy and childbirth among adolescents in Western countries is often viewed as a social problem with women who have a child during the teenage years being more likely to suffer social isolation, poverty, lower levels of educational achievement and be unemployed or work in low paid jobs[1]. In addition to the potential for adverse social outcomes the literature suggests that young maternal age may be an independent risk factor for adverse maternal and neonatal health outcomes. One systematic review[2] aiming to assess the relationship between early first childbirth and increased risk of poor pregnancy outcomes found that there was considerable evidence to suggest very young maternal age (<15 years or less than 2 years after menarche) had a negative effect on both maternal and foetal growth and infant survival. It is suggested that young women who are still themselves growing may compete with the foetus for nutrients, which may in turn impair foetal growth and result in low birth weight babies or babies who are small for their gestational age. The review also found a moderate relationship between young maternal age and anaemia, premature birth and neonatal mortality. These findings regarding foetal growth suggest maternal nutrition during adolescent pregnancy may impact on outcomes for both mother and child.

It has long been established that nutritional status in pregnancy has an important influence on birth outcomes[3]; particularly in terms of foetal growth and infant survival and that mothers need to consume adequate, yet not excessive, nutrition in order for their babies to thrive. There are two potential areas where nutritional differences may exist between adolescent and adult pregnancies. Firstly there is evidence to suggest that the general diet of adolescent girls may be of poorer quality than that of older women. The latest results of the National Diet and Nutrition Survey (years 7-8, 2014/15 - 2015/16)[4] showed that girls aged 11-18 years consumed 2.8 portions of fruit and vegetables per day compared to 4.2 portions in women aged 19-64 years. A higher proportion of adolescent girls also had intakes of key vitamins and minerals below the lower

reference nutrient intake level than adult women, including vitamin A, riboflavin, vitamin B12, folate, iron, calcium, magnesium, potassium, zinc and iodine.

Secondly there is evidence to suggest that because some adolescent women will still themselves be growing during pregnancy they may compete with the developing embryo to satisfy their own growth needs. A study of a US based prospective cohort[5] examining the relationship between maternal growth and outcomes in adolescent pregnancies found that continued maternal growth in adolescents affected nutrient partitioning between mother and child and that this, combined with poor nutritional status in pregnant adolescents, impacted negatively upon foetal growth and prematurity. This position is however contested by a UK based study[6] which found that the average birthweight of babies born to adolescent women who were still growing was in fact higher than those of young women who had finished growing, and that gestational weight gain (rather than maternal growth in stature) was more significantly correlated with birthweight. Average infant birthweight in the non-growing adolescent group was however significantly lower than that in adult controls. This suggests that the relationship between maternal and foetal growth is very complex and further work to explore this relationship is needed.

1.2 Aims and Objectives

Therefore the primary aim of this programme of research is to address the research question:

Is there a need for additional nutritional support in adolescent pregnancies?

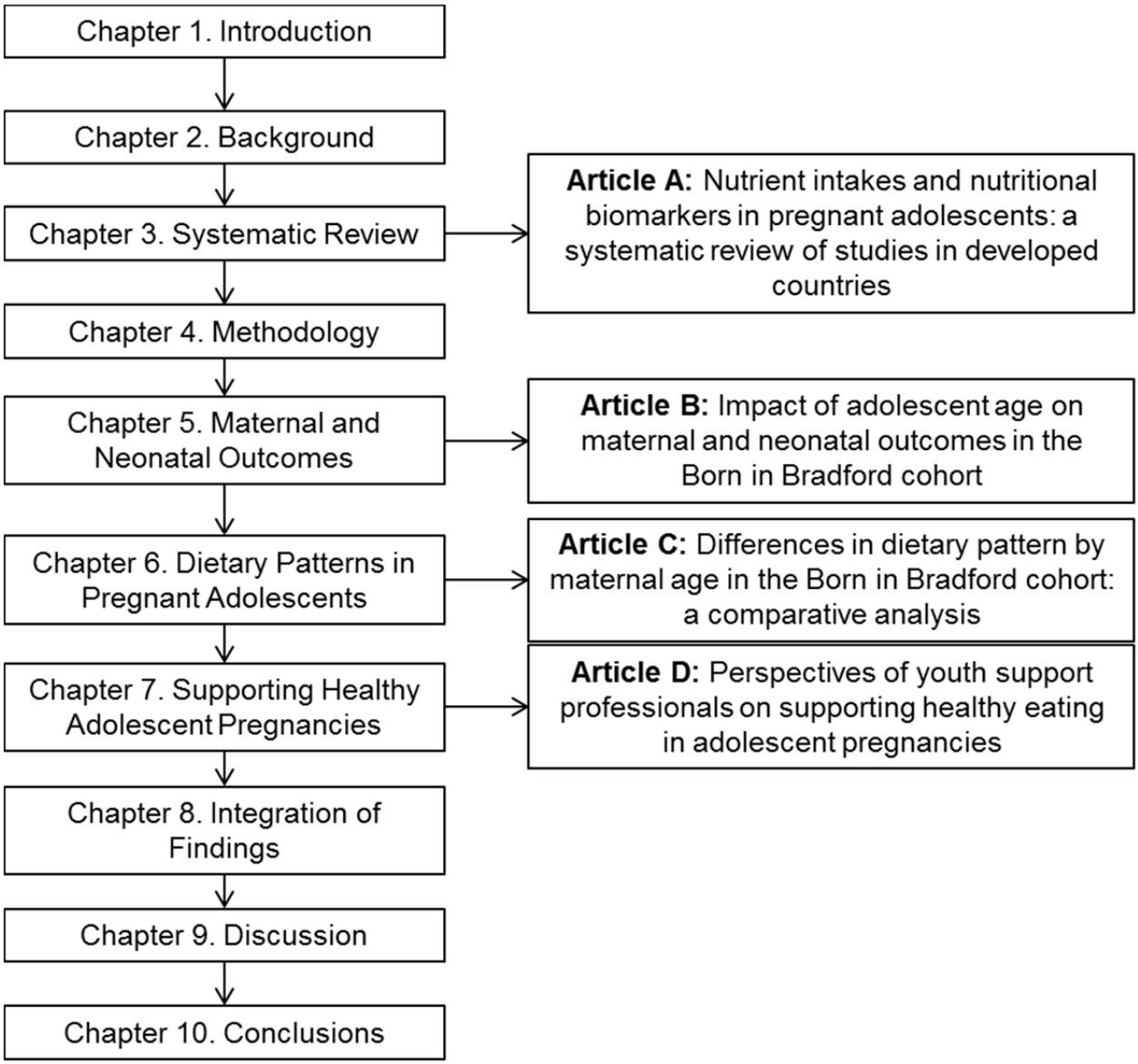
In order to consider this question the research will focus on three specific objectives:

- Establish what is known in the current research literature regarding the nutritional status of pregnant adolescents
- Examine differences in dietary intake and birth outcomes between adolescent and adult mothers in a large cohort data set
- Explore the perspectives of health and social care professionals of providing nutritional support for pregnant adolescents

1.3 Overview of the programme of research

Original research is presented in this thesis in an article based format. A collection of four research articles (three published and one that has been submitted for publication) in international, peer reviewed, scientific journals which are presented in their original forms. The overall findings of the research are drawn together and discussed, including discussion of the original contribution to knowledge offered by this work. Figure 1 shows an overview of the programme of research and how it is presented in this thesis.

Figure 1. Overview of the programme of research



1.4 Thesis structure

Chapter 1 provides an introduction to the thesis, a brief rationale and the aims and objectives of the programme of research and an overview of the included studies.

Chapter 2 contains a comprehensive review of the relevant existing literature and identifies gaps therein.

Chapter 3 contains Article A "Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries" which was accepted for publication in BMC Pregnancy and Childbirth in September 2016.

Chapter 4 details the methodology that underpins the programme of research and discussed the philosophical approach and research design, and how this influenced the choice of methods

Chapter 5 contains Article B "Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort" which was accepted for publication in BMJ Open in March 2018.

Chapter 6 contains Article C "Differences in dietary pattern by maternal age in the Born in Bradford cohort: a comparative analysis" which was accepted for publication in PLoS One in December 2018. This chapter then details how the findings from the two quantitative studies inform the qualitative enquiry.

Chapter 7 contains Article D "Perspectives of youth support professionals on supporting healthy eating in adolescent pregnancies" which at the time of submission was under review for publication in Evidence Based Midwifery.

Chapter 8 provides an integration of findings from the quantitative and qualitative phases of analysis and develops overarching themes from the research program.

Chapter 9 gives a summary of the key research findings in a discussion chapter, highlights the strengths and limitations of the thesis and discusses implications and recommendations for future research and practice development.

Chapter 10 concludes the thesis and reviews the aims and objectives set out in the introduction. The contribution of new knowledge made by this programme of research is clearly highlighted.

1.5 Anticipated contribution of new knowledge

It is anticipated that this programme of research will add to the body of literature regarding differential outcomes between adolescent and adult pregnancies by carrying out this analysis in a large, UK based cohort which has not previously been examined in this way. Furthermore this work will generate new knowledge regarding young women's patterns of eating during pregnancy and explore new perspectives on how young women can be supported to make positive dietary changes to improve the health of their pregnancy.

Chapter Two - Background

2.1 Introduction

Adolescent pregnancies are defined as pregnancies occurring in young women aged 19 years or under at the time of conception[7]. Adolescent pregnancy is a global issue with approximately 2 million girls under the age of 16 and 16 million between the ages of 15 and 19 becoming pregnant every year. There are significant disparities in adolescent fertility rates in different regions of the world with rates as high as 106 live births per 1,000 women aged 15-19 years in sub-Saharan Africa down to 6.2 births per 1,000 in Eastern Asia[7]. Figure 2 shows global fertility rates by mothers region of residence. Europe has the second lowest fertility rate amongst the global regions; there is however also significant variation within the region. Despite recent reductions, the UK still has the highest adolescent fertility rate in Western Europe, with only Bulgaria, Romania, Slovakia, Hungary, Latvia and Lithuania reporting higher rates[8] (Figure 3).

Figure 2. Live births to women aged 15-19 by mothers region of residence, 2015

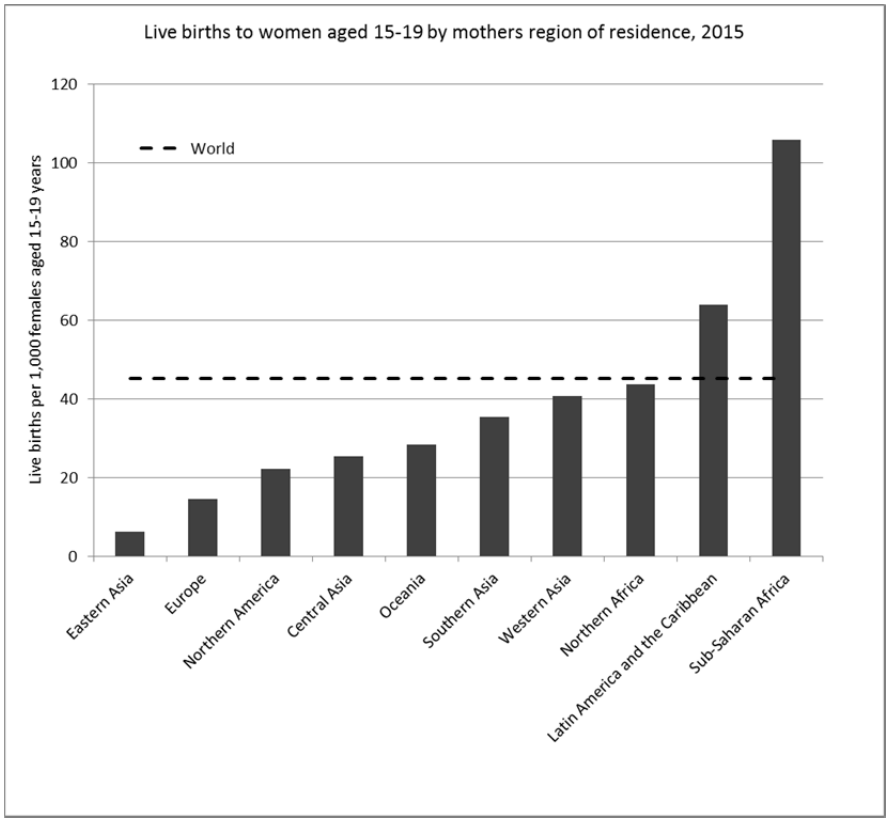
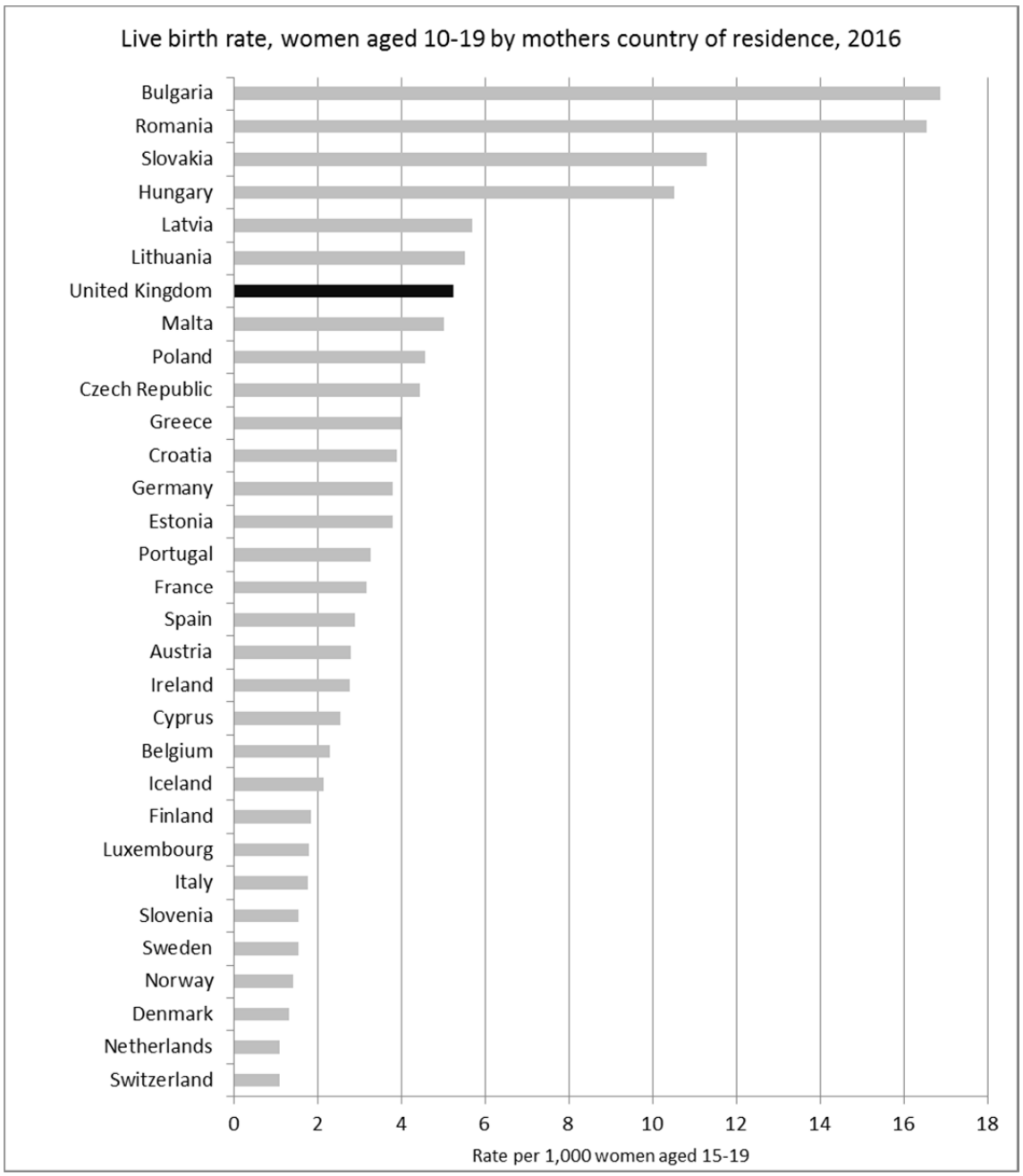


Figure 3. Live births to women aged 10-19 by mother's country of residence, 2016

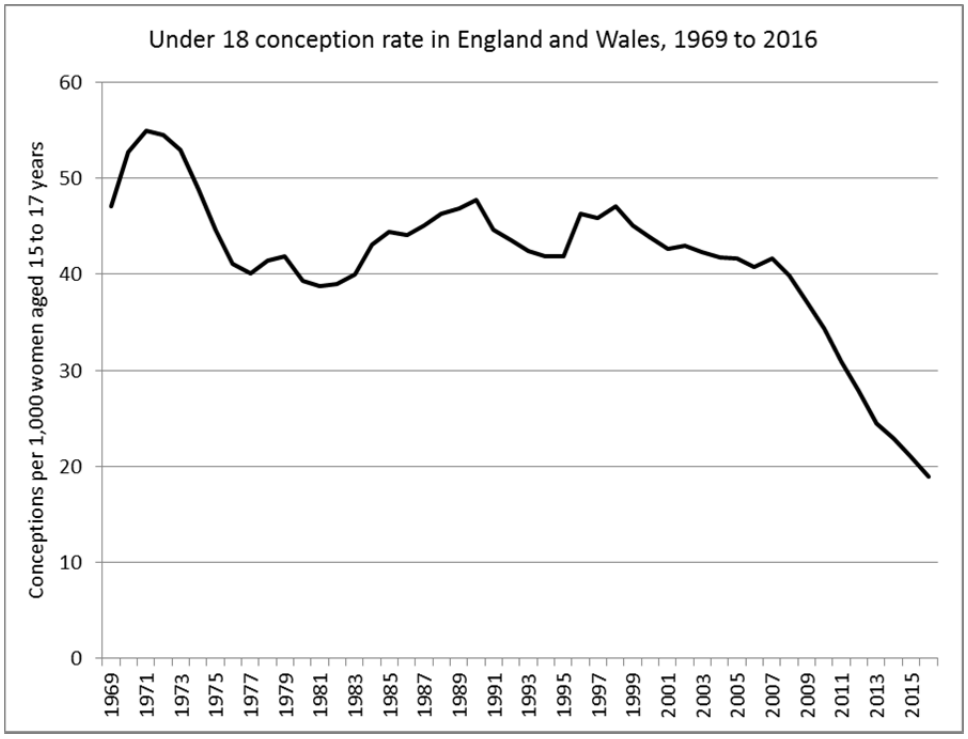


Both globally and locally, adolescent pregnancies are associated with socio-economic deprivation[9]. Those young women who are living in poverty, with low levels of education and in marginalised communities are most likely to become pregnant at an early age and continue to experience high levels of socio-economic deprivation. In the UK context, evidence also suggests that those young women who do conceive and become mothers during adolescence are

more likely to live in poverty[10], be socially isolated[11] and experience poor mental health[12] compared to women who have their first child at age 20 or older, meaning they are more vulnerable to experiencing poorer outcomes post-partum.

There have been significant reductions in the rates of conceptions to young women in the UK which have fallen by more than 50% in the last 10 years[13] with the under 18 conception rate now being at its lowest level since comparable records began in 1969, when the recorded rate was 18.9 conceptions per 1,000 female in the age group. Figure 4 shows the conception rate per 1,000 females aged 15-17 from 1969 to 2016. The data show that following a sharp decline in the early 1970's, coinciding with the wider availability of the contraceptive pill to unmarried women, rates remained largely static until 2007, where the current downward trend began its trajectory. While this is a positive trend, evidence from the National Survey of Sexual Attitudes and Lifestyles suggests that the majority of conceptions to young women aged 16-19 are still unplanned and that this is associated with less favourable behaviours and circumstances such as smoking, drug use and lower educational attainment[14].

Figure 4. Under 18 conception rate in England and Wales, 1969 - 2016



In 1999 the UK government launched a national, ten year teenage pregnancy strategy with the aim to halve the under 18 conception rate[15]. The strategy was successful with small inroads being made each year until a steep decline beginning in 2007 seeing the 1998 baseline rate halved by 2014. The strategy was designed to be multifaceted and incorporate actions relating to multiple influences on young people's lives. The four central themes of the programme were:

- Joined up action nationally and locally
- Improved sex and relationships education and access to contraception
- A targeted communications campaign for young people and parents
- Coordinated support for young parents

Due to the complex nature of both the problem and the interventions it is not possible to quantify the causal mechanisms or to identify which elements of the interventions had the largest effect on conceptions. However in a paper discussing the implementation of the programme, Hadley et.al[16] discuss the six key features contributing to the success of the strategy which are briefly outlined below.

Creating an opportunity for action

The teenage pregnancy strategy was an ambitious, long term plan which required cooperation between numerous agencies in all sectors. This was established from the start with the strategy described as being *'implemented with energy and enthusiasm, in an atmosphere of cooperation and consensus of those involved*[17]*'.*

Developing evidence based strategy

The strategy was clearly based on the best available evidence, including evidence of why alternative approaches, such as abstinence only education, were unlikely to be successful.

Effective implementation

The strategy included a comprehensive strategic action plan giving clear implementation instructions to all key agencies.

Regularly reviewing programmes

Regular evaluations were carried out during the course of the strategy, including a 'deep dive' comparing high and low performing areas carried out half way through the ten year programme. Crucially, adjustments were then made in light of new evidence.

Embedding the strategy in wider government programmes

The strategy was integral to improving wider outcomes for children and young people. This was supported by legislative changes which obliged local government to work cooperatively with other agencies, therefore maximising the available resources to be utilised for common goals.

Providing leadership throughout the programme

In a long-term strategy in which results were likely to be slow to be seen, high level commitment was essential to ensure momentum was maintained to allow in impact of the strategy to become apparent.

Despite a successful strategy to reduce under 18 conceptions in the UK the rate remains the highest in Western Europe, meaning there are still a significant number of adolescent women becoming pregnant and delivering babies. It is therefore important that work to investigate the health status of young women and their children and how this may be improved is carried out. In this chapter an overview of the literature on differences in clinical maternal and neonatal outcomes between adolescent and adult pregnancies is given. Following this an overview of nutrition during adolescence and discussion of what is known about the role of nutrition in healthy pregnancies, with particular reference to specific issues in adolescent pregnancies will be presented.

2.2 Adolescent pregnancy outcomes

2.2.1 Foetal Growth and development

Foetal growth and development plays a major part in the health and wellbeing of individuals both in terms of immediate birth outcomes and infant survival as well as longer term measures. Babies born with extremely low birthweight and those who are extremely preterm are at significantly higher risk of dying within the first few months of life compared to those born larger and later[18]. Survival rates of babies born preterm (before 37 completed weeks of gestation) in the UK increase rapidly with each additional week of gestation[19] meaning that understanding the causes of extremely preterm delivery is of paramount importance to reducing perinatal deaths. Longer term, outcomes for children born very preterm and/or with very low birthweight have been shown to include difficulties with behaviour and educational achievement[20] and low birthweight has been linked to a number of chronic conditions in adulthood such as ischaemic heart disease, hypertension and central adiposity[21].

The literature exploring the impact of maternal age on preterm delivery, infant birthweight and intrauterine growth restriction (IUGR) has established that some important differences exist between babies born to adolescent and adult women. Numerous studies have reported mean birthweight in babies born to adolescent women to be significantly lower than those born to adult mothers[22,23,24, 25]. Adolescent women have been shown to be at higher risk of pre-term delivery compared to adult women with the youngest adolescents being particularly vulnerable. Beeckman et.al[26] in a Belgian cohort consisting of 8,586 births found maternal age ≤19 to be a predictive factor for pre-term delivery after controlling for confounding factors (aOR 2.15, CI 1.31 - 3.53) while a Swedish birth register study[27] with 798,674 participants found that young women aged <17 years had increased odds of pre-term delivery (aOR 1.46, CI 1.24 - 1.72) compared to women aged 25-29 years, whereas this was not the case for young women aged 17-19 years. The same study also detected differences in the odds of very (<32 completed weeks gestation) and extremely (<28 completed weeks gestation) pre-term deliveries with the youngest

adolescents (<17 years) having increased odds of all pre-term outcomes. The literature regarding low birthweight shows similar patterns with all adolescents being at increased risk compared to adults[22,28], and the youngest women being the most likely to deliver low or very low birthweight babies[29].

2.2.2 Perinatal mortality

Perinatal mortality is defined as death of the foetus or neonate between 22 completed weeks of gestation and 7 days after birth[30], with deaths up to 28 days following birth being termed neonatal death. There is some evidence to suggest that the risk of stillbirth (deaths which occur before birth or during delivery) is higher among adolescent mothers compared to adults[31,32, 33], however a number of studies have failed to detect any differences between groups on this variable[34,35,36]. One large study (N= 5,874,203) based in the USA[37] found higher odds of stillbirth at both extremes of maternal age (≤19 years and ≥35 years) suggesting that the impact of young maternal age may be masked by the impact of older maternal age in studies which do not exclude older gravidas from the comparison group. This is further evidenced by a meta-analysis including data from 96 studies of factors associated with stillbirth in the five high income countries with the highest stillbirth rates (Australia, Canada, Netherlands, UK and USA). This review reported higher population-attributable risk (7-11%) in women aged over 35, this study did not however examine adolescent maternal age as a potential factor[38]. A meta-analysis of outcomes by parity and maternal age in low and middle income countries found an association between nulliparous women age <18 and neonatal mortality (aOR 1.49, CI 1.13 to 1.97), however no similar meta-analyses have been carried out in high income countries.

There is also some evidence to suggest that perinatal and neonatal mortality may be higher among babies born to adolescent women not least in part due to the relationship between these types of death and pre-term, low birthweight babies, which it has already been established are more common in this population. Chen et.al[39] found that the odds of neonatal death were higher in all adolescent age groups studied (10-15 years, 16-17 years and 18-19 years) but

that maternal age was no longer predictive of neonatal death once gestational age and birthweight were included in the regression model.

2.2.3 Neonatal morbidity

The most commonly used method of assessing the condition of a new born at birth is the APGAR score. The APGAR score is a value from 0 to 10 which is derived from the sum of scores out of 2 for each of the five components (**A**ppearance, **P**ulse, **G**rimace, **A**ctivity, **R**espiration). Assessments are usually made at 1 and 5 minutes following birth and scores below 7 indicate cause for concern[40]. Evidence for lower APGAR scores in babies born to adolescent mothers is mixed; while one large study reports greater relative risk of scores under 7 and under 4 in babies born to young women aged under 17[39], a number of other similar studies failed to detect a significant difference between groups for this variable[41,42,43].

A further clear indicator for neonatal morbidity is admission to a neonatal intensive care unit (NICU) or special care baby unit (SCBU). Babies born to adolescent women have been shown to be at higher risk of admission to NICU/SCBU[42,44,45]however similarly to reports of perinatal and neonatal mortality this variable is intrinsically linked to pre-term and low birthweight deliveries.

2.2.4 Maternal mortality and morbidity

Maternal mortality in the UK is very low at less than 9 deaths per 100,000 women occurring during pregnancy or up to six weeks after the end of pregnancy. Two thirds of these deaths can be attributed to pre-existing physical or mental health problems[46]. While maternal mortality is low, maternal morbidity due to conditions related to pregnancy is an important consideration, and one for which variations by maternal age can be observed.

Pre-eclamsia is a hypertensive disorder[47] which is a major cause of maternal morbidity and mortality worldwide[48]. While mortality in developed countries is low, pre-eclampsia has been associated with severe maternal morbidity such as

strokes and adverse neonatal outcomes such as prematurity and intrauterine growth restriction[48]. Pre-eclampsia is also indicated as a marker for increased risk of cardiovascular and metabolic diseases later in life[49]. Risk of pre-eclampsia in adolescent mothers has been shown to be lower than in older women. A cohort study by De Vienne et.al[50] showed a clear linear association between maternal age and relative risk of pre-eclampsia reporting relative risk of 0.080 (95% CI 0.01 - 0.6) for 16 year olds and 0.44 (95% CI 0.23 - 0.8) for 18 year olds in the cohort compared to the reference group (age 20) and a relative risk of 1.51 (95% CI 0.99 - 2.3) at age 25.

Gestational diabetes is another potentially serious condition of pregnancy which is associated with both immediate and longer term complications for the mother and the infant. Macrosomia, shoulder dystocia and birth injuries are common short term complications with evidence suggesting increased risk of obesity and impairment of glucose tolerance (leading to type 2 diabetes) for both mother and child[51] in the longer term. Gestational diabetes has also been shown to be positively correlated with maternal age; therefore adolescent women are at lower risk of developing the condition than older women[52].

There is a significant body of evidence showing that these and other maternal conditions such as pregnancy induced hypertension[53] and post-partum haemorrhage[50] occur less frequently in adolescent pregnancies than for adult women. This suggests that while maternal conditions of pregnancy are important to consider, they are unlikely to be a major cause of higher rates of adverse neonatal outcomes in this population.

2.2.5 Mode of birth

Similarly to maternal morbidity, the risk of adverse obstetric outcomes such assisted birth is lower in adolescent mothers than older women. Caesarean delivery is associated with higher rates of post-natal complications and increased recovery time for the mother[54]. Instrumental deliveries, while necessary to prevent serious neonatal complications, are associated with a higher prevalence of birth injuries and maternal rehospitalisation[55].

The literature presented regarding pregnancy outcomes shows a reasonable basis to consider that young maternal age may have a bearing on outcomes, with the strongest evidence concerning preterm deliveries and low birthweight infants. The studies in this area in high income countries are typically large cohorts or utilise birth registry data and therefore include a large number of participants, suggesting that the evidence is likely to be robust. The majority of studies also make efforts to control the analysis for potentially confounding factors, particularly the influence of socioeconomic deprivation. This said, very few studies have investigated the relationship between maternal age and extreme prematurity or extremely low birth weights and the evidence regarding the risk of stillbirth is less conclusive. It may also be the case that the inclusion of women aged 35 and over in comparator groups may mask some differences in outcomes between adolescents and women aged 20-34, for whom there is no evidence of age related complications.

2.3 Role of nutrition in pregnancy

2.3.1 The importance of optimal nutrition before and during pregnancy

It has long been established in the academic literature that individuals need to consume adequate but not excessive nutrition to support growth and repair and to provide energy for metabolic functions and everyday tasks. This is particularly important during pregnancy when dietary intake needs to not only support the mother but also the growth and development of the foetus[3].
The assessment of physiological demand for nutrients during pregnancy is complex due to the significant physiological and anatomical changes which take place during this period. The development and maintenance of placental and mammary tissues, body composition changes such as increases in fat storage, and energy mobilisation and the changing needs of the developing foetus mean that not only are the needs of pregnant women different to those who are not pregnant, physiological demand and therefore necessary nutrient intake change rapidly through the course of the pregnancy[56].

During the first trimester tissue patterns and organ systems are established through the process of embryogenesis; in the second trimester there is a significant increase in the size of the foetus and cells adapt to their specific functions, following which in the third trimester the size of the foetus continues to increase rapidly and organ systems mature ready for life in the outside world. Each of these developmental stages requires specific micronutrients to ensure optimum growth and development and reduce the incidence of adverse outcomes[57].

Micronutrient deficiency during pregnancy can have serious and long lasting impacts on the health of the child. The role of folic acid both pre-conception and during the first trimester in preventing neural tube birth defects has been well documented[58]. In addition adequate levels of vitamin A have been shown to be essential for the development and maturation of the lungs[59] and insufficient intake of vitamin A has been linked to low birthweight. Selenium, alongside other dietary antioxidants (zinc, vitamin C, vitamin E, beta-carotene) has been shown to play a role in regulating the antioxidant status of the mother, reducing oxidative stress and inflammation and in turn reducing the likelihood of a number of adverse pregnancy outcomes including birth defects, pre-eclampsia and miscarriage[60]. Both calcium and 25-hydroxy vitamin D have an important function in the development of the foetal skeleton and in maintaining bone health in the mother[61]. Calcium intake has also been linked to the incidence of pregnancy induced hypertensive disorders[62] and 25-hydroxy vitamin D to pre-eclampsia[63] and gestational diabetes[64]. Iron deficiency anaemia has been linked to a number of adverse pregnancy outcomes. Insufficient iron in early pregnancy impacts upon the size of the placenta which in turn is indicated in intrauterine growth restriction. Anaemia in the second trimester has also been associated with pre-term delivery and there is some evidence to suggest that iron has a crucial role in brain development and the prevention of cognitive and behavioural disorders in later life[65].

2.3.2 Foetal origins of adult disease

Epidemiological research of birth and death records has also led to the observation of correlations between environmental factors during gestation and health conditions in later life. These observations, which were initially made by Barker et.al[66] regarding links between undernutrition during pregnancy and ischaemic heart disease in the offspring, is referred to as the 'foetal origins of adult disease hypothesis'. This early hypothesis that states that *"an environment which produces poor fetal and infant growth is followed by an adult environment that determines high risk for ischemic heart disease"* (p. 579)[67] has since been developed into a field of study in its own right investigating the links between foetal environment in-utero and adverse outcomes later in life known as developmental origins of health and disease.

Early work[68,69] in this field investigated cohorts which had been affected by population level problems with food access to make comparisons between babies conceived in times of significant food shortage, such as a Dutch cohort exposed to famine towards the end of World War II, to those conceived in the same area at a time not impacted by food shortage. The results of these studies showed that foetal undernutrition may have significant impacts on the development of organs and systems of the body, and that this was specific to the stage of pregnancy. Those who were conceived prior to the onset of famine and so were undernourished in late gestation were found to be at higher risk for impaired glucose tolerance and insulin resistance in adulthood. Those conceived during the famine however were at higher risk for cardiovascular issues in adulthood. These findings suggest a very complex relationship between foetal environment and how this interacts with genetic influences and postnatal environments to accentuate or mediate risk for adverse health outcomes. In more recent work on the developmental origins of health and disease the Southampton Women's Survey have prospectively collected preconception data from women followed by detailed foetal measures during pregnancy as well as infancy and childhood follow ups[70]. Work from this cohort has identified mechanisms by which maternal central adiposity and diet quality affects the regulation of maternal blood flow from the liver to the developing brain, thus suggesting that the foetus may adapt their cardiovascular response

depending on the availability of nutrients[71]. In this research the participants were considered to have low risk pregnancies, meaning that women with higher risk pregnancies or mothers with higher nutritional needs may result in further foetal adaptations. It is therefore clear that nutrition during pregnancy is an important modifiable factor influencing both the immediate and long term health of the offspring. The rest of this chapter therefore considers nutritional recommendations for pregnancy and the nutritional status of women of childbearing age in the UK.

2.3.3 Dietary reference values in pregnancy

The nutritional needs of populations are difficult to estimate due to significant variations between individuals. Dietary reference values (DRVs) are therefore derived based on the estimated distribution of requirements among the individuals in a given population. In the UK the last full review of DRVs was conducted by the Committee on Medical Aspects of Food Policy (COMA) and published in 1991[72]; however, guidance on some individual nutrients has since been updated. Figure 5, reproduced from the COMA report, illustrates the method of derivation of the three most commonly used DRVs. The actual requirements for nutrients in a population are assumed to be normally distributed therefore estimated average requirement (EAR) is the estimated population mean. The reference nutrient intake (RNI) is set at two standard deviations above the mean, meaning that this is a level which is likely to be adequate for approximately 95% of the population. The lower reference nutrient intake (LNRI) is set at two standard deviations below the mean, meaning this is a level of intake which is unlikely to meet the needs of 95% of the population. DRVs are derived for population groups based on age and sex with any increase in requirements to support pregnancy being reported as increments. These increments apply across the board with no account given for the age of the mother as any age related differences in requirement should be accounted for in the pre-pregnancy DRVs. RNIs for vitamins and minerals for adolescent and adult women and any pregnancy increments are shown in table 1.

Figure 5. Method of derivation of dietary reference values

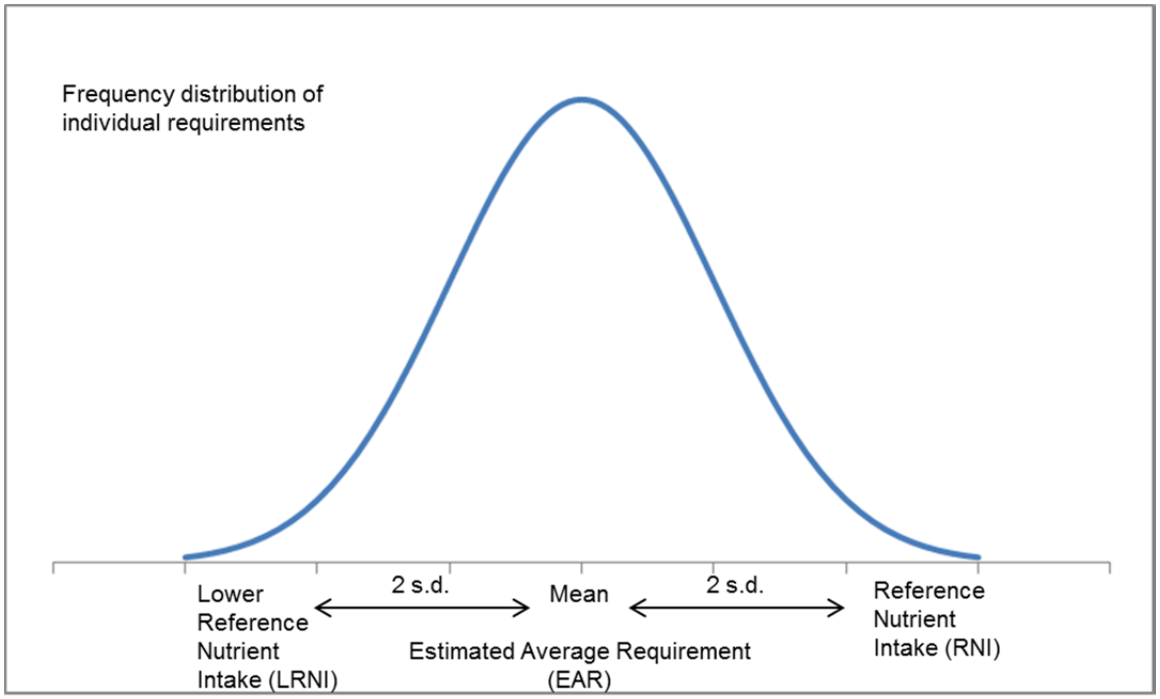


Table 1. Recommended nutrient intake for micronutrients for women of childbearing age and pregnancy increments

	UK RNI per day		
	Females 15-18	Females 19-50	Pregnancy Increment
Vitamins			
Folate	200µg	200µg	100µg
Niacin	14mg	13mg	NA
Riboflavin	1.1mg	1.1mg	0.3mg
Thiamin	0.8mg	0.8mg	0.1mg
Vitamin A	600µg	600µg	100µg
Vitamin B12	1.5µg	1.5µg	NA
Vitamin B6	1.2mg	1.2mg	NA
Vitamin C	40mg	40mg	10mg
Vitamin D	10µg†	10µg†	NA
Minerals			
Calcium	800mg	700mg	NA
Copper	1mg	1.2mg	NA
Iodine	140µg	140µg	NA
Iron	14.8mg	14.8mg	NA
Magnesium	300mg	270mg	NA
Phospherous	625mg	550mg	NA
Potassium	3.5g	3.5g	NA
Selenium	60µg	60µg	NA
Sodium	1.6g	1.6g	NA
Zinc	7mg	7mg	NA
†Updated in SACN Vitamin D and health report, 2016			

For the majority of nutrients there is no increment specified for pregnancy. This does not necessarily mean that there is no increase in requirement during pregnancy but that it is anticipated that any additional demand should be *"met by normal adaptation or increased efficiency of utilisation, or from stores of the nutrient"(pg.7)*. This is therefore an important consideration in cases where the pre-pregnancy nutrient intake may not be sufficient therefore meaning nutrient stores are also unlikely to be adequate. It is also important to consider that there is a level of uncertainty regarding estimates of nutrient requirement during pregnancy. This is due both to large individual differences in pre-pregnancy nutrient stores and body composition which alter need[73] and due to ethical and practical difficulties with collecting data from pregnant women.

The Scientific Advisory Committee for Nutrition (SACN) revised the DRVs for energy in 2011[74] and now reports the EAR for children and young people by single year of age. For young women the EAR for energy at age 11 is 2032kcal per day which rises steadily to 2462kcal per day at age 18; the EAR for adult women aged 19-34 is 2175 Kcal per day. There is an advised increment for pregnancy of 200kcal per day in the third trimester only. The EAR for protein for both adolescent and adult females is 45g per day with an increment of 6g for pregnancy. DRVs for fat and carbohydrate are expressed as percentages of total energy intake. It is recommended that calories from fat should make up no more than 35% of total calories, with no more than 11% being from saturated fatty acids. Total calories from carbohydrate are recommended to make up approximately 50% of energy intake, a figure which was maintained in a recent review of recommendations by SACN[75]. In this review the recommendations for consumption of free sugars (that is sugars added to food or drinks plus those found naturally in honey, syrups and unsweetened fruit juices) was revised to no more than 5% of total energy and recommendations for dietary fibre were set at 30g per day for all adults and adolescents aged 16 to 18 years and 25g per day for younger adolescents aged 11-16 years. There are no recommended pregnancy increments for fat or carbohydrate intake.

2.4 The nutritional status of women of childbearing age in the UK

As previously discussed, the assessment of nutritional need in populations is difficult and imperfect due to its dependence on a very large number of individual factors, meaning that physiological need varies from one individual to another. The use of dietary reference intakes based on the average need of individuals in a given population is however considered acceptable for assessing nutritional adequacy in populations[76]. For child and adolescent populations, and during pregnancy, the recommendations are therefore adjusted to account for growth needs, and taking into consideration variation in bioavailability.

In the UK, food consumption, nutrient intake and nutritional status of the general population is estimated from data collected by the National Diet and Nutrition Survey (NDNS). The NDNS is a continuous cross-sectional survey, now in its

eleventh year, which collects detailed data from a representative sample of approximately 1000 people aged 1.5 years and over. The NDNS therefore provides data on the nutrient intakes and nutritional status of adolescent and adult women in the UK which allow for estimates to be made of nutritional status in these populations preconception and in early pregnancy; pregnant women are however excluded from this survey. The data reported in this section are from the latest published results of the NDNS, years 7-8 (combined) 2014/15 - 2015/16[4]. The data for adolescent and adult populations are reported in the age groups 11-18 years and 19-64 years, therefore these are the age groups referred to in this section unless otherwise stated.

2.4.1 Energy and types of food

The mean total energy intake reported by adolescent women in the NDNS was 1555 kcal per day compared to 1632 kcal for adult women. Values for both of these populations are below the population estimated average requirement (EAR) which for adolescent girls ranges from 2032 kcal at age 11 to 2462 kcal at age 18 and for women from 2175 kcal at ages 19-24 to 2079 kcal at ages 55-64. This suggests either that women at all ages are ingesting less energy than is likely to be required to meet their needs while maintaining body weight or that there is a degree of under-reporting of foods eaten or portion sizes in the survey. Under reporting of energy intake in the NDNS has been examined using the doubly labelled water technique (DLW) in which participants are asked to consume water enriched with two stable isotopes of hydrogen and oxygen. Excretion of these isotopes can then be measured and the mean daily rate of CO_2 production derived, which then allows for the calculation of total energy expenditure (TEE). This is a widely accepted and validated method of assessing energy expenditure in free-living individuals over a period of one to two weeks[77,78]. It was concluded that energy intake was routinely under reported by participants in the NDNS, particularly in adults. This finding is consistent with other similar studies and highlights the common problem of misreporting in dietary studies[79].

The mean number of portions of fruit and vegetables consumed by adolescent women was 2.8 portions per day compared to 4.2 for adult women. Among

adult women 32% reported meeting the 5-a-day fruit and vegetable recommendations compared to only 9% of adolescents. It is also important to consider that social desirability bias may mean these values are over reported. Intakes of total fat and trans fatty acids were slightly under the recommended upper limit for both age groups however intake of saturated fatty acids was higher than the recommended population intake (no more than 11% of total energy from food) at 12.3% for both groups.

AOAC fibre intake was significantly below recommendations with only 2% of adolescent women and 4% of adult women meeting the SACN guideline. The mean intake for adolescents was 14.1g per day (recommended 25-30g/day) and for adults was 17.4g per day (recommended 30g/day).

SACN recommends that energy from intake of free sugars should not exceed 5% of total dietary energy. Adult women reported consuming more than double the recommended level of free sugars (11.2% of energy) and for adolescent women the reported intake was almost three times the recommendation (14.4% of energy). Adolescent women also reported consuming higher levels of sugar-sweetened soft drinks (183g/day) compared to adult women (100g/day).

2.4.2 Micronutrients

Table 2 shows the micronutrient intake from food (not including supplements) of women in both age groups; both the mean value expressed as a percentage of the reference nutrient intake and the proportion of the sample with intakes less than the lower reference nutrient intakes are included. With the exception of selenium, a higher proportion of adolescent women had intakes of all micronutrients below the LRNI compared to adult women. The mean micronutrient intake as a percentage of the RNI was also lower among adolescent women with mean intake only exceeding 100% of the RNI for riboflavin.

Table 2 micronutrient intake from food

Micronutrient	Females 11-18 years		Females 19-64 years	
	Mean as % RNI	% below LRNI	Mean as % RNI	% below LRNI
Vitamin A (µg/day)	83	24	138	10
Riboflavin (mg/day)	108	26	129	14
Folate (µg/day)	87	15	107	6
Vitamin D (µg/day)	19	NA	25	NA
Iron (mg/day)	56	54	76	27
Calcium (mg/day)	83	22	107	11
Magnesium (mg/day)	65	50	88	11
Potassium (mg/day)	62	38	74	23
Iodine (µg/day)	75	27	100	15
Selenium (mg/day)	70	45	73	47
Zinc (mg/day)	80	27	109	8

2.4.3 Nutritional status

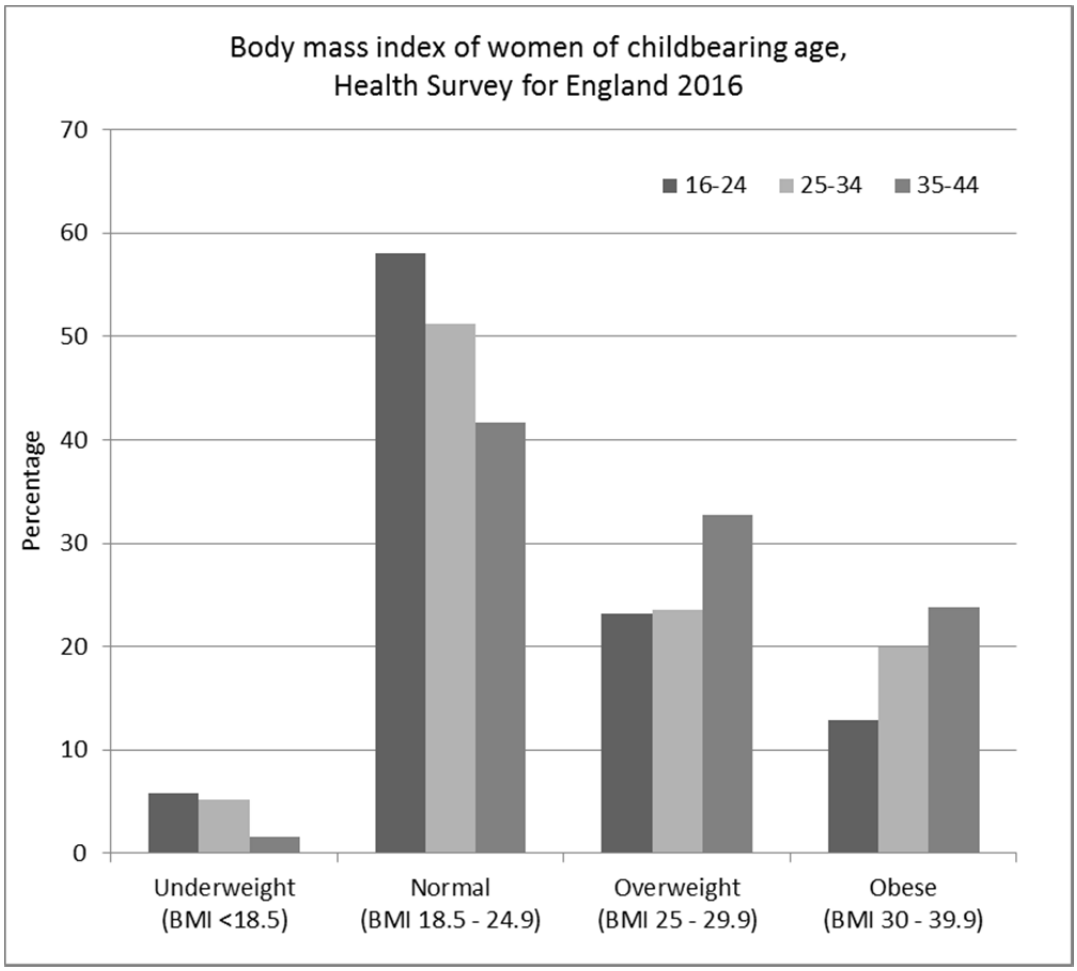
The NDNS also includes analysis of biomarkers of nutritional status. The results show cause for concern in markers of iron status, particularly among adolescent women with 9% being below the threshold for haemoglobin and 24% for plasma ferritin. The proportion of adult women below the threshold was similar for haemoglobin at 8% but only half the level among adolescent women at 12% for plasma ferritin. Levels of red blood cell folate were below the recommended level in 11% of adolescent and 7% of adult women. For serum folate 73% of adolescent and 45% of adult women were below the clinical threshold of 13nmol/L[80]. Levels of plasma 25-hydroxyvitamin D were also below recommendations in a significant proportion of women, particularly adolescents where 39% of the sample tested below the recommended level of 25 nmol/L[81]. Urinary iodine data on women of childbearing age have recently been included in the NDNS. While the results show levels to be adequate for non-pregnant women the median urinary iodine concentration was below the recommended

level for pregnant and lactating women, suggesting that women's current intake of iodine would be insufficient to support a pregnancy[82].

The results of the NDNS show some areas of concern. While the difference was greater among adolescents, intake and biomarkers of a number of key micronutrients was below recommendations for both adolescent and adult women. The mean intake of fruit and veg portions suggested that adult women were approaching achieving the recommended 5-a-day, but in fact only 32% consistently exceeded the thresholds, with levels even lower again among adolescents. High levels of free sugar and sugar sweetened beverage consumption and low intake of dietary fibre were also observed. These results suggest that the diet of adolescent women is nutritionally poorer compared to adult women, but also that there is significant room for improvement in the diets of all women of childbearing age.

The Health Survey for England (HSE)[83] reports data on body weight status of adults by age group and sex; that of women of childbearing age is shown in figure 6. The graph shows high levels of overweight and obesity in women of childbearing age with 26.5% of women being overweight and a further 19% obese, meaning almost half of women in this population are carrying excess body weight. There is a clear association between age and body mass index (BMI) with women in older age groups being more likely to be overweight or obese. However due to the cumulative effect of poor diet and excess energy intake on body weight this does not necessarily mean that older women's diet is currently poorer, rather that they are likely to have been consuming excess energy for a longer period of time. These findings also provide further evidence that energy intake is systematically under reported in the NDNS, as a population which routinely consumes fewer calories than needed for weight maintenance is unlikely to have high levels of overweight and obesity.

Figure 6. Body mass index of women of childbearing age, 2016



2.5 Nutritional issues for pregnant adolescents

As has previously been discussed, pregnancy is a life-stage at which the body's demand for nutrients is increased. In adolescent pregnancies this increased need may be compounded by the mothers' own growth needs.

There is some evidence to suggest that competition for nutrients between the mother and the foetus in growing adolescents may contribute to the higher risk of adverse outcomes. Early work on this topic published by Naeye in 1981[84] hypothesised that competition for nutrients may be an important cause for differences in birthweight, prematurity and mortality in young mothers compared to older ones based on measurement of urinary biomarkers associated with undernourishment in pregnancy. This work was expanded upon in a Peruvian study[85] which assessed nutritional status during pregnancy of adolescent and older mothers and compared neonatal outcomes. This study found that the risk of low birthweight, independent of prematurity, was higher in adolescent

mothers despite similar nutritional status to their older peers and that the availability of nutrients for the accumulation of calories in the foetus was lower in adolescents. The authors conclude therefore that the nutritional requirements of rapidly growing teenagers during pregnancy may be substantially greater than those of older women and that therefore the physiological growth needs of the mother compete with the growth needs of the foetus. More recent work by Scholl et.al[5] has investigated differences in outcomes between growing adolescents, adolescents who were not actively growing (assessed by measuring changes in knee height/leg length) and adult women. They found that growing adolescents tended to give birth to smaller infants despite higher gestational weight gain. Further work[86] by this team to investigate the mechanisms behind this association found that growing adolescents experienced a surge in leptin concentrations in the third trimester which may increase the mother's use of glucose for energy by inhibiting breakdown of maternal fat stores. It is suggested that this partitioning of maternal energy sources could explain the lower infant birthweight despite higher gestational weight gain in growing adolescents.

Evidence[87] from the 1980's concerning the partitioning of nutrients between organs and tissues in the body assumed that nutrients were distributed depending on the varying metabolic rate of the tissue - organs with higher metabolic rates therefore demanding higher levels of nutrients. Applied to pregnancy the assumption being that because the metabolic rate of the foetal-placental unit was higher than any of the maternal organs (with the exception of the brain), the foetus would compete successfully for nutrients, even when these were limited. Both animal and human studies have however challenged this assumption with evidence suggesting that dietary restriction is correlated with impaired foetal growth well before dietary intake is restricted to the extreme. For example evidence from a study of dietary restriction in rats has shown that foetal weight is unaffected only when maternal intake is sufficient to support some maternal weight gain. Dietary restriction beyond this level resulted in reduction in tissue gains with the foetus being disproportionately more affected compared to the mother[88]. A more recent review of published data on the effect of maternal feed restriction on prenatal development in rats

and rabbits[89] found that foetal growth was negatively affected by reduced maternal feed intake and that this impairment of growth was often accompanied by reduced skeletal ossification.

2.6 Summary

It has been demonstrated that babies born to adolescent women are at higher risk of adverse neonatal outcomes compared to those born to adult women. It has also been discussed that dietary intake and nutritional status are important modifiable factors which influence the outcome of pregnancies. While the diet of all women of childbearing age may be sub-optimal this is most pronounced in adolescent women, suggesting that there are likely to be problems with young women's nutritional status at conception, with any substantial dietary changes being unlikely and, even if changes were made, which are difficult to recover from as pregnancy progresses. It has also been discussed that the needs of adolescent women who are themselves still growing are likely to be substantially higher than women who have achieved their full adult stature, meaning that the nutrient availability to the foetus may be sacrificed for the mothers own growth needs. There is a lack of good quality systematic evidence regarding adolescent's nutritional status during pregnancy. In order to begin to address this gap in the current academic literature the following chapter presents a systematic review of nutrient intakes and nutritional biomarkers in pregnant adolescents in developed countries.

Chapter Three - Systematic Literature Review

3.1 Introduction

In this chapter the rationale for conducting a systematic literature review and its context is briefly summarised, followed by the full published version of the review. The chapter then concludes with a summary of key points, measurable impact of the work and discussion of its contribution to the thesis. As discussed in chapter two, there is a clear evidence base to suggest that the dietary intake and nutritional status of adolescent women may be insufficient to adequately support their own needs, and consequently would be inadequate to support a pregnancy. Two previous systematic reviews on this topic have addressed nutrient intakes[90] and nutritional biomarkers[91] separately; in which the results were presented narratively. This review therefore aims to both update this previous work and to synthesise the results of the included papers to achieve a better understanding of the topic. This work addresses the first of the research objectives as set out in the introduction to "*Establish what is known in the current research literature regarding the nutritional status of pregnant adolescents."*

3.2 Publication and Impact

This systematic review was accepted for publication in BMC Pregnancy and Childbirth in September 2016. BMC Pregnancy and Childbirth is a well-regarded open access, peer reviewed journal with a respectable impact factor of 2.9. Since publication online the article has been accessed 2,109 times and has achieved 6 citations (correct as of 20.01.19).

3.3 Published paper: Article A

The published paper entitled *"Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries"* is reproduced here in the format in which it was published online. Supplementary materials which were published alongside the article can be found in appendix 1.

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BMC Pregnancy and Childbirth

RESEARCH ARTICLE Open Access

Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries

Katie Marvin-Dowle[1], Victoria Jane Burley[2] and Hora Soltani[1*]

Abstract

Background: Babies born to adolescent mothers have been shown to have poorer outcomes compared to those born to adults. Nutritional status may have an important role to play in improving the health of pregnant adolescents; however there is a lack of evidence regarding the adequacy of adolescent diets during pregnancy. This systematic review aims to examine what is known about the nutritional status of adolescent pregnant women.

Methods: A systematic search of the literature identified 21 studies which met the inclusion criteria for the review. Primary research papers using any methods were included where they were published in English between January 1995 and May 2015 and included measurements of nutrient intakes or biological markers of nutritional status in pregnant women aged 11–19 years. Individual study data was first summarised narratively before study means were pooled to give an estimate of nutritional status in the population.

Results: The results show that individual studies reported intakes of energy, fibre and a number of key micronutrients which were below recommended levels. Biological markers of iron and selenium status also showed cause for concern. Pooled analysis of individual means as a percentage of UK Dietary Reference Intakes showed intakes of vitamin D (34.8 % CI 0–83.1) to be significantly below recommendations ($p = 0.05$). Serum selenium levels were also found to be low (61.8 μg/L, CI 39–84).

Conclusions: This review has identified a number of areas where the nutritional status of pregnant adolescents is sub-optimal, which may have implications for the health of adolescent mothers and their babies. It was not however possible to examine the impact of supplement use or socio-demographic characteristics which limits the interpretation these results. Further work is needed to establish the characteristics of those most at risk within this population, how this differs from adult pregnant women and the role of supplementation in achieving adequate nutrition.

Keywords: Adolescent, Pregnancy, Nutrition, Systematic review

Background

Pregnancy during adolescence is often viewed as a social problem with women who have a child during the teenage years being more likely to suffer social isolation, poverty, lower levels of educational achievement and be unemployed or work in low paid jobs [1]. Rates of teenage conceptions both in the UK and internationally have reduced over recent years; however there are still a significant number of young women having pregnancies and giving birth at a young age. The rate of deliveries to young women aged 15–19 in the UK in 2012 was the highest in the European Union at 19.7 births per 1,000 females in the age group. This does however represent a reduction of more than a quarter (26.8 %) in the UK since 2004. The birth rates to young women in other developed countries have followed a similar pattern of decline, yet rates remain relatively high in the United States (29.4), New Zealand (24.9) and Australia (16.1) [2].

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As well as the potential for adverse social outcomes associated with adolescent pregnancies there is evidence to suggest that health outcomes may be less favourable for younger mothers. A systematic review [3] aiming to assess the relationship between early first childbirth and increased risk of poor pregnancy outcomes found that very young maternal age (<15 years or less than 2 years after menarche) had a negative effect on both maternal and foetal growth and infant survival. It is suggested that young women who are still themselves growing may compete with the foetus for nutrients, which may in turn impair foetal growth and result in low birth weight babies or babies who are small for their gestational age. The review also found a moderate relationship between young maternal age and anaemia, premature birth and neonatal mortality.

It has long been established that good pregnancy nutrition has an important influence on birth outcomes, foetal growth and infant survival [4]. While specific nutritional issues may have changed since this early work, it is still maintained that mothers need to consume an adequate, yet not excessive diet in order to optimise pregnancy and birth outcomes [5]. Quantification of dietary adequacy in populations is difficult because individuals will have differing nutrient needs. This is especially true during phases of growth and physical change such as adolescence. However, the use of dietary reference intakes to estimate the adequacy of nutritional intakes has been established as acceptable [6] where the appropriate values for the age, sex and, in the case of pregnant women, stage of pregnancy are used. Evidence also suggests that nutritional needs change during the course of pregnancy with requirements for energy and several micronutrients increasing as pregnancy progresses [7].

Dietary habits of adolescent girls are often poorer than that of older women. The latest results of the UK National Diet and Nutrition Survey [8] showed that girls aged 11–18 years consumed 2.7 portions of fruit and vegetables per day compared to 4.1 portions in women aged 19–64, and adolescent girls also had some of the highest intakes of sugar-sweetened beverages within this dataset. A higher proportion of adolescent girls also had intakes of key vitamins and minerals below the lower reference nutrient intake level than adult women, including vitamin A, riboflavin, vitamin B_{12}, folate, iron, calcium, magnesium, potassium, zinc and iodine. Dietary patterns across highly developed countries have been shown to have substantial similarities [9], while the same cannot be said for less developed regions.

While the evidence presented above suggests that adolescent girls often have a poorer diet than adult women in the general population this may not also necessarily be the case in those who are pregnant. Two systematic reviews have previously been conducted [10, 11] which explored nutritional intake and biochemical markers in pregnant adolescents living in developed countries. It was acknowledged in these reviews that there was a lack of good quality evidence in relation to these topics. However the author concluded that there was some consensus in the available literature that pregnant adolescents had intakes of energy, iron, folate, calcium, vitamin E and magnesium which were below the dietary recommended intakes. The review of biochemical markers reported that indicators of anaemia and iron status were compromised in this population; however no further conclusions could be drawn from the limited available evidence. It is therefore important that the most recent evidence relating to the nutritional intake and status of pregnant adolescents is examined in order to establish what the particular issues may be for this group. The aim of his systematic review was therefore to investigate the nutritional status of pregnant adolescents living in developed countries.

Methods

Search strategy

The search strategy was developed using search terms detailed in Table 1 and applied across nine key electronic databases (AMED, ASSIA, CINAHL, Child Development and Adolescent Studies, Cochrane Library, Health Source: Nursing, Maternity and Infant Care, MEDLINE and MEDLINE in Process, SCOPUS). Reference lists of identified papers were hand searched, and reference and citation functions were used where available.

Table 1 search terms The main stages of the review including the number of references identified at each stage are illustrated in Fig. 1.

Inclusion criteria

Studies were limited to primary research papers using any methods published in English between 1995 and May 2015.

Studies were included where they provided data regarding either the nutritional intake or a biological marker of nutrient status of adolescents aged 11–19 years at any stage of pregnancy, from countries considered as having very high levels of human development by the United Nations Human Development Index [12]. This index has been selected as it provides a multidimensional model incorporating not only wealth but also health and education, and so provides a more reliable basis for assuming some commonality between countries of origin of the included studies. The definition of adolescence has been chosen to correspond with the World Health Organisation Growth Index [13].

Quality appraisal

The identified papers were assessed for risk of bias using the Critical Appraisal and Skills Program (CASP) checklist for

Table 1 Search terms

Theme	Nutritional Intake	Pregnancy	Age	Nutritional Status
Search Terms	nutrient	pregnan*	adolescen*	biomarker*
	nutrition*	gestatio*	teen	iron
	diet*	matern*	teenage*	folate
	eat*	mother*	youth	calcium
	food	gravid*		anaemi*
	nutrition assessment (MH)	Pregnancy in adolescence (MH)		anemi*
	Food habits (MH)			Biological markers (MH)
	Dietary surveys (MH)			

* indicates truncation of search tearm

systematic reviews [14] which was adapted to accommodate cross-sectional studies. Aspects of the studies giving an indication of methodological and interpretive rigor (e.g. research design, clear statement of research aims, recruitment of participants, consideration of confounding factors and reporting of results) were graded as either 'good' (+), 'adequate or unclear' (−/+) or poor (−), studies were then given an overall grade for quality.

Data extraction

Included studies were grouped depending on whether the study examined nutrient intake, biological markers of nutritional status or both. Information from the included studies was entered in to data extraction sheets using Microsoft Excel, one each for nutrient intakes and biological markers, and checked by a second reviewer.

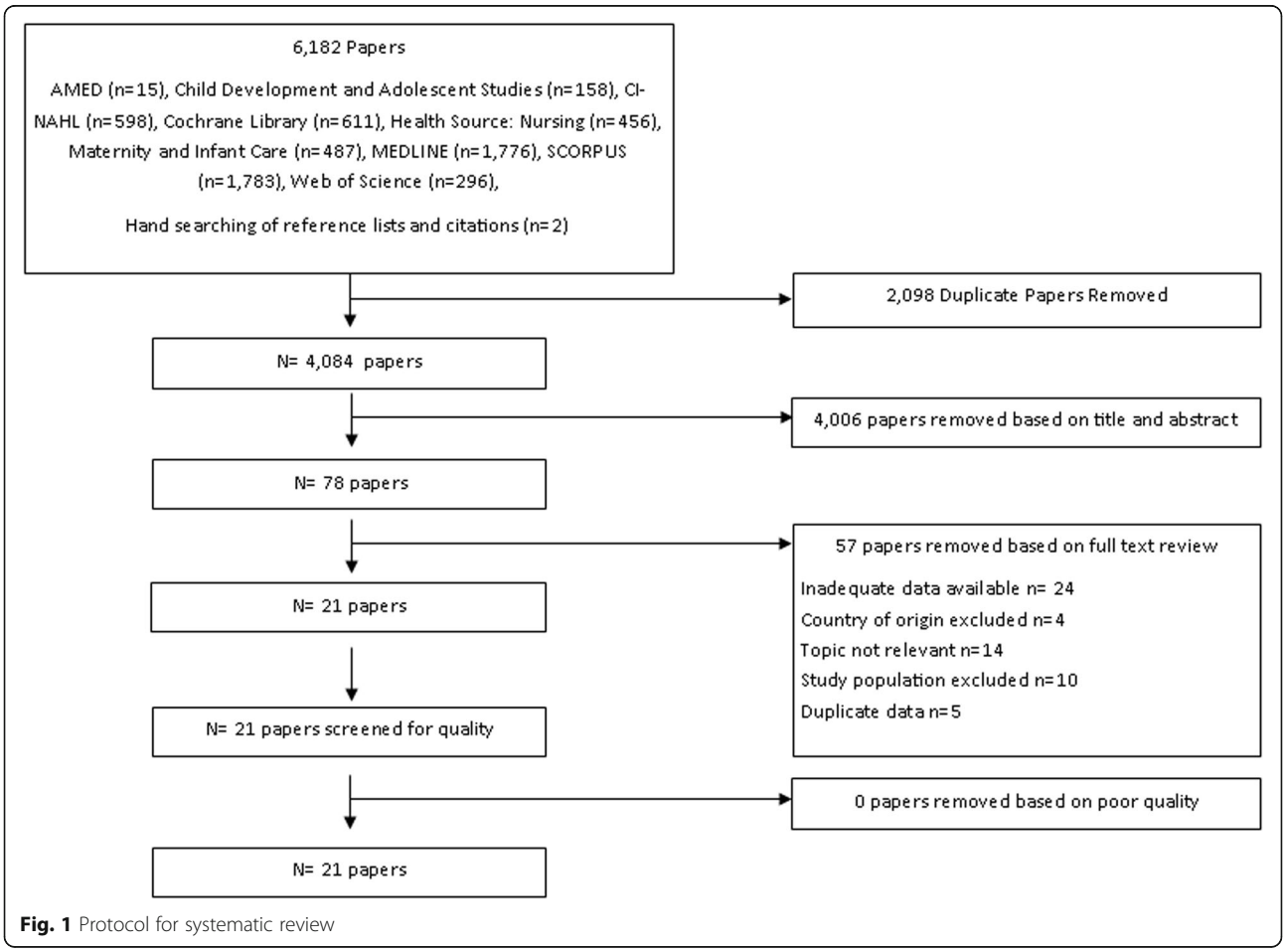

Fig. 1 Protocol for systematic review

Data synthesis

Reported data were first tabulated to explore patterns across the included studies and described narratively. Where 95 % confidence intervals were not reported they were calculated for the mean and used to assess the extent to which the study mean differed from the relevant reference value. Where the lower confidence limit was above the reference value the study mean was considered to be significantly higher, where the upper confidence limit was below the reference value the study mean was considered significantly lower, otherwise no significant difference was reported.

Analysis of micronutrient intakes was undertaken by comparing the reported data from included studies with the UK reference nutrient intake (RNI) [15] and US recommended daily allowance (RDA) [16] where available. Analysis has been undertaken using both UK and US thresholds as, while the majority of studies were undertaken in the USA, this review is also concerned with applying the results to the UK context. Energy intake was calculated by taking the mean of the single year of age estimated average requirements (EAR) for young women aged 11–19 with an increment applied in the third trimester; a population level EAR is only available in the UK [17]. For macronutrients an estimate of the percentage contribution to energy, if not provided, was calculated from the mean macronutrient intake and the mean energy intake.

In the case of biological markers, minimum thresholds for nutrient deficiency provided by WHO, UK and US authorities (where available) have been compared with reported study data. Nationally or internationally recognised cut offs for deficiency are not currently available for zinc, selenium, copper, magnesium and phosphorous, therefore these elements have been compared with suggested thresholds in academic literature [18–22].

Where data were available from two or more studies for a single nutrient or biological marker a pooled mean was calculated and weighted by the number of participants in each study. Mean measures of micronutrient and energy intake were expressed as a percentage of dietary reference values to allow for comparisons across different nutrients.

Sub-group analyses were performed by country of origin (USA only and UK only), stage of pregnancy (first, second and third trimester and reported average over the pregnancy) and age of adolescents (15 years and under and 16–19 years).

Results

A total of 4,084 unique papers were identified from the search of the literature with 78 studies remaining after title and abstract screening. Following examination of the full text of these papers a total of 21 papers were identified that met the review inclusion criteria. Details of the excluded studies are given in Additional file 1: Table S1. In brief, the main reasons for exclusion were not reporting appropriate data and the study population not meeting the inclusion criteria for age or pregnancy.

No studies were excluded for reasons of poor quality; after quality assessment 16 of the included studies were considered to be of good quality while the remaining five studies were of a satisfactory standard (Table 2).

Of the included studies, six provided information on dietary intakes only, 12 on biological markers only and three reported both types of information. Nutrient intakes from food sources were reported (therefore excluding any contribution from supplements) in all but one paper [23]. However, the majority (10 out of 15) of papers reporting biological markers also reported that participants were taking nutritional supplements, details of which along with other characteristics of the included studies are shown in Table 2. Due to inconsistencies in the type, dose, duration and compliance with supplement use it was not possible to quantify the impact of supplements on the results.

Of the 21 included studies 14 were carried out in the USA [24–37], one in the US territory of Guam [38], three in the UK [23, 39, 40] and one in each of Australia [41], Canada [42], Chile [43] and Poland [44]. Nutritional status was a primary outcome measure in all but one of the included studies where the primary outcomes were birth weight and prematurity [43].

The study designs of the included studies are listed within Table 2. The majority of the studies were cross-sectional surveys. Five studies were randomised controlled trials, where baseline dietary assessments before randomisation, or data from the control group only, permitted the inclusion of nutritional intake or biomarker data cross-sectionally. One study was a retrospective cohort analysis and one was a retrospective chart review.

Participants were all aged between 12 and 20 years with the majority being aged 16 and over. The majority of studies selected participants using convenience samples; other sampling methods used were purposive [26], representative probability sample [32], stratified random sample [44] and a retrospective medical chart review including all eligible records [37].

The majority of studies reported a range of ethnicities in the sample with the exception of three studies where all participants were African American [31, 36, 37], one including only Mexican American participants [28] and one where all participants were White [26]. Where reported the majority of participants had a BMI in the healthy range. Six studies reported participant's weight gain from recruitment to delivery which ranged from 14 to 17 kg.

All but two of the studies reporting biological markers collected venous blood samples which were

Table 2 Characteristics of included studies

Study Information				Participants				Supplements			Measurement		Quality
Study	Country	Study design	Study groups	Number	Age	Inclusion criteria	Exclusion criteria	Supplement type and dose	Number with available data	Estimated compliance: N (%)	Data collection method (s)	Time period(s)	Quality rating
Baker et.al (2009) [23]	UK	Cross-sectional study	NA	500	14–18	Singleton pregnancy, age 14–18, gestational age < =20 weeks	Inability to provide informed consent, preeclampsia, clotting disorders, HIV/AIDS, haemoglobinopathies, diabetes, renal disease, hypertension, multiple gestations, history of 3= > previous miscarriages	Preconception folic acid	498	34 (6.9)	24 h recall (multiple)	Third trimester	+
								Folic acid in early pregnancy	498	220 (44.2)			
								Iron in early pregnancy	498	39 (7.8)			
								Multivitamins in early pregnancy	498	19 (3.8)			
								Folic acid only in 3rd trimester	290	5 (1.7)			
								Iron and folic acid in 3rd trimester	290	13 (4.5)			
								Iron only in 3rd trimester	290	42 (14.5)			
								Multivitamins in 3rd trimester	290	7 (2.4)			
Castillo-Duran et.al (2001) [43]	Chile	RCT	Zinc supplemented	249	16.4 (mean)	Beginning prenatal visits before 20 weeks gestation, aged <19 at estimated due date	Adolescents whose background included chronic diseases, drug abuse, mental retardation, illiteracy or pregnancy due to incest or rape	20 mg Zinc sulphate daily	Intervention group - 249	At least 50 % compliance	24 h recall (multiple)	Second and third trimester	+
			Placebo	258				40 mg iron sulphate	All participants - 507				
Chan et.al (2006) [24]	USA	RCT	Control group, 2 intervention groups excluded from review*	23	15–17	Enrolled before 20 weeks gestation	Hypertension, diabetes, renal or liver disease, alcohol or tobacco use, using medicines effecting Ca metabolism	No additional supplements reported			Food diary (weighing not mentioned)	Second and third trimester	−/+
Chang et.al (2003) [37]	USA	Retrospective chart review	NA	918	12–17	Self-reported racial group as African-American; singleton pregnancy	Birth results not available due to abortion, miscarriage or transfer of care	90 mg carbonyl iron daily plus additional up to 120 mg for those classified as anaemic	918	Not reported	Not reported	Second and third trimester	+

Table 2 Characteristics of included studies *(Continued)*

Dawson et.al (2000) [35]	USA	RCT	One-A-Day without Iron	20	16–20	Aged 16–20, less than 16 weeks gestation, no iron supplementation for previous 30 days	Hypertension; diabetes; other medical problems; haemoglobin <11 g/dL; haematocrit <30 %	Vitamin A 5000 IU, vitamin D 400 IU, vitamin E 10 mg, vitamin C 60 mg, folic acid 0.4 mg, thiamine 1.5 mg, riboflavin 1.7 mg, niacin 20 mg, pyridoxine 2 mg, vitamin B- 6 mg, pantothenic acid 10 mg	20	Not reported	Venous blood sample	Second and third trimester and delivery	−/+
			One-A-Day with Iron	20				18 mg Iron, Vitamin A 5000 IU, vitamin D 400 IU, vitamin E 10 mg, vitamin C 60 mg, folic acid 0.4 mg, thiamine 1.5 mg, riboflavin 1.7 mg, niacin 20 mg, pyridoxine 2 mg, vitamin B- 6 mg, pantothenic acid 10 mg	20				
Derbyshire (2009) [39]	UK	Cross-sectional study	NA	20	15–19	Attending antenatal classes or community clinics	Incomplete diary	None reported			Food diary unweighed	Third trimester	+
Gadowsky et.al (1995) [42]	Canada	Cross-sectional study	NA	58	14–19	Not reported	Not reported	Folic Acid Mean 479 µg/day Elemental Iron Mean 31.5 mg/day Cyanocobalamin (B12) Mean 2.24 µg/d	58	82 %	Venous blood sample	Third trimester	+
Giddens et.al (2000) [27]	USA	RCT (subset from a larger study)	NA	59	13–18	Singleton pregnancies, between 13 and 19 weeks gestation	Not reported	Reported that any contribution from supplements was not included in analysis			Food diary weighed	Mean over pregnancy	−/+

Table 2 Characteristics of included studies *(Continued)*

Ginde et.al (2010) [32]	USA	Secondary analysis of cross sectional survey	NA	84	13–19	Not reported	Not reported	Some participants taking vitamin D supplements	Not reported	Not reported	Venous blood sample	Mean over pregnancy	+
Gutierrez et.al (1999) [28]	USA	Cross-sectional study	NA	46	13–18	Self-identified ethnicity as Mexican American, primigravida, 13–18 years of age	History of miscarriage or health problems, involved in competitive athletic performances or heavy exercise, planned to move away during study period	None reported			24 h recall (single)	Second and third trimester	+
Iannotti et.al (2005) [36]	USA	Cross-sectional study	NA	80	13–18	Self-reported racial group as African-American; singleton pregnancy	Not reported	None reported			10 ml Venous blood sample	Second and third trimesters	+
Job et.al (1995) [41]	Australia	Cross-sectional study	NA	35	13–19	Not reported	Not reported	None reported			24 h recall	Mean over pregnancy	+
Lee et.al (2013) [25]	USA	Cross-sectional study	NA	156	13–18	Age 18 or under, carrying a single fetus, 12–30 weeks gestation at recruitment	Not reported	Reported that any contribution from supplements was not included in analysis			24 h recall (multiple)	<23 weeks gestation, 23–30 weeks gestation and Mean over pregnancy	+
McGuire et.al. (2010) [31]	USA	Cross-sectional study	NA	80	Under 18 (mean 16.5)	Self-reported ethnic group as African American, singleton pregnancy	Not reported	Routinely prescribed prenatal supplements containing 400 IU vitamin D		Data not available	Venous blood sample	Second and third trimester	+
Meier et.al (2002) [34]	USA	RCT	Iron supplemented	20	15–18	Not reported	Iron deficiency anaemia at recruitment	60 mg elemental iron & 1 mg folic acid	20		Venous blood sample	Second and third trimesters	+
			Placebo	17				1 mg folic acid	17				

Table 2 Characteristics of included studies *(Continued)*

Mistry et.al (2014) [40]	UK	Cross-sectional study	Appropriate for gestational age babies Small for gestational age babies	107 9	14–18	Not reported	Inability to provide informed consent, pre-eclampsia, clotting disorders, HIV/AIDS, Haemoglobinpathies, diabetes, renal disease, hypertension, multiple pregnancy and previous miscarriage	None reported			30 ml venous blood sample	Third trimester	+
O'Brien et.al (2003) [33]	USA	Cross-sectional study	NA	23	Mean 16.5	First, singleton pregnancies; no medical problems; no medications known to influence calcium metabolism; non-smokers; no history of drug or alcohol abuse	Not reported	Prenatal supplement including 5 mmol Ca	23	39 %	Not reported	Third trimester	+
Pobocik et.al (2003) [38]	Guam (USA Teritory)	Cross-sectional study	NA	434	14–20	Not reported	Not reported	Reported that any contribution from supplements was not included in analysis			24 h recall (single)	Mean over pregnancy	−/+
Rycel et.al (2009) [44]	Poland	Retro-spective cohort	NA	102	15–18	Not reported	Not reported	none reported			Venous blood sample	Before and after delivery	−/+
Young et.al (2010) [29]	USA	Cross-sectional study	NA	92	14–18	Healthy, singleton pregnancy	HIV, diabetes, pre-eclampsia, eating disorders, malabsorption diseases, self-reported drug use	Prenatal supplement including 27 mg iron	92	Not reported	Venous blood sample	Second trimester and delivery	+
Young et.al (2012) [30]	USA	Cross-sectional study	NA	171	Under 18 (mean 17.1)	Healthy, singleton pregnancy	HIV, diabetes, pre-eclampsia, eating disorders, malabsorption diseases	400 IU Vitamin D supplement given to participants found to be deficient	46 (estimated from reported percentages)	26.4 % - daily, 35.8 % at least twice per week	10 ml venous blood sample	Delivery	+

analysed in laboratories using standard testing procedures. One study which was a medical records review [37] did not provide details of how samples were collected. One study also assessed biological markers of calcium absorption using a 24 h urine collection followed by daily spot urine collections [33]. Data relating to participants nutrient intakes used a variety of data collection methods. Three studies used food diaries [24, 27, 39], one of which was weighed [27]. The remaining studies used single [28, 38, 41] or multiple [25, 43, 23] 24 h recalls. Four out of the nine studies reporting nutrient intakes stated that dietary assessments were carried out by a trained nutritionist or similar professional [25, 26, 43, 27].

Nutrient intakes

Energy intake was reported by nine studies with seven of these reporting intakes below the recommendations at one or more time point (Table 3). Four studies also reported gestational weight gain which ranged from 14 to 17 kg. Pooled analysis of the percentage of the EAR for energy in these 10 studies revealed wide confidence limits around the estimated mean, with an average intake 9 % lower than the UK EAR (mean % EAR, 91.2 %, CI 29.6–152.8 %). Analysis of energy intake by trimester and study country of origin did not show any significant differences (UK studies 89.1 % CI 39.2–139.1 %, US studies 100.4 %, CI 24.2–176.6 %). Analysis of those studies reporting gestational weight gain only showed young women to be achieving a higher percentage of the EAR for energy (99.1 %, CI 41.0–157.2 %) than those studies which did not report weight gain (90.2 %, CI 27.9–152.5 %) but this difference was not statistically significant.

Mean intakes of macronutrients are show in Table 4. Intakes of protein and total carbohydrate were roughly in line with recommendations. There were too few studies reporting intakes of total fat, fat types or sugars to permit conclusions to be drawn. Three studies reported any measurements of dietary fibre, all of which were below recommended levels.

Tables 5 and 6 show the pattern of micronutrient intakes across the included studies compared to UK and US Dietary Reference Values (DRVs).

The individual study results show that the majority of reported nutrient intakes were significantly below both the UK RNI and US RDA for vitamin D, potassium and magnesium and below the US RDA for calcium, vitamin E, folate, phosphorous and iron. Zinc intakes reported as the mean intake over pregnancy were low whereas this was not the case in the studies reporting intakes in the second or third trimesters specifically.

Results of the pooled analyses however showed that only intake of vitamin D remained significantly below both the UK RNI and US RDA, and intakes of potassium below the US RDA. Sub-group analysis showed that micronutrient intake was lower in UK based studies than those based in the USA for all micronutrients with the exception of vitamin C, however vitamin D was the only micronutrient where the percentage of the DRV in UK based studies was below the UK RNI (21.4 %, CI 0–63.5 %) and US RDA (14.3 %, CI 0–42.3 %). Results of the pooled analysis of micronutrients are shown in Fig. 2. Detailed results of the sub-group analysis of nutrient intakes are available in Additional file 1: Table S2 and Additional file 1: Table S3.

Micronutrient analysis by stage of pregnancy showed that intake of vitamin D in the second (28 % of the UK RNI, CI 26–30 %) and third (31.2 % of the UK RNI, CI 0–47 %) trimesters was below recommendations; this was not the case for measures reported as a mean over pregnancy (54 % of the UK RNI, CI 0–114.3 %). In the

Table 3 Mean energy intake in individual studies compared to UK estimated average requirement

	Study	Second Trimester			Third Trimester			Mean over pregnancy		
		N=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval
Energy kcal/day [a]	Baker (2009)				290	↓2147	2075, 2219			
	Castillo-Duran (2001) a	249	↓1887	1825, 1949	249	↓2030	1968, 2092			
	Castillo-Duran (2001) b	258	↓1863	1790, 1936	258	↓1982	1927, 2038			
	Chan (2006)	23	↔2223	2057, 2389	23	↓2276	2059, 2493			
	Derbyshire (2009)				20	↓2273	2052, 2494			
	Giddens (2000)							59	↓2342	2187, 2497
	Gutierrez (1999)	46	↔2390	2150, 2630	46	↔2620	2389, 2851			
	Job (1995)							70	↓2134	1949, 2320
	Lee (2013)				133	↓2303	2161, 2446	156	↔2273	2167, 2379
	Pobocik (2003)							434	↑2487	2388, 2586

[a]Comparison to UK EARs, First and Second Trimester requirement (Average UK EAR for Females aged 11–19) 2355 kcal/day, Third Trimester requirement 2546 kcal/day, Mean over pregnancy requirement (average of three trimester values) 2419 kcal/d, ↑ Study mean higher than reference value ($p < 0.05$), ↔ Study mean not different to reference value ($p < 0.05$), ↓ Study mean lower than reference value ($p < 0.05$)

Table 4 Mean intakes of macronutrients (g/day or percent of energy) and dietary fibre (g/day) in individual studies compared to UK and US dietary reference values

Nutrient	Study	Comparison to UK Dietary Reference Value									Comparison to US Dietary Reference Value								
		Second Trimester			Third Trimester			Mean over pregnancy			Second Trimester			Third Trimester			Mean over pregnancy		
		N=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval
Protein grams/day [a]	Castillo-Duran (2001) a	249	↑60	58, 62	249	↑62	59, 64				249	↓60	58, 62	249	↓62	59, 64			
	Castillo-Duran (2001) b	258	↑59	57, 61	258	↑60	58, 61				258	↓59	57, 61	258	↓60	58, 61			
	Chan (2006)	23	↑76	65, 87	23	↑76	65, 87				23	↔76	65, 87	23	↔76	65, 87			
	Derbyshire (2009)				20	↑72	65, 79							20	↔72	65, 79			
	Giddens (2000)							59	↑82	77, 87							59	↑82	77, 87
	Gutierrez (1999)	46	↑111	98, 124	46	↑118	105, 130				46	↑111	98, 124	46	↑118	105, 130			
	Job (1995)							70	↑73	73, 73							70	↑73	73, 73
	Lee (2013)				133	↑81	76, 87	156	↑70	65, 75				133	↑81	76, 87	156	↔70	65, 75
	Pobocik (2003)							434	↑99	95, 103							434	↑99	95, 103
Englyst Fibre grams/day [b]	Derbyshire (2009)					↓12	11, 13												
AOAC Fibre grams/day [c]	Giddens (2000)																59	↓14	13, 15
	Lee (2013)													133	↓13	12, 14	156	↓14	13,14
		N=	% of Energy		*N*=	% of Energy		*N*=	% of Energy										
Total Carbohydrate	Derbyshire (2009)				20	54 %													
	Giddens (2000)							59	50 %										
	Lee (2013)				133	51 %		156	52 %										
	Gutierrez (1999)	46	56 %		46	56 %													
Total Fat	Chan (2006)	23	29 %		23	29 %													
	Gutierrez (1999)	46	29 %		46	27 %													

Table 4 Mean intakes of macronutrients (g/day or percent of energy) and dietary fibre (g/day) in individual studies compared to UK and US dietary reference values *(Continued)*

Saturated Fat	Chan (2006)	23	9 %		23	10 %			
Total Sugars	Derbyshire (2009)				20	25 %			
Added Sugars	Lee (2013)				133	17 %		156	17 %

[a] Comparison to UK RNI 51 g/day and US RDA 71 g/day, [b] Comparison to UK RNI 18 g/day, [c] Comparison to US RDA 28 g/day, ↑ Study mean higher than reference value ($p < 0.05$), ↔ Study mean not different to reference value ($p < 0.05$), ↓ Study mean lower than reference value ($p < 0.05$)

Table 5 Intake of micronutrients in individual studies compared to UK and US dietary reference values - minerals

Nutrient	Study	Comparison to UK Dietary Reference Value									Comparison to US Dietary Reference Value								
		Second Trimester			Third Trimester			Mean over pregnancy			Second Trimester			Third Trimester			Mean over pregnancy		
		N=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval
Calcium mg/day [a]	Baker (2009)				290	↔840	800, 880							290	↓840	800, 880			
	Chan (2006)	23	↔835	711, 959	23	↔862	714, 1010				23	↓835	711, 959	24	↓862	714, 1010			
	Derbyshire (2009)				20	↑1007	867, 1147							20	↓1007	867, 1147			
	Giddens (2000)							59	↑989	904, 1074							59	↓989	904, 1074
	Gutierrez (1999)	46	↑1561	1334, 1789	46	↑1655	1424, 1886				46	↑1561	1334, 1789	46	↑1655	1424, 1886			
	Job (1995)							70	↔923	756, 1090							70	↓923	756, 1090
	Lee (2013)				133	↑916	838, 995	156	↑886	824, 948				133	↓916	838, 995	156	↓886	824, 948
	Pobocik (2003)							434	↓743	689, 797							434	↓743	689, 797
Phosphorous mg/day [b]	Chan (2006)	23	↑934	811, 1057	23	↑961	812, 1110				23	↓934	811, 1057	24	↓961	812, 1110			
	Giddens (2000)							59	↑1340	1248, 1432							59	↔1340	1248, 1432
	Lee (2013)				133	↑1264	1182, 1347	156	↑1196	1131, 1261				133	↔1264	1182, 1347	156	↔1196	1131, 1261
	Pobocik (2003)							434	↑1338	1279, 1397							434	↑1338	1279, 1397
Iron mg/day [c]	Baker (2009)				290	↑17	15, 19							290	↓17	15, 19			
	Castillo-Duran (2001) a	249	↑15.5	15, 16	249	↑16.8	16, 17				249	↓15.5	15, 16	249	↓16.8	16, 17			
	Castillo-Duran (2001) b	258	↑16.6	16, 17	258	↑16.8	16, 17				258	↓16.6	16, 17	258	↓16.8	16, 17			
	Chan (2006)	23	↑22	18, 26	23	↑25	20, 30				23	↓22	18, 26	23	↔25	20, 30			
	Derbyshire (2009)				20	↓12.6	11, 14							20	↔12.6	11, 14			
	Giddens (2000)							59	↔16	15, 17							59	↓16	15, 17
	Gutierrez (1999)	46	↑17.7	15, 20	46	↑22.7	17, 28				46	↓17.7	15, 20	46	↔22.7	17, 28			
	Job (1995)							70	↓11.2	10, 12							70	↓11.2	10, 12
	Lee (2013)				133	↑18.8	17, 20	156	↑18.6	17, 20				133	↓18.8	17, 20	156	↓18.6	17, 20
	Pobocik (2003)							434	↑20	19, 21							434	↓20	19, 21

Table 5 Intake of micronutrients in individual studies compared to UK and US dietary reference values - minerals *(Continued)*

Magnesium mg/day [d]	Baker (2009)				290	↓236	227, 245								↓236	227, 245			
	Chan (2006)	23	↓263	230, 296	23	↓264	231, 297					↓263	230, 296		↓264	231, 297			
	Derbyshire (2009)				20	↓244	218, 270								↓244	218, 270			
	Giddens (2000)							59	↓252	234, 270								↓252	234, 270
	Lee (2013)				133	↓237	222, 253	156	↓231	218, 244					↓237	222, 253		↓231	218, 244
	Pobocik (2003)							434	↓270	258, 282								↓270	258, 282
Potassium mg/day [e]	Chan (2006)	23	↓2802	2512, 3092	23	↓2954	2635, 3273				23	↓2802	2512, 3092	23	↓2954	2635, 3273			
	Derbyshire (2009)				20	↓2948	2659, 3237							20	↓2948	2659, 3237			
Zinc mg/day [f]	Baker (2009)				290	↑8.1	7.8, 8.4							290	↓8.1	7.8, 8.4			
	Castillo-Duran (2001) a	249	↑7.4	7.1, 7.7	249	↑7.7	7.4, 8				249	↓7.4	7.1, 7.7	249	↓7.7	7.4, 8			
	Castillo-Duran (2001) b	258	↑7.4	7.1, 7.7	258	↑7.4	7.2, 7.6				258	↓7.4	7.1, 7.7	258	↓7.4	7.2, 7.6			
	Chan (2006)	23	↑16	11.9, 20.1	23	↑18	13.5, 22.5				23	↔16	11.9, 20.1	23	↑18	13.5, 22.5			
	Derbyshire (2009)				20	↑8.1	7.4, 8.9							20		7.4, 8.9			
	Giddens (2000)							59	↑11.6	10.5, 12.7							59	↑11.6	10.5, 12.7
	Gutierrez (1999)	46	↑14.5	12.6, 16.4	46	↑15.3	13.4, 17.2				46	↑14.5	12.6, 16.4	46	↑15.3	13.4, 17.2			
	Job (1995)							70	↑9.5	8.5, 10.5							70	↑9.5	8.5, 10.5
	Lee (2013)				133	↑12.8		156	↑12.6	11.4, 13.8				133	↑12.8		156	↑12.6	11.4, 13.8
	Pobocik (2003)							434	↑13	12.2, 13.8							434	↑13	12.2, 13.8
Sodium mg/day [g]	Chan (2006)	23	↑3316	2809, 3823	23	↑3323	2812, 3834					↑3316	2809, 3823		↑3323	2812, 3834			
	Derbyshire (2009)				20	↑3089	2722, 3456								↑3089	2722, 3456			
Copper μg/day [h]	Giddens (2000)							59	↑1200	1098, 1302							59	↑1200	1098, 1302
	Lee (2013)				133	↑1100	1015, 1185	156	↑1085	1021, 1151				133	↑1100	1015, 1185	156	↑1085	1021, 1151
Selenium μg/day [i]	Giddens (2000)							59	↑116	109, 123							59	↑116	109, 123

[a]Comparison to UK RNI 800 mg/day and US RDA 1300 mg/day, [b]Comparison to UK RNI 625 mg/day and US RDA 1250 mg/day, [c]Comparison to UK RNI 14.8 mg/day and US RDA 27 mg/day, [d]Comparison to UK RNI 300 mg/day and US RDA 400 mg/day, [e]Comparison to UK RNI 3500 mg/day and US RDA 4700 mg/day, [f]Comparison to UK RNI 7 mg/day and US RDA 12 mg/day, [g]Comparison to UK RNI 1500 mg/day and US RDA 1600 mg/day, [h]Comparison to UK RNI 1000 μg/day and US RDA 1000 μg/day, [i]Comparison to UK RNI 60 μg/day and US RDA 60 μg/day, ↑ Study mean higher than reference value ($p < 0.05$), ↔ Study mean not different to reference value ($p < 0.05$), ↓ Study mean lower than reference value ($p < 0.05$)

Table 6 Intake of micronutrients in individual studies compared to UK and US dietary reference values - vitamins

Nutrient	Study	Comparison to UK Dietary Reference Value									Comparison to US Dietary Reference Value								
		Second Trimester			Third Trimester			Mean over pregnancy			Second Trimester			Third Trimester			Mean over pregnancy		
		N=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval
Vitamin D µg/day [a]	Baker (2009)				290	↓2.1	2, 2.3							290	↓2.1	2, 2.3			
	Chan (2006)	23	↓2.8	1.9, 3.7	23	↓3.1	2.2, 4				23	↓2.8	1.9, 3.7	23	↓3.1	2.2, 4			
	Derbyshire (2009)				20	↓2.0	1.5, 2.6							20	↓2.0	1.5, 2.6			
	Giddens (2000)							59	↓6.4	5.7, 7.1							59	↓6.4	5.7, 7.1
	Lee (2013)				133	↓5.4	4.7, 6.1	156	↓5.1	4.6, 5.6				133	↓5.4	4.7, 6.1	156	↓5.1	4.6, 5.6
Vitamin E [b]	Baker (2009)													290	↓8.9	8.3, 9.5			
	Derbyshire (2009)													20	↓7.7	6.5, 8.9			
	Gutierrez (1999)										46	↓10.7	10.7	46	↓11.2	8.2, 14.1			
	Lee (2013)													133	↓6.9	6.2, 7.6	156	↓6.9	6.4, 7.4
	Pobocik (2003)																434	↓8	7.2, 8.8
Vitamin C [c]	Baker (2009)				290	↑160	146, 174							290	↑160	146, 174			
	Derbyshire (2009)				20	↑138	111, 165							20	↑138	111, 165			
	Giddens (2000)							59	↑128	112, 144							59	↑128	112, 144
	Gutierrez (1999)	46	↑252	208, 296	46	↑231	190, 271				46	↑252	208, 296	46	↑231	190, 271			
	Job (1995)							70	↑135	92, 178							70	↑135	92, 178
	Lee (2013)				133	↑97	81, 113	156	↑106	94, 118				133	↑97	81, 113	156	↑106	94, 118
	Pobocik (2003)							434	↑167	150, 184							434	↑167	150, 184

Table 6 Intake of micronutrients in individual studies compared to UK and US dietary reference values - vitamins *(Continued)*

Folate [d]	Baker (2009)				290	↔285	269, 301							290	↓285	269, 301			
	Derbyshire (2009)				20	↓227	205, 249							20	↓227	205, 249			
	Giddens (2000)							59	↔312	277, 347							59	↓312	277, 347
	Gutierrez (1999)	46	↑447	355, 540	46	↑393	340, 445				46	↓447	355, 540	46	↓393	340, 445			
	Lee (2013)				133	↑829	723, 935	156	↑849	645, 1053				133	↑829	723, 935	156	↑849	645, 1053
	Pobocik (2003)							434	↔292	269, 315							434	↓292	269, 315
Riboflavin [e]	Chan (2006)	23	↑2.3	1.8, 2.8	23	↑2.4	2, 2.8				23	↑2.3	1.8, 2.8	23	↑2.4	2, 2.8			
	Giddens (2000)							59	↑2.3								59	↑2.3	2.1, 2.5
	Lee (2013)				133	↑2.5	2.3, 2.7	156	↑2.4					133	↑2.5	2.3, 2.7	156	↑2.4	2.2, 2.6
	Pobocik (2003)							434	↑2.1								434	↑2.1	2, 2.2
B12 [f]	Baker (2009)				290	↑5.3	4.7, 5.9							290	↑5.3	4.7, 5.9			
	Chan (2006)	23	↑5	3.8, 6.2	23	↑5.2	3.7, 6.7				23	↑5	3.8, 6.2	23	↑5.2	3.7, 6.7			
	Giddens (2000)							59	↑5.3	4.6, 6							59	↑5.3	4.6, 6
	Lee (2013)				133	↑5.6	5, 6.2	156	↑5.5	5, 6				133	↑5.6	5, 6.2	156	↑5.5	5, 6
	Pobocik (2003)							434	↑5.5	4.8, 6.2							434	↑5.5	4.8, 6.2
Thiamin [g]	Baker (2009)				290	↑1.6	1.5, 1.7							290	↑1.6	1.5, 1.7			
	Giddens (2000)							59	↑2.1	1.9, 2.3							59	↑2.1	1.9, 2.3
	Lee (2013)				133	↑2.1	1.9, 2.3	156	↑2.1	1.9, 2.3				133	↑2.1	1.9, 2.3	156	↑2.1	1.9, 2.3
	Pobocik (2003)							434	2.4	2.3, 2.5							434	2.4	2.3, 2.5
Niacin [h]	Baker (2009)				290	↑33	32, 35							290	↑34	32, 35			
	Giddens (2000)							59	↑24	22, 26							59	↑24	22, 26
	Lee (2013)				133	↑28	26, 30	156	↑26	24, 27				133	↑28	26, 30	156	↑26	24, 27
	Pobocik (2003)							434	↑30	29, 31							434	↑30	29, 31

Table 6 Intake of micronutrients in individual studies compared to UK and US dietary reference values - vitamins *(Continued)*

B6 [i]	Baker (2009)				290	↑2.3	2.1, 2.4							290	↑2.3	2.1, 2.4			
	Giddens (2000)							59	↑1.9	1.7, 2.1							59	↑1.9	1.7, 2.1
	Lee (2013)				133	↑2.2	2, 2.4	156	↑2.1	1.9, 2.3				133	↑2.2	2, 2.4	156	↑2.1	1.9, 2.3
	Pobocik (2003)							434	↑2	1.9, 2.1							434	↑2	1.9, 2.1
Vitamin A [j]	Baker (2009)				290	↑759	651, 867							290	↑759	651, 867			
	Derbyshire (2009)				20	↑555	439, 671							20	↓555	439, 671			
	Giddens (2000)					↑105		59	↑1053	907, 1199					↑1053		59	↑1053	907, 1199
	Gutierrez (1999)	46	↑2492	1466, 3518	46	↑197	1432, 2523				46	↑2492	1466, 3518	46	↑1978	1432, 2523			
	Job (1995)							70	↑973	802, 1144							70	↑973	802, 1144
	Lee (2013)				133	↑698	614, 783	156	↑666	615, 717				133	↑698	614, 783	156	↓666	615, 717
	Pobocik (2003)							434	↑109	944, 1242							434	↑1093	944, 1242
Vitamin K [k]	Lee (2013)													133	↔70	57, 83	156	↔70	59, 81

[a] Comparison to UK RNI 10 μg/day and US RDA 15 μg/day, [b] Comparison to US RDA 15 mg/day, [c] Comparison to UK RNI 40 mg/day and US RDA 80 mg/day, [d] Comparison to UK RNI 200 μg/day and US RDA 600 μg/day, [e] Comparison to UK RNI 1.1 mg/day and US RDA 1.4 mg/day, [f] Comparison to UK RNI 1.5 μg/day and US RDA 2.6 μg/day, [g] Comparison to UK RNI 0.8 mg/day and US RDA 1.4 mg/day, [h] Comparison to UK RNI 14 mg/day and US RDA 18 mg/day, [i] Comparison to UK RNI 1.2 mg/day and US RDA 1.9 mg/day, [j] Comparison to UK RNI 600 μg/day and US RDA 750 μg/day, [k] Comparison to US AI 75 μg/day, ↑ Study mean higher than reference value ($p < 0.05$), ↔ Study mean not different to reference value ($p < 0.05$), ↓ Study mean lower than reference value ($p < 0.05$)

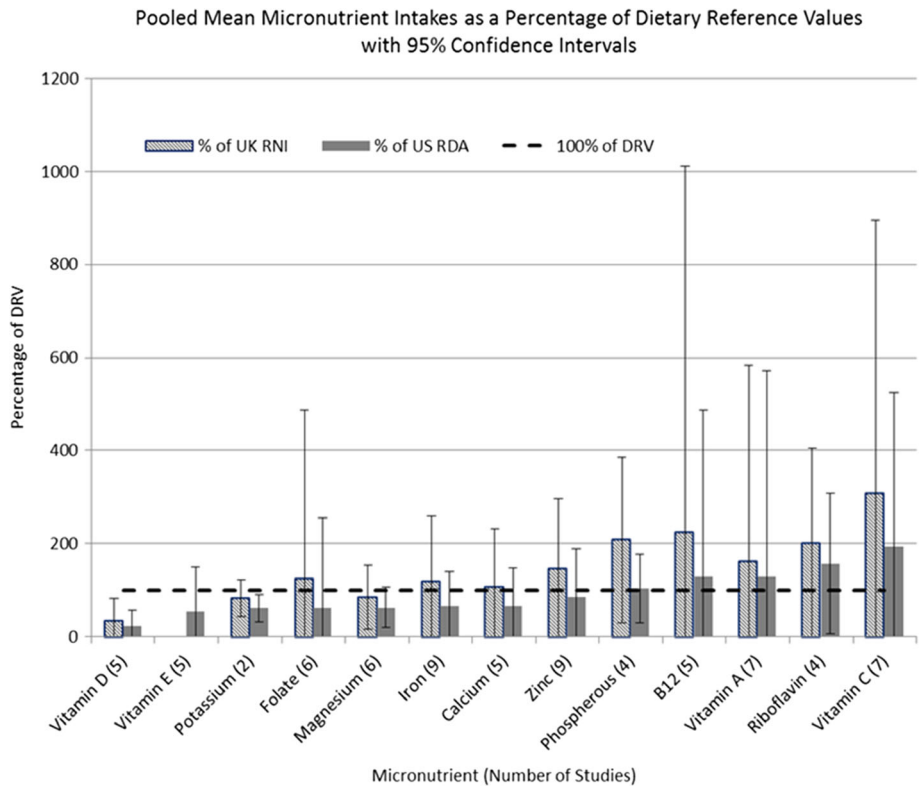

Fig. 2 Pooled weighted mean micronutrient intake compared to UK and US dietary reference values

third trimester the percentage of the US RDA represented by intakes of magnesium (19.9 %, CI 20.4–98.6 %) and potassium (62.8 %, CI 32.5–93.1 %) were also below recommendations.

Biological markers

Table 7 shows the pattern of biological markers reported across the included studies compared to WHO, UK and US minimum thresholds for deficiency where available. As the recommended cut off points given by all three authorities are consistent, the results are presented in one combined table for clarity. Other nutrients were considered compared to deficiency thresholds suggested in the academic literature as previously discussed.

The results show that the mean reported biomarker values in the majority of studies suggested that young women's nutritional status was sufficient, with the exception of markers of iron and selenium status. Results for haematocrit and plasma ferritin were mixed, with results being more likely to be below the cut off in the third trimester and at delivery. Measures of serum selenium were reported to be less than the cut off in the majority of studies.

Examination of pooled, weighted means showed that only mean selenium concentration was below the reference value. The weighted means for all biological markers where there were two or more valid results are shown in Table 8.

The sub-group analysis by country of origin was only possible by US vs. non-US studies as there was only one UK based study reporting biological markers. The analysis failed to detect any differences by study country of origin. Analysis by stage of pregnancy suggests a decline in iron status markers haemoglobin, haematocrit and ferritin as pregnancy progresses; the levels observed however do not necessarily reflect iron deficiency. Detailed results of the sub-group analysis of biological markers are available in Additional file 1: Table S4 and Additional file 1: Table S5.

Discussion

Compared with reviews of the nutritional status of pregnant adolescents published in 2007, this review identified a further 13 studies that reported data on nutritional intakes and biomarkers of status. The summary results show that there may be areas of concern in adolescent's nutritional intake during pregnancy, particularly compared to US recommendations, with regard to calcium, vitamin D, vitamin E, folate, potassium and magnesium. The evidence also suggests that overall energy intake may be lower than recommended.

Table 7 Biological markers of nutritional status in individual studies compared to reference values

	Study ID	First Trimester			Second Trimester			Third Trimester			Delivery		
		N=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval	*N*=	Mean	Confidence Interval
Haemoglobin (g/L) [a]	Baker (2009)	404	↑122	121, 123				362	↓108	107, 109			
	Chang (2003)	445	↑121	121, 122	319	↑112	112, 114	836	↓107	107, 109			
	Dawson (2000) a				21	↑124	123, 125	21	↑115	114, 116	20	↑114	111, 112
	Dawson (2000) b				20	↑125	124, 126	20	↑119	118, 120	21	↑116	112, 114
	Dawson (2000) a							21	↑114	113, 115			
	Dawson (2000) b							20	↑120	119, 121			
	Gadowsky (1995)							50	↑119	115, 123			
	Iannotti (2005)				35	↔111	107, 115	70	↔107	104, 110			
	McGuire Davies (2010)				78	↑118	118, 118	76	↓107	107, 108			
	Meier (2002) a				20	↑125	122, 129	15	↑123	119, 128			
	Meier (2002) b				17	↑128	124, 132	16	↑117	112, 123			
	Meier (2002) a				19	↑116	112, 120						
	Meier (2002) b				16	↑113	110, 116						
	Rycel (2009)										102	↑120	120, 229
	Rycel (2009)										102	↓103	103, 103
	Young (2010)				48	↑113					62	↑117	113, 121
Ferritin (μg/L or ng/ml) [b]	Gadowsky (1995)				50	↓7.4	5.7, 9.1						
	Iannotti (2005)				44	↑33	26.8, 40.6	59	↔15	12.6, 17.8			
	Meier (2002) a				19	↑42	31.3, 52.8	15	↔25	14.6, 35.4			
	Meier (2002) b				17	↑57	36.5, 77.5	15	↓6.8	5.2, 8.5			
	Meier (2002) a				19	↑46	24, 68.8						
	Meier (2002) b				16	↓10	7.9, 13						
	Young (2010)				81	↔16	12.9, 20.1				88	↔17	14.9, 20.3
Haematocrit (g/L) [c]	Chang (2003)	445	↑36	35.7, 36.3	319	↔33	32.7, 33.3	836	↓32	31.8, 32.2			
	Gadowsky (1995)							50	↑36	34.8, 37.2			
	Iannotti (2005)				35	↔33	32, 34	70	↓32	31.3, 32.7			
	Rycel (2009)										102	34	34.6, 34.8
	Rycel (2009)										102	↓31	31.4, 31.6
Zinc μmol/L-1 [d]	Castillo-Duran (2001) a	249	↑11.9	11.7, 12.1				249	↑10.9	10.7, 11.1			
	Castillo-Duran (2001) b	258	↑11.7	11.5, 11.9				258	↑10.9	10.7, 11.1			
	Castillo-Duran (2001) a							249	↑10.5	10.3, 10.7			
	Castillo-Duran (2001) b							258	↑10.2	10, 10.4			
	Chan (2006)										23	↑26.3	23.2, 29.4
	Mistry (2014) a							107	↑9.71	8.8, 10.5			
	Mistry (2014) b							19	↑10.8	7.8, 13.9			

Table 7 Biological markers of nutritional status in individual studies compared to reference values *(Continued)*

Magnesium mmol/l [e]	Chan (2006)							23	↑0.99	0.9, 1.1
Phosphorous mg/dl [f]	Chan (2006)							23	↑5	4, 6
Copper μg/dl [g]	Mistry (2014) a				107	↑206	1991, 2128			
	Mistry (2014) b				19	↑196	1712, 2207			
Selenium μg/L [h]	Dawson (2000) a	21	↓49	46, 52	21	↓55	52.9, 57.1	21	↑114	108.9, 119.1
	Dawson (2000) b	20	↓44	39.6, 48.4	20	↓53	50.8, 55.2	20	↓55	50.2, 59.8
	Dawson (2000) a	21	↓50	46.2, 53.8	21	↔85	76.9, 93.1			
	Dawson (2000) b	20	↓44	39.6, 48.4	20	↓62	57.2, 66.8			
	Mistry (2014) a				107	↓65	62.7, 67.5			
	Mistry (2014) b				19	↓49	45.9, 52.9			
Red blood cell folate (nmol/l) [i]	Baker (2009)				266	↑647	616, 680			
Serum folate (nmol/l) [j]	Baker (2009)				291	↑12	12, 14			
	Chan (2006)							23	↔13	10, 17
Vitamin A (μg/dL)	Chan (2006)							23	↑38	31, 45
B12 (pmol/l) [k]	Baker (2009)				293	↑177	169, 185			
	Chan (2006)							23	↑265	216, 315
	Gadowsky (1995)				50	↑170	146, 194			
Homocysteine (μmol/L) [l]	Baker (2009)				293	7.9	7.6, 8.2			
	Gadowsky (1995)				50	6.1	3, 9			
25OHD (nmol/L) [m]	Baker (2009)				263	↑33	30.4, 35.8			
	Chan (2006)							23	↑57	48, 67
	Ginde (2010)									
	McGuire Davies (2010)	44	↑52	46, 58	36	↑56	50, 63			
	O'Brien (2003)				23	↑50	41, 60			
	Young (2012)							171	↑54	51, 59

[a] Target value 110 g/L, [b] Target value 15 μg/L, [c] Target value33 g/L, [d] Target value 6.12 μmol/L-1, [e] Target value 0.9 mmol/L, [f] Target value 2.5 mg/dl, [g] Target value 63.7 μg/dl, [h] Target value 90 μg/L, [i] Target value 340 nmol/L, [j] Target value 20 μg/dl, [k] Target value 150pmol/L, [l] Target value less than 13 μmol/L, [m] Target value 25 nmol/L, ↑ Study mean higher than reference value ($p < 0.05$), ↔ Study mean not different to reference value ($p < 0.05$), ↓ Study mean lower than reference value ($p < 0.05$)

In terms of comparison with dietary reference values, combined analysis of the individual study means showed very few statistically significant results, with the exception of vitamin D. One possible explanation for this is that there was a high level of variance between participants in the majority of studies resulting in very wide confidence intervals. This suggests that there may be sub-groups of young women within the total population who are at higher risk of poor nutritional status which this review has failed to detect. Differences in micronutrient intake were observed between UK and USA based studies which may in part be explained by routine fortification of food products in the USA compared to the UK. Only one study reported that supplements were included in the reported intake values, and the compliance rates for supplements in this study were low, meaning that the impact of supplement use on intakes data is marginal.

Macronutrient contributions to energy were found to be roughly in line with recommendations, however there was a significant lack of data for carbohydrates (including sugars and fibre) and fats (including saturated fat)

Table 8 Pooled weighted means of biological markers

Biological Marker	Pooled Mean	Confidence Interval	Target Value	Number of studies
Haemoglobin (g/dL)	112.4	95.4–133.8	110	9
25_OH_D (nmol/L)	55.9	6.2–105.7	25	6
Ferritin (μg/L)	18.2	0–48.3	15	4
Haematocrit (g/L)	32.5	28.0–39.4	33	4
Zinc (μmol/L-1)	11.5	5.9–17.1	6.12	3
B12 (pmol/L)	181.6	0–271.1	150	3
Serum Folate (nmol/L)	12.8	0–26.8	10	2
Selenium (μg/L)	61.8*	39.2–84.4	90	2
Homocystine (μmol/L)	7.6	0–17.0	Less than 13	2

* Significant at the $p<0.005$ level

meaning these results should be interpreted with caution. Further research into macronutrient intakes in this population, particularly with regard to types of carbohydrates and fats, is needed.

The methods used to assess dietary intake varied across the included studies. The two methods reported by the included studies were 24 h dietary recalls (single and multiple) and food diaries. While these are validated and accepted methods of nutritional surveillance [45], it is acknowledged that underreporting biases may exist [46] and so results should be considered with this in mind.

Four of the studies reporting energy intake also reported mean gestational weight gain which ranged from 14 kg to 17 kg, consistently higher than the required pregnancy weight gain [47]. Mean percentage intake of the EAR for energy was higher in the studies reporting weight gain than those which did not report this measure, but not significantly so. This is potentially contradictory of the finding that energy intake was low in individual studies and suggests further work is needed regarding the potential level of under reporting in this population and the relationship between dietary patterns, overall energy consumption and gestational weight gain.

Inadequacies in nutrient intakes did not necessarily translate to systemic deficiencies as measured by mean values of biological markers, with the possible exceptions of markers of iron and selenium status. One possible explanation for this is that food intake may have been under reported therefore suggesting that intake was insufficient when this was not the case. A further possible explanation is that measures of biological markers were elevated by dietary supplements. Details regarding the type, dose, duration and number of participants taking supplements were inconsistent in the included papers meaning that detailed analysis of the impact of supplement use on nutritional status was not possible, however 10 out of the 15 included studies reporting biomarkers did report some level of supplementation. This finding does suggest that supplements may play an important role in ensuring young women do not experience nutrient insufficiency, however attention to clear reporting of supplement use in research papers is essential to allow a better understanding of the impact of supplementation on nutritional status.

The participants in all of the included studies where supplements were provided may also have been more compliant with taking supplements due to the very fact that they were taking part in a research study than might be expected outside of a study environment. A systematic review [48] of the effect of dietary interventions in adolescent pregnancies found some evidence to suggest that nutritional supplements may reduce the likelihood of low birth weight; however the review also reported a serious lack of good quality research papers in this area. Further work to establish the extent to which pregnant young women in the general population suffer more from nutrient deficiencies and the impact of supplement use would be advantageous.

There is significant evidence in the literature regarding the role of nutrition in supporting healthy pregnancies and allowing the foetus to achieve its full potential. Adolescent girls are at particular risk of iron deficiency anaemia due in part to rapid growth during adolescence [49] combined with the onset of menarche. This coupled with the increased demand for iron in pregnancy for expansion of maternal tissues and foetal growth, makes pregnant adolescents a particularly vulnerable group. There is some evidence to suggest that iron deficiency is implicated in the risk of adverse birth outcomes such as prematurity and low birth weight [50], meaning this is potentially an important factor in improving maternal and infant health. While analysis of mean values for markers of iron deficiency in this review did not indicate a significant issue, consideration of the reported

prevalence of iron deficiency anaemia in the included studies suggests that this may be a concern for this population.

Vitamin D and calcium have an essential role in the mineralization of the developing foetal skeleton and insufficient intake of these nutrients may impact on foetal bone growth. The interaction between these two nutrients has been shown to be key to maximising foetal bone growth in pregnant adolescents and that growth is adversely affected when either of the two nutrients were lacking [30]. The pooled mean for vitamin D status as reflected in blood 25 (OH)D in this review was significantly below recommended levels across all trimesters. It was not possible to conduct analysis of vitamin D status by ethnicity or exposure to sunlight, however, which are factors known to have a significant impact on vitamin D status [51–53].

The role of folate in the prevention of neural tube defects in early pregnancy has been well documented [54]. There is a lack of data collected in early pregnancy in the papers included in the current review, however the observed failure to meet recommendations for folate intake in later pregnancy reported may suggest that the participants were unlikely to have been meeting recommendations prior to taking part in a research study. A systematic review of the impact of folate intake over the course of pregnancy [55] also found a significant effect in the second and third trimesters on infant birth weight, suggesting that the importance of folate for a healthy pregnancy extends beyond the first trimester.

Selenium status has been identified as a potential area of concern in this review. Selenium is a trace element which has an anti-oxidative effect and protects cell membranes [56]. The target value used to assess selenium status was based on the intake necessary for maximisation of plasma glutathione peroxidase activity, which is the criteria used in the derivation of the US RDA [18]. Selenium status has been shown to be associated with a number of adverse outcomes for both mother and child including neural tube defects [57], lower birth weights [58], cholestasis [59] and gestational diabetes [60].

While demographic characteristics of participants were reported in the included studies data was generally reported for the study population as a whole, meaning that sub-group analysis was not possible. This is significant in that evidence suggests that younger adolescents, those who smoke and those from more deprived backgrounds may be at higher risk of nutritional issues [3, 61, 62].

There is also evidence to suggest that the nutritional status of adult pregnant women may raise similar concerns to those identified within this review. A systematic review of micronutrient intakes in pregnancy found that intakes of folate, vitamin D and iron were sub-optimal [63]. A further review focusing on energy and macronutrient intake in this population found that intakes of energy and fibre were also below recommendations [64]. These results are consistent with the findings of this review suggesting that maternal age alone may not be the most important factor in sub-optimal nutritional status during pregnancy. Further work to identify the characteristics of those most at risk, particularly within the adolescent population, and the nature of that risk is needed.

Limitations

There were some significant limitations which impact on the conclusions of this review. The majority of the included papers used convenience samples meaning that there is likely to be an element of bias in the reported outcomes. The majority of participants in the included studies were aged 16 and over meaning that the results may not be generalisable to younger adolescents, who may also be at greater nutritional risk compared to older adolescents due to competing growth needs [3]. The lack of detail regarding participant's supplement use meant that it was not possible to evaluate the impact of supplements on biological markers of nutritional status. It is therefore likely that these results may have been biased by supplement use in some participants.

There was significant heterogeneity in the included papers in terms of study design. Measurements of dietary intake differed between papers however the majority of studies used 24 h recall methods to assess nutrient intake. This has been shown to have limitations in terms of both participants reporting their intake accurately and the likelihood that the recorded intake is representative of the usual diet, particularly in adolescents [46]. Three studies used multiple 24 h recalls in order to produce more reliable estimates of intakes; however this approach was not consistent across the included studies using this method.

There were also considerable differences in the number of nutritional indicators represented. Pooled means were calculated wherever two or more data points were available in order to maximise the results available from the review. This however means that some estimates will be more robust than others depending on the number of data points on which they are based. There was a large degree of variation in the amount of data available for different nutrients, for example assessment of serum selenium was based on data from only two papers whereas nine independent studies contributed data on haemoglobin concentration.

The pooling of study means gives a useful indication of potential inadequacies across the population as a

whole; however this approach lacks the sensitivity to draw conclusions regarding the prevalence of nutrient deficiencies in the population. Examination of the reported prevalence of deficiency in the included studies shows results which are inconsistent with the analysis based on study means. The prevalence of iron deficiency anaemia measured by haemoglobin concentration reportedly ranged from 1.2 to 63.5 %, with prevalence in the third trimester ranging from 29 to 63.5 %. Other markers of iron status followed a similar pattern with higher prevalence of deficiency occurring in the third trimester. The prevalence of vitamin D deficiency in many of these studies was also higher than suggested by the analysis of study means. This suggests, similarly to the data regarding nutrient intakes, that there are substantial skews within the data and sub-groups of young women who may be more at risk of deficiencies.

Conclusion

This review identifies some concerns in the nutritional status of pregnant adolescents which may impact on maternal and infant outcomes. Intake of vitamin D and serum selenium status were identified as being significantly low in pooled analysis of included studies. Fibre intake was also below recommendations.. This said there are some significant limitations meaning these results should be interpreted with caution. No analysis of the effect of demographic characteristics on either nutritional intake or biological markers was possible, nor was it possible to examine the impact of supplement use on biological markers.

Patterns in this population are also similar to those reported in the adult population during pregnancy. These findings suggest that targeted work to identify those most at risk, and the nature of that risk, is needed. Recommendations for other areas of further research include the macronutrient composition of adolescent's diet during pregnancy, the relationship between nutrient intakes and birth outcomes and the role of nutritional supplements in this population.

Additional file

Additional file 1: Table S1. Characteristics of Excluded Studies. **Table S2.** Pooled, Weighted Mean Nutrient Intakes Expressed as Percentages of Dietary Reference Values by Stage of Pregnancy. **Table S3.** Pooled, Weighted Mean Nutrient Intakes Expressed as Percentages of Dietary Reference Values by Study Country of Origin. **Table S4.** Pooled, Weighted Mean Biological Markers of Nutritional Status by Stage of Pregnancy. **Table S5.** Pooled, Weighted Mean Biological Markers of Nutritional Status by Study Country of Origin. (DOCX 57 kb)

Abbreviations

CASP: Critical appraisal and skills program; DRV: Dietary reference value; EAR: Estimated average requirement; RDA: Recommended daily allowance; RNI: Reference nutrient intake; WHO: World Health Organisation

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Availability of data and materials

All data on which the paper is based has been made available in either the main tables or Additional file 1: Tables S1-S5.

Authors' contributions

KM-D Primary responsibility for development of research question and study design, extraction and analysis of data and writing the main body of the article. VB Advisory role in development of research question and study design, revisions to and approval of final article. HS Advisory role in development of research question and study design, cross-checking of all extracted data, revisions to and approval of final article. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Ethical approval was not required for this systematic review due to only studies previously published in the academic literature being eligible for inclusion.

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3.4 Summary and Implications for Thesis

This review was carried out in a robust and transparent manner, utilising appropriate, validated methods and reported in line with current best practice reporting standards for systematic reviews. The review met the research objective which it was designed to address by creating a comprehensive and structured review of the available literature regarding adolescent women's nutrient intake and nutritional status during pregnancy.

The review also identifies significant remaining gaps in the current research evidence on this topic, particularly in regard to identifying the characteristics of young women at greatest risk of nutritional deficiencies and how these differ from older women.

The following chapter sets out the proposed methodology for this programme of research and details the approach to exploring further these identified gaps in the literature.

Chapter 4 - Methodology

4.1 Introduction

This chapter gives an overview of relevant research paradigms and discusses the theoretical approach underpinning this programme of research. This chapter also explains and justifies the decision to use a mixed method, sequential exploratory design. A brief description of the methods employed at each stage of the research process is also given to complement the methods described in the published papers.

4.2 Research paradigms

A research paradigm has been defined as *"the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed"*[92]*.* These are characterised by a set of assumptions regarding the nature of reality (ontology), ideas about how we can discover this reality (epistemology) and what methods and procedures we can use to go about acquiring new knowledge (methodology)[93].

Traditionally the dominant paradigms have been regarded as holding diametrically opposed views regarding the nature of reality and therefore the appropriate approaches to acquiring new knowledge. The positivist perspective posits that there is a single, objective reality which exists independently regardless of any individual's beliefs or understandings. This single reality can be known and measured using objective and value-free enquiry[94]. Positivists therefore favour quantitative methods and validated tools with which to gather empirical data.

Conversely the constructivist or interpretivist paradigm contends that there is no single reality or truth, rather there are multiple realities which are socially constructed and interpreted by individuals[95]. Therefore in order to learn about the social world it is necessary to collect data, usually using qualitative methods, which helps the researcher to understand these realities from the perspective of the individuals being studied.

The approach to this research is informed by a pragmatic research philosophy. Pragmatic research philosophy asserts that there are numerous different ways in which the natural world may be interpreted and therefore that no single point of view can ever give the full picture[96]. Therefore, research is strongly driven by the research question or questions and the methods employed are those which are judged to fit the question most appropriately. This has often resulted in the reduction of pragmatism as a research paradigm to a 'what works' approach or a purely practical way of selecting research methods with a focus on the 'how' research should be conducted, while neglecting the questions of 'why' research is to be carried out.

The importance of these issues is summarised by Denzin[97] who advances that classical pragmatism is a theory of truth as opposed to a methodology per se. The central argument being that the meaning of an event cannot be given in advance of experience and that therefore the focus of enquiry should be on the consequences and meanings of an action or event.

Pragmatism is strongly influenced by the work of John Dewey[98] which sought to reorient philosophy of knowledge away from abstract concepts and towards a focus on human experience. Human experience is described as being built upon two questions which are perpetually linked in a cycle: what are the sources of our beliefs? And, what are the meanings of our actions? In which our beliefs inform our actions and the outcomes of our actions subsequently inform our beliefs. Dewey categorises experiences as those which happen relatively automatically with little conscious thought termed habits, and self-conscious decision making described as inquiry. Conscious inquiry occurs when an element of an experience becomes problematic or has not been encountered before. Central to these ideas about human experience is also the impact of individual emotions or feelings and the influence of others on beliefs and actions. Human beings are inescapably social and emotional creatures and it is this focus on human experience which separates pragmatists from other thinkers who focus on metaphysical discussions about the nature of reality and truth.

4.3 Mixed methods research

As described above, a pragmatic philosophical approach to research is primarily directed by the research question, meaning that the choice of methods is focused on those which address the research question most fully. For this reason this is the paradigm most commonly associated with mixed methods research, where researchers employ both quantitative and qualitative methods which are integrated to address the research problem[99].

Creswell and Plano Clark[100] describe the core characteristics of mixed methods research as follows:

1. It collects and analyses rigorously both qualitative and quantitative data
2. It mixes the two forms of data
3. It gives priority to one or both forms of data
4. It can be a single phase or in multiple phases of a programme of study
5. It frames the procedures within philosophical worldviews
6. It combines procedures into specific research designs that direct the plan for conducting the study

Use of mixed methods research has been gathering significant momentum over recent years and has significant strengths as a means to enhance understanding of complex issues[101]. As described in previous chapters, the health of adolescent women during pregnancy and the extent to which this may be influenced by nutritional status is a complex problem requiring a nuanced research approach which can help to address this complexity.

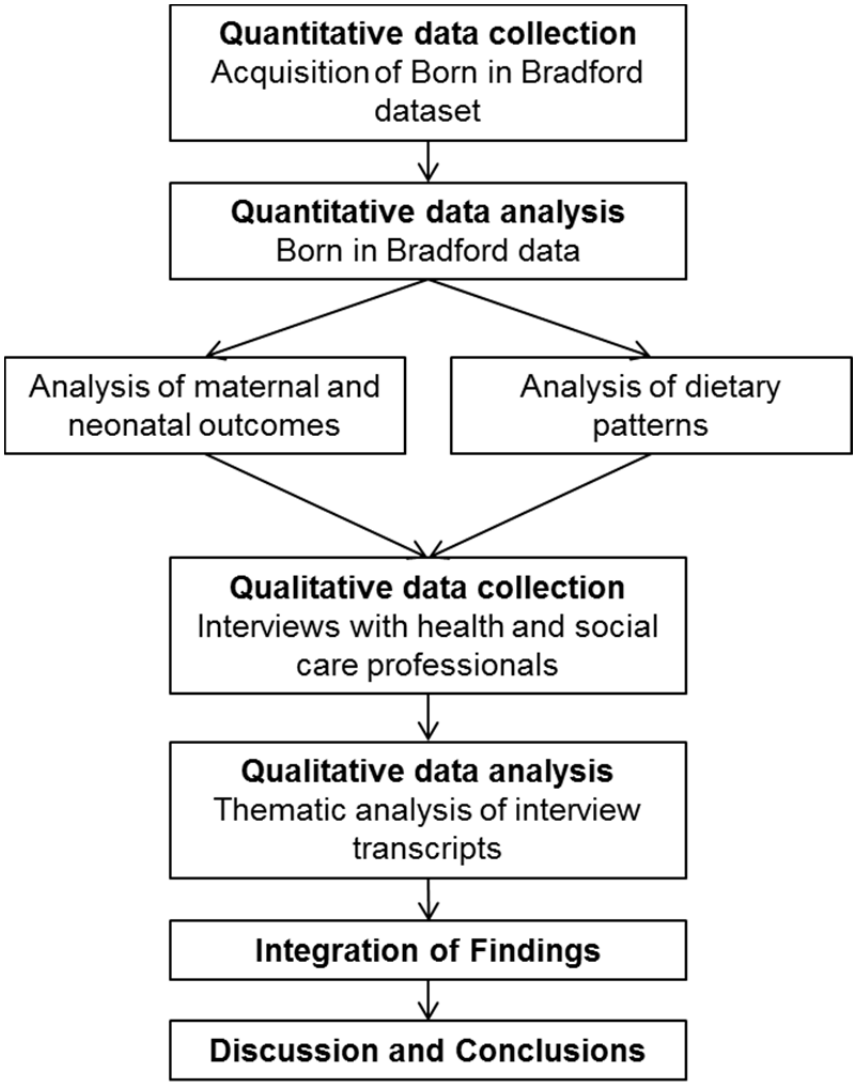
4.4 Methods

This thesis is presented in an article based format meaning that the methods used are reported in the published papers. This section therefore includes more detailed information on the methods employed by the Born in Bradford cohort from which data for the present study is drawn. It also gives a brief overview of the rationale for the analysis methods used and details of ethics and consent procedures.

This programme of research follows a sequential explanatory mixed methods design which, as discussed in the previous section, encompasses two distinct

phases. The first involves quantitative analysis of numerical data which is followed by a qualitative phase in which data is collected to help to explain or elaborate on the findings of the quantitative phase[102]. This research design is being employed in this thesis to first establish quantitative differences in birth outcomes and dietary patterns between adolescent pregnant women and older gravidas, following which potential explanations for the anticipated differences will be explored in more depth using qualitative enquiry. In this design, priority is given to the quantitative phases with the qualitative phase employed to expand upon the findings and explore the implications in more detail. The results of the study will then be reported in two distinct phases before being drawn together in a final discussion of findings[100]. An overview of the research design is illustrated in figure 7.

Figure 7. Research design



4.4.1 Born in Bradford

The Born in Bradford (BiB) study was set up in response to high rates of childhood morbidity and mortality compared to other similar cities in the UK. Infant mortality had been consistently higher than the national average in the years leading up to the formation of the cohort and rates of congenital abnormalities and childhood disability were among the highest in the UK. Bradford is a large city in the north of England with high levels of deprivation and a large South Asian community, the majority of who are from Pakistan. Due to the differential age and fertility rates between the Pakistani and the majority white British populations almost half of the babies born in Bradford have parents of Pakistani origin, despite making up only around 20% of the total population of the city.

The BiB cohort was therefore established to examine how genetic, nutritional, environmental, behavioural and social factors impact upon children's health and their development. It is also intended that the cohort be followed up into adult life to examine the relationships between birth factors and health outcomes in later life. Pregnant women were recruited to take part in the study at approximately 28 weeks gestation; between 2007 and 2011 a total of 12,453 women with 13,776 pregnancies were recruited to take part. Detailed questionnaire data including information on demographic characteristics, family histories and environmental risk factors was collected from all of the women taking part, a copy of the baseline questionnaire is shown in appendix 2. Anthropometric and blood biomarker measures were also recorded from mothers at recruitment and babies at birth. The study has a biobank containing over 250,000 samples of DNA, maternal blood, urine, cord blood and paternal saliva. The full published cohort profile[103] and further information regarding the Born in Bradford cohort is available at https://borninbradford.nhs.uk/.

Data from the baseline questionnaire has also been linked to hospital records providing information regarding the birth. It is this linked data which has been utilised in this programme of research.

4.4.2 Statistical analysis

The details of how specific methods were used in each phase of the data analysis are given in the published papers and therefore will not be repeated here. This section therefore briefly states the statistical analysis methods selected and gives a rationale for their use.

4.4.2.1 Rationale for use of binary logistic regression

The first of the published original research papers *"Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort"* uses binary logistic regression as the main analysis method to assess the extent to which maternal age group influences maternal and neonatal outcome. This method was selected as the primary interest of this programme of work is to assess the needs of adolescent pregnant women; therefore by grouping the participants by age it was possible to assess to what extent adolescent maternal age is a predictor of adverse maternal and neonatal outcomes in comparison to a reference group[104].

Potentially confounding variables were identified based on the academic literature and considered for inclusion in the regression model. In the final model only two confounding variables were included, index of multiple deprivation score and ethnicity due high levels of correlation between other potentially confounding variables. The analysis was also restricted to primiparous women delivering a singleton in order to mediate the effects of parity and multiple births on the outcomes.

Due to the nature of the study being a secondary analysis of an existing data set no sample size calculations were carried out and rather all of the eligible women in the cohort were included in the analysis. A post-hoc power analysis has not been carried out as it is not appropriate. Observed power is directly derived from the p-value of the statistical test, therefore providing a post-hoc power calculation would be superfluous; where the tests produce a statistically non-significant result it can be assumed that the study is insufficiently powered to detect an effect of the size obtained in the study[105].

4.4.2.2 Rationale for use of principle component analysis

The second of the published original research papers *"Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis"* uses principle component analysis (PCA) to identify patterns in the types of foods consumed by individuals, the results of which then being compared between age groups.

PCA was selected as it allows for a larger number of variables to be reduced and underlying factors exposed. Portions per day of food groups were entered into PCA in SPSS using 'DIMENSION REDUCTION' -> 'FACTOR' functions. The PCA was conducted based on the correlation matrix in order to control for differences in variances among the variables.

Rotation was used in order to maximise the loading of each variable on to one of the extracted factors whilst minimising the loading on all other factors. Because there is a reasonable theoretical rationale for expecting dietary intake variables to be correlated with one another an oblique rotation (direct oblimin) was selected.

Factor scores were retained as new variables; the regression method was selected due to correlations between the factor scores being considered to be acceptable.

Several combinations of food grouping were explored to see which gave the most sensitive output. Further tests were carried out to assess the suitability of the data for carrying out a PCA. The overall Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy test returned a result of 0.677 which is higher than the suggested minimum of 0.5[106]. The anti-image correlation matrix was also examined to ensure that the KMO statistic for each individual variable was adequate. Bartlett's Test of Sphericity was also undertaken to confirm that the correlation matrix was significantly different to an identity matrix (in which all of the included variables are perfectly independent) which returned a statistically significant result (P=0.000).

4.5 Data sharing, consent and ethics

Ethical considerations in research are of paramount importance to ensure that research is of good quality and of benefit to the communities it is designed to answer questions about. The key principles of social research ethics are to minimise any risk of harm to individuals, including avoiding deceptive practices, to obtain informed consent from participants including informing them of their right to withdraw from the study and to protect the anonymity and confidentiality of individuals wherever possible[107].

Different types of research therefore require different actions in order to ensure that these basic principles are upheld. These are discussed below along with details of the formal processes undertaken to ensure the project adheres to ethical guidelines.

4.5.1 Born in Bradford

The use of secondary data in research has a number of significant advantages including saving time, money and other resources and ensuring that populations are not unnecessarily overburdened by repeated research[108]. The main ethical concerns with the use of secondary data are to do with avoiding potential harm to participants and the issue of consent for specific use of personal data beyond the original research project. The original consent procedure for the Born in Bradford study included obtaining consent for anonymised data to be used for future research projects, meaning that explicit consent for the use of data for this study is not required. Any potential harm to participants is minimised as individuals are not identifiable from the data provided for this study, meaning that their confidentiality is protected. This said participants still have the right to withdraw consent and for their data to be removed from the analysis up until the time that the research is published. Use of the anonymised Born in Bradford data set was agreed subject to a data transfer agreement (appendix 3). Ethical approval for the main Born in Bradford cohort study was granted in April 2008 and a copy of the approval letter is included in appendix 4. Further to this, ethical approval for the specific use of the data for the current program of research was granted by Sheffield Hallam University Ethics Committee, a copy of which is shown in appendix 5.

4.5.2 Qualitative interviews

The ethical considerations associated with the qualitative interviews were similar to those addressed in the quantitative phase in that the same ethical principles are to be adhered to. Participants were self-selected by responding to recruitment materials circulated in their place of work. The purpose and scope of the project was explained to participants both at the time of recruitment and immediately prior to the interview, ensuring that the consent they provided was fully informed. Participants were given a participant information sheet (appendix 6) and the opportunity to ask any questions at least 24 hours ahead of being asked to sign a consent form (appendix 7). Interviews were audio recorded and transcribed verbatim with any identifying information removed, following which the audio files were destroyed. This process ensures that individuals are not identifiable from the data and their confidentiality is maintained. Consent forms containing participant's personal details have been stored securely and will be destroyed when they are no longer needed. Ethical approval for the qualitative phase of this programme of research was granted by Sheffield Hallam University Ethics Committee in July 2016, a copy of the approval letter is included in appendix 8.

4.6 Summary

In this chapter the concept of philosophical research paradigms has been discussed and a rationale given for the adoption of a pragmatic approach to this programme of research. The research design has been described with reference to the philosophical underpinnings. The cohort from which the participants for the quantitative phase of enquiry are drawn has been described and the statistical methods used in the analysis, which are presented in the published papers, have been elaborated on with rationale given for the choice of methods.

The following three chapters present the three main studies which make up this programme of research. The studies are presented as published research articles in their original form.

Chapter 5 - Maternal and neonatal outcomes

5.1 Introduction

This chapter briefly summarises the rationale for the first study in this programme of research assessing the impact of age on maternal and neonatal outcomes in the Born in Bradford cohort, followed by a copy of the full published research paper in its original form. The chapter concludes with a summary of key points, measurable impact of the work and discussion of its contribution to the thesis. As discussed in chapter two there is a body of evidence suggesting that the rates of some adverse neonatal outcomes such as low birthweight and pre-term delivery are higher among babies born to adolescent mothers despite lower rates of adverse maternal outcomes such as pre-eclampsia. This study aims to contribute to this body of evidence by comparing outcomes in adolescent women to an adult reference group (20-34 years) in the Born in Bradford cohort. This large data set, the characteristics of which were described comprehensively in the methods chapter, has not previously been interrogated in this way, providing the opportunity to contribute original knowledge to the field of research. This study contributes to addressing the second research objective as set out in chapter one to *"Examine differences in dietary intake and birth outcomes between adolescent and adult mothers in a large cohort data set".*

5.2 Publication and Impact

The manuscript describing this study was accepted for publication in BMJ Open in March 2018. BMJ Open is a medical journal which publishes open access papers in the fields of clinical medicine, public health and epidemiology. With an impact factor of 2.413 the journal is internationally well regarded. Since publication online the full text of the article has been accessed 1220 times and has achieved 3 citations (correct as of 20.01.19).

5.3 Published paper: Article B

The published paper entitled *"Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort"* is reproduced here in the format in which it was published online.

BMJ Open

Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort

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ABSTRACT

Objectives Explore associations between maternal and neonatal outcomes and maternal age, with particular reference to adolescent women.

Design Population-based cohort study.

Setting Maternity department of a large hospital in Northern England.

Participants Primiparous women delivering a singleton at Bradford Royal Infirmary between March 2007 and December 2010 aged ≤19 years (n=640) or 20–34 years (n=3951). Subgroup analysis was performed using women aged ≤16 years (n=68). Women aged 20–34 years were used as the reference group.

Primary outcome measures Maternal and neonatal outcomes.

Results The odds of extremely low birth weight (<1000 g) were significantly higher in the adolescent group (≤19 years) compared with the reference group (adjusted OR (aOR) 4.13, 95% CI 1.41 to 12.11). The odds of very (<32 weeks) and extremely (<28 weeks) preterm delivery were also higher in the adolescent group (aOR 2.12, 95% CI 1.06 to 4.25 and aOR 5.06, 95% CI 1.23 to 20.78, respectively). Women in the adolescent group had lower odds of gestational diabetes (aOR 0.35, 95% CI 0.20 to 0.62), caesarean delivery (aOR 0.53, 95% CI 0.42 to 0.67 and instrumental delivery (aOR 0.53, 95% CI 0.41 to 0.67).

Conclusions This study identifies important differences in maternal and neonatal outcomes between women by age group. These findings could help in identifying at-risk groups for additional support and tailored interventions to minimise the risk of adverse outcomes for these vulnerable groups. Further work is needed to identify the causal mechanisms linking age with outcomes in adolescent women where significant gaps in the literature exist.

Strengths and limitations of this study

- A particular strength of this work is that it uses well-established, ethnically diverse, UK-based cohort data in a way that is unique to this study.
- A further strength is in the large number of participants available for analysis that enables robust conclusions to be drawn.
- Despite the large number of participants, however, this study is limited by small numbers of occurrences of some rare outcomes, particularly in subgroup analyses.
- It should also be considered that the generalisability of this study to contexts that are very different in terms of socioeconomic and demographic characteristics is limited.

INTRODUCTION

Pregnancy during adolescence is often associated with less favourable outcomes for both mother and child. Childbearing in adolescence is associated with social problems such as isolation, poverty, low levels of education and unemployment.[1]

The impact of maternal age on obstetric and neonatal outcomes has been studied in various parts of the world and with variable results. A WHO multicountry study including 29 low-income and middle-income countries[2] found adolescent mothers were at higher risk of several adverse outcomes including low birth weight, preterm delivery eclampsia and infections compared with mothers aged 20–24 years.

Similarly in higher income countries, there is evidence to suggest that health outcomes may be less favourable for younger mothers. Babies born to adolescent mothers have been shown to be at higher risk of preterm birth and low birth weight,[3 4] and higher rates of stillbirth and neonatal mortality have also been reported.[5] Adolescents have, however, been consistently shown to experience lower rates of caesarean and instrumental delivery[6] and therefore are at lower risk of complications associated with assisted births. It is not currently clear from the available literature, however, to what extent differences in birth outcomes between adolescent and adult mothers are predicted by age alone.

A systematic review[7] aiming to assess the relationship between early first childbirth and increased risk of poor pregnancy outcomes found that there was considerable evidence to suggest that very young maternal age (<15 years or less than 2 years after menarche) had a negative effect on both maternal and

fetal growth and infant survival. It is suggested that young women who are still themselves growing may compete with the fetus for nutrients, which may in turn impair fetal growth and result in low birthweight babies or babies who are small for their gestational age. The review also found a moderately increased risk of anaemia, premature birth and neonatal mortality associated with young maternal age. Advanced maternal age (35+ years) has also previously been shown to be an independent risk factor for adverse maternal and neonatal outcomes.[8] This suggests that women aged 20–34 years could reasonably be considered as the population less likely to suffer age-related pregnancy complications.

Differences in outcomes have also been associated with demographic and behavioural characteristics. Lifestyle and sociodemographic factors such as smoking,[9] alcohol use[10] and deprivation[11] have all been shown to contribute to less favourable birth outcomes. It is also established that adolescent mothers in high-income countries are at higher risk of exhibiting these characteristics.[12]

The Born in Bradford study is a cohort of approximately 13 500 children born at Bradford Royal Infirmary between March 2007 and December 2010. The cohort reflects the diversity of the population in Bradford and as such is a largely biethnic sample with high levels of socioeconomic deprivation, which presents a unique opportunity to explore any differences in birth outcomes between adolescent and adult women and the factors that contribute to these differences. A detailed profile of the cohort has been previously published.[13]

Some work has already been carried out looking at maternal and neonatal outcomes in the Born in Bradford cohort, particularly with reference to maternal ethnicity[14 15]; however, this cohort has not previously been examined with reference to maternal age.

While these studies have shown some interesting associations between maternal and neonatal outcomes and maternal ethnicity, the impact of maternal age on outcomes is yet to be explored in this cohort. The size and diversity of this cohort allow for detailed analysis to be carried out and factors known to impact on maternal and neonatal outcomes to be controlled for, making this study unique in a UK context. For these reasons, the primary aim of this investigation is to explore the relationship between maternal and neonatal outcomes and maternal age in the Born in Bradford cohort.

METHODS

Born in Bradford is a prospective cohort study for which participants were recruited during pregnancy. The cohort was originally established in response to concerns regarding the high rates of morbidity and mortality in the city. All women booked for delivery at Bradford Royal Infirmary are offered an oral glucose tolerance test at 26–28 weeks' gestation. Women were invited to participate in the Born in Bradford study when attending this appointment or when attending other antenatal appointments. Informed consent was obtained, and women were asked to complete a baseline questionnaire providing data on maternal characteristics. Blood and urine samples were also collected from the mothers as well as cord blood samples collected at birth. Recruitment took place between March 2007 and December 2010, and over 80% of women eligible in this period agreed to take part, which represents approximately 64% of the births occurring in Bradford during this period.[13] This study uses baseline questionnaire data and hospital maternity data collected by Born in Bradford to examine maternal and neonatal outcomes. The youngest women recruited to the cohort were 15 years old; therefore, data for this study were limited to primiparous women aged 15–34 years at delivery who had a singleton pregnancy; data relating to 4591 pregnancies were available for this analysis. A flow chart describing the Born in Bradford cohort and the subset used for this study is shown in figure 1.

Outcome variables

The binary neonatal outcome variables studied were low birth weight (below 2500 g), very low birth weight (below 1500 g), extremely low birth weight (below 1000 g), macrosomia (birth weight over 4000 g), small for gestational age (birth weight lower than the 10th percentile for the sample),[16] large for gestational age (birth weight higher than the 90th percentile for the sample),[16] preterm birth (<37 completed weeks gestation), very preterm birth (<32 completed weeks' gestation), extremely preterm birth (<28 completed weeks' gestation), outcome of birth (live birth or stillbirth) and Apgar score at 1 min and 5 min (analysed as two groups: <7 and 7–10). Low, very low and extremely low birthweight and macrosomic infants were compared with infants born weighing 2500–4000 g, small and large for gestational age infants were compared with appropriate for gestational age infants and those born preterm or very or extremely preterm to those born ≥37 completed weeks' gestation. Birth weight and gestational age at delivery were also considered as continuous variables. The maternal outcome variables included in this analysis were diagnosis of pre-eclampsia (diagnosis in this cohort was made when proteinuria is >0.3 mg and blood pressure is ≥140/90mmHg on more than one occasion), diagnosis of gestational diabetes (defined as a 2-hour postglucose load plasma glucose level of 7.8 mmol/L or a fasting plasma glucose level of 6.1 mmol/L)[14] and mode of birth (normal vaginal, instrumental (including both forceps and ventouse deliveries) or caesarean section). Distinction between elective and emergency caesarean sections was not available. The outcome variables were collected in the process of routine maternity care and were made available for this analysis via data linkage to questionnaire data.

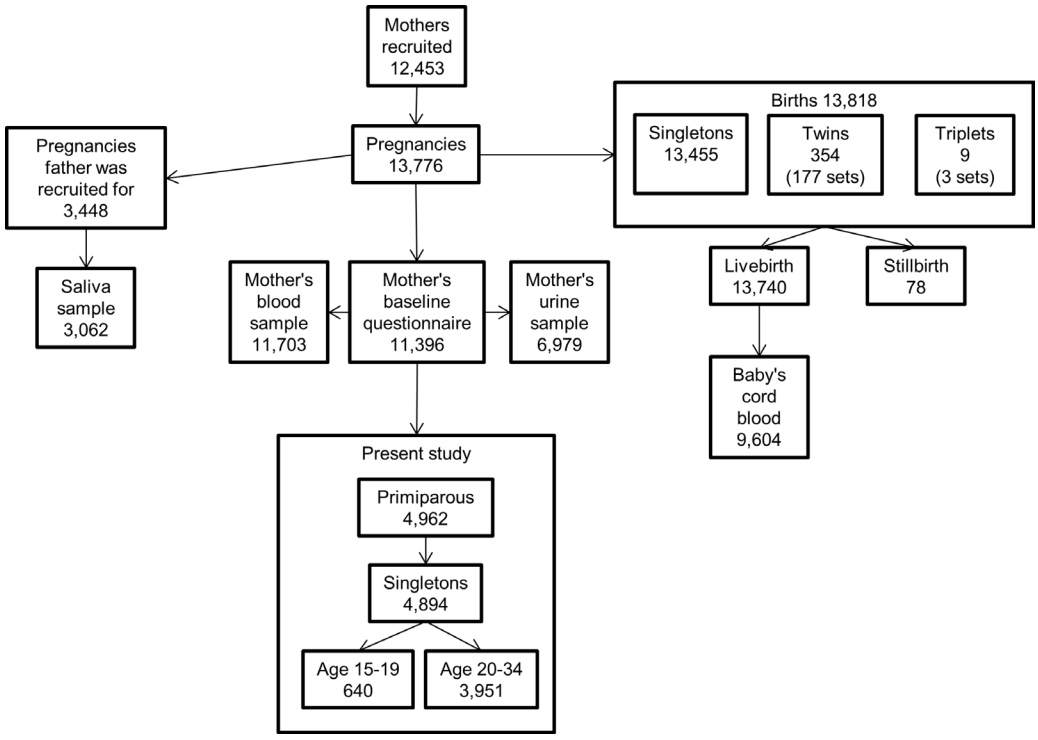

Figure 1 Details of the Born in Bradford cohort and subset used for the present study. This shows participants recruited to the main Born in Bradford cohort study and the subset of these participants whose data is used in the present study.

Statistical analysis

Outcomes in women aged ≤19 years were compared with outcomes for women in the reference group (20–34 years). Age group of 20–34 years was selected as the reference group as this group is the least likely to suffer age-related complications as discussed in the introduction.

Characteristics of the sample were described, presenting categorical variables as percentages and continuous variables as means and SD. This analysis was carried out both for demographic characteristics and for maternal and neonatal outcome variables. Differences between maternal age groups were explored using $\chi 2$ for categorical data and Student's t-test for continuous data.

Simple linear regression was calculated to predict both birth weight and gestation to last completed week at delivery based on maternal age at delivery.

Logistic regression analyses were used to compare the rate of each of the binary outcome variables for adolescents and the reference group and differences between groups estimated using ORs.

Multivariate logistic regression models were then used to adjust these comparisons for confounding variables. Crude and adjusted ORs (OR and aOR) are therefore presented with 95% CIs. Index of multiple deprivation (IMD) score and maternal ethnicity (white British, Pakistani or any other ethnicity) were included as covariates in the adjusted analysis. IMD is the official measure of relative deprivation for small areas in England and combines information from seven domains of deprivation (income, employment, education, health, crime, housing and environment) to give a deprivation score.[17]

In the multivariate logistic regression model for this study, there is no clear logical or theoretical basis for assuming any variable to be prior to any other, either in terms of its relevance to the research goal of explaining phenomena or in terms of a hypothetical causal structure of the data. For this reason, a simultaneous model of including independent variables in the multivariate logistic regression model was considered to be most appropriate.

Further subgroup analysis was also undertaken to examine the maternal and neonatal outcomes for young women aged ≤16 years compared with the reference group and reported in the same way as the main analysis. Statistical analysis was undertaken using SPSS V.24.

RESULTS

Characteristics of the sample

Data were available for 4591 pregnancies for this analysis; characteristics of the participants included in the study are shown in table 1. The majority of participants in the cohort were aged 20–34 years (86.1%) with 13.9% aged 19 years or under. The sample overall was made up of 37.7% Pakistani women, 44.4% white British woman and 17.6% women of other ethnicities. Among women aged 19 years and under only 16.7% were of Pakistani ethnicity and 70% were white British. Women in the adolescent group were also more likely to have been born in the UK

Table 1 Characteristics of the sample by maternal age

	≤19		20–34		Total		Missing		
	n	%	n	%	n	%	n	%	P values
Whole cohort	640	13.9	3951	86.1	4591	100			
Ethnicity							14	0.3	
Pakistani	107	16.7	1623	41.1	1730	37.7			<0.001
White British	448	70.0	1590	40.2	2038	44.4			
Any other ethnicity	85	13.3	724	18.3	809	17.6			
Mother's country of birth							1	0.0	
UK and Ireland	564	88.1	2588	65.5	3152	68.7			<0.001
Southeast Asia	41	6.4	984	24.9	1025	22.3			
Eastern Europe	15	2.3	135	3.4	150	3.3			
Other/unknown	20	3.1	243	6.2	263	5.7			
Marital status							9	0.2	
Married	87	13.6	2445	61.9	2532	55.2			<0.001
Not married – living with partner	147	23.0	841	21.3	988	21.5			
Single	406	63.4	656	16.6	1062	23.1			
Parents related other than by marriage							3	0.1	
Yes	76	11.9	988	25.0	1064	23.2			<0.001
No	564	88.1	2960	74.9	3524	76.8			
Highest level of education							14	0.3	
Less than 5 GCSEs grades A–C or equivalent	231	36.1	553	14.0	784	17.1			<0.001
5 GCSEs grades A–C or equivalent	298	46.6	1121	28.4	1419	30.9			
A-levels or higher	60	9.4	1971	49.9	2031	44.2			
Other/unknown	50	7.8	293	7.4	343	7.5			
Smoked during pregnancy							7	0.2	
Yes	302	47.2	608	15.4	910	19.8			<0.001
No	338	52.8	3336	84.4	3674	80.0			
Drunk alcohol in the first 3 months of pregnancy							2862	62.3	
Yes	185	28.9	698	17.7	883	19.2			0.068
No	140	21.9	702	17.8	842	18.3			
Don't know	1	0.2	3	0.1	4	0.1			
Drunk alcohol since the fourth month of pregnancy							2872	62.6	
Yes	89	13.9	478	12.1	567	12.4			0.06
No	233	36.4	916	23.2	1149	25.0			
Don't know	1	0.2	2	0.1	3	0.1			
Used recreational drugs during pregnancy							771	16.8	
Yes	29	4.5	47	1.2	76	1.7			<0.001
No	509	79.5	3235	81.9	3744	81.6			
Used any vitamins or iron supplements in the last 4 weeks							16	0.3	

Continued

Table 1 Continued

	≤19		20–34		Total		Missing		
	n	%	n	%	n	%	n	%	P values
Yes	152	23.8	1610	40.7	1762	38.4			<0.001
No	487	76.1	2326	58.9	2813	61.3			
BMI category							413	9	
Underweight (below 18.5)	59	9.2	199	5.0	258	5.6			<0.001
Healthy weight (18.5–24.9)	368	57.5	1853	46.9	2221	48.4			
Overweight (25–29.9)	113	17.7	955	24.2	1068	23.3			
Obese (30 or higher)	46	7.2	585	14.8	631	13.7			
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	%	P values
BMI at booking appointment	594	23.3 (4.6)	3641	25.1 (5.4)	4235	24.8 (5.3)	356	7.8	<0.001
IMD score	640	44.7 (18.0)	3948	41.6 (17.9)	4588	41.8 (17.9)	3	0.1	<0.001
Number of weeks' gestation at booking appointment	640	12.1 (5.0)	3951	11.4 (4.3)	4246	12.4 (3.1)	345	7.5	<0.001

BMI, body mass index (kg/m²); GCSE, General certificate of secondary education; IMD, Index of multiple deprivation.

or Ireland (88.1%) compared with the reference group (65.5%). There were other significant variations in the characteristics of the sample by maternal age. Women in the adolescent age group were more likely to not be married or living with a partner, to be expecting their first child and to have completed lower levels of education compared with older women. Women in the adolescent age groups were also more likely to have smoked or used recreational drugs during pregnancy; they were also more likely to have drunk alcohol in the first trimester. Women in the reference group were more likely to be overweight or obese, while adolescent women were found to have higher prevalence of underweight. Older women were also more likely to have taken nutritional supplements in the 4 weeks before questionnaire completion compared with younger women. Analysis of continuous variables showed that IMD score decreased as maternal age increased suggesting adolescent women lived in areas of higher deprivation. Adolescent women also booked with a midwife for antenatal care later than older women; there was a mean difference of 1 week between the two groups.

Descriptive analysis relating to maternal and neonatal outcomes is shown in table 2. This analysis suggests that there are several outcome variables that show significant variation by maternal age group. Among the neonatal outcomes, the results show babies born to adolescent women were significantly more likely to have extremely low birth weights or to be born very or extremely preterm. Among the maternal outcomes, lower rates of gestational diabetes, caesarean delivery and instrumental birth were associated with adolescent age.

Linear regression models

A simple linear regression was carried out to assess the relationship between birth weight and maternal age. A statistically significant relationship was found (P=0.044). The slope coefficient for maternal age was 3.749, meaning that for each 1-year increase in maternal age, birth weight increases by 3.749 g. The R^2 value was 0.001, meaning that only 0.1% of the variation in birth weight can be explained by the model containing only maternal age.

Similarly, a simple linear regression to assess the relationship between gestation at delivery to last completed week and maternal age found a significant relationship (P=0.011). The slope coefficient for maternal age was −0.016, meaning that for each 1-year increase in maternal age gestation at delivery decreases by 0.016 weeks. The R^2 value for this regression was also 0.001, meaning that only 0.1% of the variation in gestation at delivery can be explained by the model containing only maternal age.

Logistic regression analysis

The crude and aORs for maternal and neonatal outcomes by maternal age group are shown in table 3.

Women in the adolescent age group were found to have a significantly higher odds of delivering extremely low birthweight babies (<1000 g) compared with the reference group (aOR 4.13, 95% CI 1.41 to 12.11) and delivering extremely preterm (<28 weeks) (aOR 5.06, 95% CI 1.23 to 20.78). Adolescent pregnant women experienced lower odds of being diagnosed with gestational diabetes than the reference group (aOR 0.35, 95% CI 0.20 to 0.62). The odds of women in this age group delivering by caesarean section were decreased (aOR 0.53, 95% CI 0.42 to 0.67), as were the odds of having an instrumental delivery (aOR 0.53, 95% CI 0.41 to 0.69) compared with the reference group.

Subgroup analysis

For some outcomes, the number of events occurring in the subgroup aged ≤16 years, was either very small or no events took place. This resulted in either the regression model failing to produce a valid result or the aOR being

Table 2 Descriptive analysis of maternal and neonatal outcomes by maternal age

	≤19		20–34		Total		Missing		
	n	%	n	%	n	%	n	%	P values
Whole cohort	640	13.9	3951	86.1	4591	100			
Neonatal outcomes									
Low birth weight (<2500 g)	56	9.3	349	9.4	405	9.3	0	0.0	0.933
Very low birth weight (<1500 g)	9	1.6	36	1.1	45	1.1	0	0.0	0.248
Extremely low birth weight (<1000 g)	6	1.1	10	0.3	16	0.4	0	0.0	0.007
Macrosomia (birth weight >4000 g)	35	6.0	223	6.2	258	6.2	0	0.0	0.852
Small for gestational age	81	14.0	576	16.3	657	16.0	0	0.0	0.153
Large for gestational age	61	10.9	426	12.6	487	12.4	0	0.0	0.256
Preterm delivery (<37 weeks)	44	6.9	236	6.0	280	6.1	0	0.0	0.376
Very preterm delivery (<32 weeks)	12	2.0	35	0.9	47	1.1	0	0.0	0.021
Extremely preterm delivery (<28 weeks)	4	0.7	5	0.1	9	0.2	0	0.0	0.008
Stillborn	5	0.8	26	0.7	31	0.7	0	0.0	0.724
Apgar score <7 at 1 min	75	11.7	456	11.5	531	11.6	0	0.0	0.896
Apgar score <7 at 5 min	24	3.8	136	3.4	160	3.5	0	0.0	0.694
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	%	P values
Birth weight (g)	640	3167.6 (580.6)	3950	3183.1 (556.3)	4590	3180.9 (559.7)	1	0.0	0.919
Gestation to last completed week	640	39.2 (2.2)	3951	39.2 (1.9)	4591	39.2 (1.9)	0	0.0	0.516
Maternal outcomes									
Pre-eclampsia	19	3.0	146	3.7	165	3.6	0	0.0	0.36
Gestational diabetes	13	2.0	264	6.7	277	6.0	0	0.0	<0.001
Caesarean delivery	93	14.5	990	25.1	1083	23.6	0	0.0	<0.001
Instrumental birth*	78	14.3	706	23.9	784	22.4	5	0.1	<0.001

*Vaginal deliveries only, included both forceps and ventouse deliveries.

subject to extremely wide CIs. The results presented do however provide a useful indication of the outcomes that may be important for further investigation. Results of the subgroup analysis are shown in table 4. The only variable to return a significant result in this analysis was for incidence of caesarean section where the odds were lower for women in the ≤16 subgroup (aOR 0.31, 95% CI 0.13 to 0.72).

DISCUSSION

Analysis of maternal and neonatal outcomes in the Born in Bradford cohort in this study has found some important differences between women in different age groups.

Adolescent women in the sample were found to be at significantly increased risk of delivering babies extremely preterm and with extremely low birth weights after adjustment for confounding factors. Identifying the risk of delivering babies with an extremely low birth weight is of particular importance due to its association with neonatal mortality and morbidity. Babies with extremely low birth weight are more likely to die in the first few months of life[18] and are more likely to have long lasting physical and cognitive developmental issues[19]compared with babies born at higher weights. Extreme low birth weight and extreme preterm delivery are intrinsically linked, and thus morbidity and mortality in extremely preterm infants is similar to those with extremely low birth weights.[20]

Preterm deliveries may be clinically indicated due to medical factors such as intrauterine growth restriction or spontaneous. Both spontaneous preterm delivery[20] and intrauterine growth restriction[21] have been shown to be associated with maternal under nutrition, and the links between intrauterine growth restriction and maternal smoking during pregnancy are well established.[20 22 23] This study has identified a higher prevalence of both maternal underweight and smoking during pregnancy among the adolescent group compared with controls, suggesting that these may be important mechanisms for further investigation in examining the causes of poorer outcomes in adolescent pregnancies.

In the UK, survival rates for babies born extremely preterm increase rapidly with each additional week the fetus remains in the womb from close to 0 at 22 weeks' gestation to 92% at 28 completed weeks,[24] meaning that neonatal death is a significant concern for babies born in this time period. Mortality data were not available for this

Table 3 Neonatal and maternal outcomes for adolescent women

	n	Crude OR (95% CI)	aOR (95% CI)*
Neonatal outcomes			
Low birth weight (<2500 g)	4332	0.99 (0.73 to 1.33)	1.10 (0.81 to 1.50)
Very low birth weight (<1500 g)	3972	1.54 (0.74 to 3.21)	1.59 (0.74 to 3.42)
Extremely low birth weight (<1000 g)	3943	3.69 (1.34 to 10.20)	4.13 (1.41 to 12.11)
Macrosomia (birth weight >4000 g)	4185	0.97 (0.67 to 1.40)	0.78 (0.54 to 1.14)
Small for gestational age	4104	0.83 (0.65 to 1.07)	1.05 (0.81 to 1.37)
Large for gestational age	3934	0.85 (0.64 to 1.13)	0.74 (0.55 to 0.99)
Preterm delivery (<37 weeks)	4591	1.16 (0.83 to 1.62)	1.10 (0.78 to 1.56)
Very preterm delivery (<32 weeks)	4358	2.14 (1.10 to 4.14)	2.12 (1.06 to 4.25)
Extremely preterm delivery (<28 weeks)	4320	4.99 (1.34 to 18.62)	5.06 (1.23 to 20.78)
Stillborn	4591	1.19 (0.46 to 3.11)	1.39 (0.51 to 3.80)
Apgar score <7 at 1 min	4591	1.02 (0.79 to 1.32)	0.95 (0.73 to 1.25)
Apgar score <7 at 5 min	4591	1.09 (0.70 to 1.70)	1.11 (0.70 to 1.76)
Maternal outcomes			
Pre-eclampsia	4591	0.80 (0.49 to 1.30)	0.84 (0.51 to 1.39)
Gestational diabetes	4591	0.29 (0.17 to 0.51)	0.35 (0.20 to 0.62)
Caesarean delivery	4591	0.51 (0.40 to 0.64)	0.53 (0.42 to 0.67)
Instrumental birth†	3503	0.53 (0.41 to 0.69)	0.53 (0.41 to 0.69)

Reference group: maternal age 20–34 years.
*Adjusted for IMD score and ethnicity.
†Vaginal deliveries only, included both forceps and ventouse deliveries.
aOR, adjusted OR; IMD, Index of multiple deprivation.

study for infants who were born alive; this would be an important area for further study to assess how mortality rates in preterm infants born to adolescent mothers compare with those born to older women.

The linear regression analysis of both birth weight and gestation at delivery showed statistically significant results. This said, the R^2 value for both of these analyses showed that maternal age accounted for only 0.1% of the variation in the analysis, meaning that the clinical importance of this finding is limited. It is likely that there are a number of variables that were either not measured in this study or that are currently unknown in the research literature that contribute to these outcomes.

Adolescent women were also found to be at significantly lower risk of caesarean and instrumental delivery in this analysis. Caesarean delivery is associated with higher rates of postnatal complications and increased recovery time for the mother.[25] Instrumental deliveries, while necessary to prevent serious neonatal complications, are associated with a higher prevalence of birth injuries and maternal rehospitalisation.[26] These results are consistent with a large body of existing work where these outcomes have been found to be associated with maternal age.[27 28] It is not known whether these differences are due to biological differences between younger and older women or whether the reasons are more likely to be social or cultural. Further investigation regarding the reasons for difference in mode of birth in women of different ages would be advantageous. The results of this study are consistent with a number of previous similar studies. Results from a study looking at differences in outcomes between adolescent mothers and an older reference group from the North Western Perinatal Survey[29] found an increased risk of low birth weight and preterm delivery among adolescent mothers. This study also measured the effect of parity on these outcomes and reported and increased effect in the second pregnancies of adolescents. Analysis in the present study was limited to primiparous mothers only in order to control for the impact of parity in comparison with the control group. There were insufficient numbers of multiparous women in the adolescent group to allow for analysis of these as a separate group in this study; however, the results of this previous study suggest that by excluding second and subsequent pregnancies, the extent of low birth weight and preterm delivery may have been underestimated.

A further study[30] comparing adolescent pregnancy outcomes with those of older women found a decreased risk of caesarean section and instrumental delivery in the adolescent group, which is consistent with the findings of this study. This study did however fail to find any association with low birth weight or preterm delivery after adjusting for confounding variables. This analysis did not however look at extreme low birth weight or extreme preterm delivery, which is where the present study has detected differences between groups. Comparison of the

Table 4 Subgroup analysis of neonatal and maternal outcomes

	n ≤16	n 20–34	Total valid n	Crude OR (95% CI)	aOR (95% CI)*
	68	3951			
Neonatal outcomes					
Low birth weight (<2500 g)	5	349	3792	0.81 (0.32 to 2.02)	0.83 (0.32 to 2.13)
Very low birth weight (<1500 g)	2	36	3476	3.13 (0.74 to 13.29)	3.00 (0.66 to 13.59)
Extremely low birth weight (<1000 g)	1	10	3449	5.63 (0.71 to 44.68)	5.90 (0.67 to 51.85)
Macrosomia (birth weight >4000 g)	3	223	3664	0.76 (0.24 to 2.43)	0.62 (0.19 to 2.02)
Small for gestational age	6	576	3585	0.57 (0.24 to 1.33)	0.74 (0.31 to 1.77)
Large for gestational age	8	426	3437	1.03 (0.49 to 2.17)	0.91 (0.42 to 1.95)
Preterm delivery (<37 weeks)	5	236	4019	1.25 (0.50 to 3.14)	1.08 (0.42 to 2.76)
Very preterm delivery (<32 weeks)	1	35	3814	1.69 (0.23 to 12.49)	1.66 (0.21 to 12.88)
Extremely preterm delivery (<28 weeks)	1	5	3784	11.79 (1.36 to 102.41)	6.24 (0.61 to 64.20)
Stillborn	0	26	4019	†	†
Apgar score <7 at 1 min	9	456	4019	1.17 (0.58 to 2.37)	1.02 (0.50 to 2.11)
Apgar score <7 at 5 min	2	136	4019	0.85 (0.21 to 3.51)	0.85 (0.20 to 3.60)
Maternal outcomes					
Pre-eclampsia	4	146	4019	1.63 (0.59 to 4.53)	1.71 (0.59 to 4.91)
Gestational diabetes	0	264	4019	†	†
Caesarean delivery	6	990	4019	0.29 (0.13 to 0.67)	0.31 (0.13 to 0.72)
Instrumental birth‡	14	706	3025	0.83 (0.46 to 1.50)	0.87 (0.47 to 1.60)

Reference group: maternal age 20–34 years.
*Adjusted for IMD score and ethnicity.
†No valid result available due to small numbers.
‡Vaginal deliveries only, included both forceps and ventouse deliveries.
aOR, adjusted OR; IMD, Index of multiple deprivation.

results of this study to key indicators published by Public Health England's Child and Maternal Health Intelligence Network[31] suggests that despite the uniqueness of this cohort, the results are generalisable to other areas of the UK. Reported national rates for smoking in pregnancy, low birth weight and stillbirth are similar both among the adolescent population and the population as a whole to those reported in this study.

The results of this study contribute to the wider understanding of neonatal and maternal morbidity and mortality both in a UK context and internationally. This study identifies important differences in the risk of adverse outcomes by maternal age, which align with the United Nations sustainable development goals[32] and the targets outlined in the Every Woman, Every Child Global Strategy.[33] Preterm births and low birth weights are a major cause of neonatal death and cause more than 1 million deaths globally per year.[34] In addition to this, the second leading cause of death for young women aged 15–19 years is complications during pregnancy and childbirth.[35] Identifying characteristics that put individuals at higher risk of these complications will help in targeting interventions to populations that are appropriate to their setting.

A significant strength of this study is that it uses a large cohort study, meaning that the majority of statistical analyses do not suffer from problems due to small numbers and the population recruited the cohort is largely representative of the population as a whole. There are however some small difference between the populations recruited and not recruited that should be acknowledged. A lower proportion of mothers aged 20–24 years were recruited compared with those not in the cohort and a higher proportion of South Asian and primiparous women. A lower proportion of mothers at the lower end of the control group may therefore have had some bearing on the prevalence of some outcomes in that group, which is a limitation of this study.

Attempts were made to control for the effect of confounding variables in the multivariate logistic regression model by including a measure of socioeconomic deprivation and ethnicity in the model and by restricting the analysis to primiparous women delivering a singleton. These variables were selected due to their independent association with the outcome variables. Other variables were not included in the model due to a high degree of correlation between variables. There still exists, however, the possibility that the effect sizes detected in this study

are influenced by unmeasured or residual confounding variables.

Despite the large numbers overall, there was still only a relatively small number of adolescent women in the cohort, particularly in the subgroup analysis. Stillbirth, premature deliveries and very and extremely low birth weights were also relatively rare events, meaning that this study may have failed to detect differences in outcomes between groups due to being insufficiently powered.

The availability of routine hospital data linked to the cohort data was also a significant strength of this study. The use of this data did however also present limitations in that the analysis was restricted to the variables collected routinely, and there was no opportunity to recover missing data.

CONCLUSIONS

This study identifies some important variations in obstetric and perinatal outcomes by maternal age. Extremely low birth weight and extremely preterm delivery were concerns for adolescent mothers. Findings relating to maternal outcomes were also consistent with the existing literature showing lower risk of gestational diabetes, caesarean delivery and instrumental birth. Further work to establish the causal mechanisms behind the links between maternal age and maternal and neonatal outcomes would be advantageous, particularly for adolescent mothers where there are significant gaps in the existing literature.

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Contributors KM-D: completion of data analysis and responsible for writing the manuscript. KK: providing specialist input on statistical methods. VJB: providing specialist input on methods and structure, providing comments and making amendments to the manuscript. HS: providing specialist input on methods and structure, providing comments and making amendments to the manuscript.

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Competing interests None declared.

Patient consent Detail has been removed from this case description/these case descriptions to ensure anonymity. The editors and reviewers have seen the detailed information available and are satisfied that the information backs up the case the authors are making.

Ethics approval Ethical approval for the study was granted by Bradford Research Ethics Committee (ref no. 07/H1302/112).

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5.4 Summary and implications for thesis

This study provides a robust comparative analysis of how rates of important health outcomes differ between adolescent women and a reference group aged 20-34 years. The study has identified associations between young maternal age and extremely low birthweight and very and extremely preterm delivery which have not previously been reported in UK based studies. This work also concurs with and contributes to the body of evidence showing that adolescent women are less likely to experience gestational diabetes or have assisted deliveries. This study met the element of the research objective it was designed to address by examining differences in birth outcomes between adolescent and adult mothers in a large cohort data set; this objective also aimed to examine differences in dietary patterns between the two age groups which is presented in the following chapter.

Chapter 6 - Dietary patterns

6.1 Introduction

This chapter briefly summarises the rationale for the second study in this programme of research assessing the relationship between maternal age and dietary patterns in the Born in Bradford cohort, followed by a copy of the full published research paper in its original form. The chapter also includes a summary of key points, measurable impact of the work and discussion of its contribution to the thesis.

The systematic literature review presented in chapter three showed that there were some areas of concern regarding adolescent women's nutrient intake and nutritional biomarker status during pregnancy. This review also identified that there were gaps in the existing literature regarding the characteristics of the young women at highest risk of nutritional deficiencies and the extent to which the intake of older pregnant women differed to that of adolescents. This study therefore aims to begin to address these identified gaps in the literature and to contribute to addressing the second research objective as set out in chapter one to *"Examine differences in dietary intake and birth outcomes between adolescent and adult mothers in a large cohort data set".*

6.2 Publication and Impact

The manuscript describing this study was accepted for publication in PLoS One in December 2018. PLoS One is a multidisciplinary open access journal with a focus on scientific rigour regardless of subject area. The journal has an impact factor of 2.766 and an international readership. Since publication online the full text of the article has been accessed 109 times (correct as of 20.01.19).

6.3 Published paper: Article C

The published paper entitled *" Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis"* is reproduced here in the format in which it was published online.

PLOS ONE

RESEARCH ARTICLE

Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis

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Data Availability Statement: The data on which this study is based have not been uploaded because they belong to a third party. Data requests can be made directly to Born in Bradford by completing an expression of interest form available from https://borninbradford.nhs.uk/research/how-to-access-data/ and submitting it to the BiB Programme Director (rosie.mceachan@bthft.nhs.uk).

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Abstract

Objective

Explore associations between dietary patterns and maternal age

Design

Population based cohort study

Setting

Maternity department of a large hospital in northern England

Sample

Women delivering a singleton at Bradford Royal Infirmary between March 2007 and December 2010 (N = 5,083).

Methods

Survey data including maternal dietary patterns derived from food frequency questionnaire data using principal component analysis (PCA) were compared by maternal age using one-way ANOVA and chi-squared as appropriate.

Main outcome measures

Dietary pattern PCA scores, supplement use, familiarity and compliance with 5-a-day fruit and vegetable recommendations, consumption of cola, maternal BMI.

Results

Three distinct dietary patterns were derived from the data; snack and processed foods, meat and fish and grains and starches. Mean PCA score for snack and processed foods was higher among women aged ≤19 (0.6, CI 0.4 to 0.8) than women aged 20–34 (-0.02, CI -0.1 to 0.01) and those aged 35≥ (-0.3, CI -0.4 to -0.2). Women aged 35≥ had a significantly

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Competing interests: The authors have declared that no competing interests exist.

higher mean PCA score for the grains and starches dietary pattern (0.1, CI 0.03 to 0.3) compared to both the 20–34 years (-0.01, CI -0.05 to 0.02) and the ≤19 (-0.04, CI -0.2 to 0.1) groups. No differences were observed between groups in mean PCA scores for the meat and fish dietary pattern. Adolescent women also had higher intakes of sugar sweetened cola (0.9 cups per day, CI 0.7 to 1.1) and reported lower levels of fruit and vegetable and supplement intake. Women aged 35≥ had a higher mean BMI (28.0, CI 27.5 to 28.4) and higher prevalence of overweight (36.8%) and obesity (29.6%, p<0.001).

Conclusions

Significant differences were observed between age groups both in terms of diet quality and BMI. Interventions targeted by age group may be advantageous in improving maternal nutrition and contribute to healthy pregnancies.

Introduction

Nutrition during pregnancy is a well-established modifiable factor which has the potential to impact upon the health and well-being of both mother and child[1]. Study of nutritional intake and nutrient sufficiency in populations is difficult owing to the fact that individuals will have differing nutritional needs due to differences in environmental and genetic factors such as energy expenditure, body composition and metabolism. This is particularly true when investigating the relationship between nutrition and maternal and neonatal health as this is complicated by other biological, demographic and social factors, which vary substantially between different populations.

One such factor is the age of the mother during pregnancy. Adolescence is a time of substantial physiological change during which the nutritional needs of adolescent women are likely to differ from those of older women. Previous work examining the impact of maternal growth on outcomes in adolescent pregnancies suggested that nutrient partitioning between mother and child in growing adolescents negatively affected foetal growth and prematurity[2]. A further study[3] also found mean birthweight in babies born to adolescent women to be lower than those born to adult women; however this was not related to maternal growth in the adolescent participants. This suggests that the relationship between maternal age, maternal growth and foetal growth is complex and warrants further investigation, given that low birthweights are associated with short and long term adverse health outcomes[4].

A recent systematic review of nutritional status of pregnant adolescents in developed countries found that intakes of energy, fibre and a number of micronutrients were below recommended levels in this population[5]. The study also found that there was some cause for concern with regard to biological markers of iron and selenium status.

Similar results were however reported in two reviews which were not confined to adolescent populations[6–7]. This suggests that while there is evidence that diet quality may vary by maternal age, more work to examine the nature of these differences would be advantageous.

These previous works suggest that there may be nutritional issues that may impact on the health of both mother and child which vary by maternal age. This study therefore aims to assess differences in dietary pattern by maternal age in the Born in Bradford cohort.

Methods

Born in Bradford is a largely bi-ethnic cohort of approximately 13,500 children with high levels of socio-economic deprivation. Pregnant women who were booked to deliver at Bradford Royal Infirmary were invited to join the cohort between March 2007 and December 2010. A detailed profile of the cohort has been published elsewhere[8]. This study uses data collected in phase 2 of the Born in Bradford cohort study[8] to examine dietary patterns of women delivering singletons who took part in the study. The Born in Bradford study is a prospective cohort study for which participants were recruited during pregnancy. All women booked for delivery at Bradford Royal Infirmary are offered an oral glucose tolerance test (OGTT) at 26–28 weeks gestation. Women were invited to participate in the Born in Bradford study when attending this appointment. Informed consent was obtained from all participants women were asked to complete a baseline questionnaire. All participants including those aged under 18 were considered competent to consent on their own behalf. Documents including participant information, consent forms and questionnaires are available on the Born in Bradford website[9] Recruitment took place between March 2007 and December 2010 and over 80% of women eligible in this period agreed to take part. A sub-set of the whole cohort completed a food frequency questionnaire (FFQ) as part of the baseline data collection; therefore data relating to 5,083 pregnancies was available for this analysis. Ethical approval for the study was granted by Bradford Research Ethics Committee (ref no. 07/H1302/112).

Variables in the analysis

The following demographic characteristics of the sample reported in the baseline questionnaire were explored; ethnicity, marital status, parity, education, smoking during pregnancy, alcohol and illegal drug use during pregnancy and index of multiple deprivation (IMD) score (IMD is the official measure of relative deprivation for small areas in England and combines information from seven domains of deprivation; income, employment, education, health, crime, housing and environment)[10]. Body mass index and number of weeks gestation at the booking appointment (usually before 12 weeks of pregnancy) were obtained from medical records. Variables related to nutrition examined were: use of any vitamins or iron supplements in the last 4 weeks, use of Pregnacare multivitamins at least twice per week, familiarity with 5-a-day fruit and vegetable recommendations, consumption of 5 fruit and vegetable portions per day and sources of advice about healthy eating, number of cups of regular (sugar sweetened) and diet (artificially sweetened) cola consumed per day. Dietary patterns were derived from FFQ data using principal component analysis as described below.

Statistical analysis

Due to the focus of this study being on detecting differences between age groups the study population was categorised into three groups for analysis according to maternal age; $\leq$19, 20–34 and 35$\geq$ years, with women aged 20–34 being considered as the reference group. Statistical analysis was undertaken using SPSS 24.

Principal component analysis

In order to evaluate nutrition in this population a series of statistical analyses were conducted using responses to the FFQ and applying principal component analysis (PCA) to identify distinct patterns of food types consumed. The FFQ was completed at 26–28 weeks gestation and refers to food intake during the preceding 4 weeks. There were a total of 37 items included in the FFQ, details of which are given with the results of the PCA. Since the original objective of

the FFQ was to characterise the intakes of key food items only, it was not appropriate to derive an estimate of total energy intake. Responses to the food frequency questionnaire were given on either an eight (1 = Rarely or never, 8 = 5+ times per day) or five (1 = Rarely or never, 5 = 7 + times per week) point scale, these responses were therefore transformed to give an estimation of frequency per day in order to standardise questions asked in different formats.

Individual items on the FFQ were then grouped by type and total frequency of consumption of different food groups estimated. The grouped nutritional variables were then used as the basis for a PCA in order to examine the dietary patterns which exist within the data set. PCA was selected as it allows for a larger number of variables to be reduced and underlying factors exposed.

Analysis of differences between age groups

Differences between maternal age groups in both the demographic and nutrition related variables were explored using Chi-Square for categorical data and one-way ANOVA for continuous data; categorical variables are presented as percentages and continuous variables as means and 95% confidence intervals. Logistic regression analyses were used to compare the rate of each of the categorical nutrition related variables by age group and differences between groups estimated using odds ratios. Multivariate logistic regression models were then used to adjust these comparisons for confounding variables.

Crude and adjusted odds ratios (OR and aOR) are therefore presented with 95% confidence intervals. Index of multiple deprivation (IMD) score and maternal ethnicity (white British, Pakistani or any other ethnicity) were included as covariates in the adjusted analysis, due to the association of these variables with dietary pattern identified in the literature[11–12]. Where dependent variables were dichotomous, binary logistic regression models were produced. There were also two variables with more than two categorical outcomes for which multinomial logistic regression models were produced. In order to examine the continuous variables regarding consumption of cola linear regression models were produced and dummy variables created to enable the inclusion of categorical independent variables in the model.

In the multivariate regression models for this study there is no clear logical or theoretical basis for assuming any variable to be prior to any other, either in terms of its relevance to the research goal of explaining phenomena, or in terms of a hypothetical causal structure of the data. For this reason a simultaneous method of including independent variables in the multivariate regression models was considered to be most appropriate, as opposed to a stepwise method.

Due to the assumptions required to produce statistical models not being met for the dietary pattern scores (the distribution of the dietary pattern scores is significantly skewed, even following attempts to transform the data) it was not possible to adjust the analysis of these variables for potentially confounding variables.

Results

Characteristics of the sample

Data were available for 5,083 pregnancies for this analysis; demographic characteristics of the participants included in the study are shown in Table 1. Most participants in the cohort were aged 20–34 (84%) with 9.5% aged 35 or over and 6.5% aged 19 or under. The sample has a diverse ethnic mix consisting of 46.8% women describing themselves as of Pakistani origin, 38.4% white British and 14.8% of other ethnicities; this distribution of ethnic groups was roughly consistent across the age groups with the exception of the adolescent group which was significantly different. Among women aged 19 and under only 17.6% were of Pakistani

Table 1. Demographic characteristics.

	≤19		20–34		35≥		Total		
	N	%	N	%	N	%	N	%	p =
Whole Cohort	330	6.5	4269	84.0	484	9.5	5083	100.0	
Ethnicity									
Pakistani	58	17.6	2052	50.0	266	41.9	2376	46.8	<0.001
White British	229	69.4	1454	35.4	264	41.6	1947	38.4	
Any other ethnicity	43	13.0	602	14.7	105	16.5	750	14.8	
Marital Status									
Married	48	14.5	2869	69.9	493	77.9	3410	67.3	<0.001
Not married—living with partner	84	25.5	704	17.1	85	13.4	873	17.2	
Single	198	60.0	533	13.0	55	8.7	786	15.5	
Parity									
0	295	90.2	1571	39.0	112	17.9	1978	39.7	<0.001
1	29	8.9	1296	32.2	164	26.2	1489	29.9	
2	3	0.9	723	18.0	121	19.4	847	17.0	
3 or more	0	0.0	435	10.8	228	36.5	663	13.3	
Highest level of education									
Less than 5 GCSEs* grade A-C or equivalent	129	39.1	825	20.0	184	29.0	1138	22.4	<0.001
5 or more GCSEs grade A-C or equivalent	152	46.1	1307	31.7	132	20.8	1591	31.3	
A-levels** or higher	21	6.4	1696	41.2	248	39.1	1965	38.7	
Other/unknown	28	8.5	290	7.0	71	11.2	389	7.7	
Smoked during pregnancy									
Yes	159	48.2	644	15.7	62	9.8	865	17.1	<0.001
No	171	51.8	3461	84.3	573	90.2	4205	90.2	
Drunk alcohol in the first three months of pregnancy									
Yes	102	58.3	574	47.8	119	52.2	795	49.6	0.59
No	73	41.7	621	51.7	109	47.8	803	50.1	
Drunk alcohol since the fourth month of pregnancy									
Yes	43	24.4	459	38.4	105	47.1	607	38.1	<0.001
No	133	75.6	733	61.4	118	52.9	984	61.8	
Used recreational drugs during pregnancy									
Yes	18	5.5	42	1.0	1	0.2	61	1.2	<0.001
No	312	94.5	4062	99.0	632	99.8	5006	98.8	
BMI Category									
Underweight (Below 18.5)	23	7.1	183	4.6	5	0.8	211	4.3	<0.001
Healthy weight (18.5–24.9)	200	61.7	1837	46.4	200	32.8	2237	45.7	
Overweight (25–29.9)	63	19.4	1142	28.8	224	36.8	1429	29.2	
Obese (30 or higher)	38	11.7	798	20.2	180	29.6	1016	20.8	
	N	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**p =**
BMI at booking appointment	324	23.7 (23.2 to 24.3)	3972	25.9 (25.7 to 26.1)	609	28.0 (27.5 to 28.4)	4905	26.0 (25.9 to 26.2)	<0.001
IMD Score	330	45.1 (43.1 to 47.0)	4117	43.0 (42.5 to 43.6)	635	37.3 (35.8 to 38.7)	5082	42.4 (42.0 to 42.9)	<0.001
Number of weeks gestation at booking appointment	311	13.9 (13.5 to 14.4)	3905	12.7 (12.6 to 12.8)	602	13.1 (12.8 to 13.3)	4818	12.8 (12.7 to 12.9)	<0.001

*General Certificate of Secondary Education—subject specific examinations taken at the end of compulsory education at age 16 in England

** Advanced Level—non-compulsory subject specific examinations taken at age 18 in England

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ethnicity and 69.4% were white British, the proportion belonging to other ethnic groups was similar to other age groups. There were other significant variations in the characteristics of the sample by maternal age. Women in the adolescent age group were more likely to be unmarried or living with a partner, to be expecting their first child and to have completed lower levels of education compared to older women. Women in the adolescent age groups were also more likely to have smoked or used recreational drugs during pregnancy, however there was no difference in reported alcohol use in the first trimester between age groups, and adolescents were less likely to have used alcohol since the fourth month of their pregnancy compared to older women. Women in the oldest age category were most likely to be overweight or obese while adolescent women were found to have higher prevalence of underweight. IMD score decreased as maternal age increased suggesting adolescent women lived in areas of higher deprivation. Adolescent women also booked with a midwife for antenatal care later than older women.

Nutrition related variables

Analysis of the nutrition related variables (Table 2) showed that young women aged 19 and under were less likely to have used any vitamins or iron supplements in the 4 weeks preceding completing the questionnaire compared to other age groups. Adolescents were also the least likely group to have used Pregnacare multi-vitamins at least twice per week during their pregnancy. While there was no differences between age groups in awareness of the recommendations to eat at least five portions of fruit and vegetables a day the adolescent group were less likely than older women to achieve this recommendation. The adolescent group consumed significantly more sugar sweetened cola compared to older women; there were no statistically significant differences in consumption of artificially sweetened cola between age groups.

Adjustment for ethnicity and IMD score in the regression analysis produced similar results as shown in Table 3.

Results of the principal component analysis

Several combinations of food groupings were explored to see which gave the most sensitive output in the PCA. These included loading all of the food items in separately, separating whole grains from other grains and starches, analysing all proteins as one group and separating proteins by type (red meat, poultry and fish). The groupings outlined in Table 4 explained the highest amount of variance; therefore these were the input variables which were selected. Loading all of the foods individually returned very low levels of correlation between the variables, meaning that a very large number of factors (11) were returned. This suggested that grouping the variables to form new variables would improve the correlation of intake between food types and therefore make the PCA more meaningful.

When the analysis was completed without stipulating the number of factors to be retained two factors were retained which explained 43.8% of the total variance. On closer examination of the output, including examination of the inflection point of the scree plot, it was considered that a third and fourth factor with Eigen values of 0.971 and 0.939 respectively should be considered for inclusion. The analysis was therefore run with both 3 and 4 factors stipulated and the results compared with the initial analysis. The inclusion of a third factor presented a distinct dietary pattern which added to the logical understanding and interpretation of the data. The inclusion of a fourth factor did not however add to the understanding of the data. The decision was therefore made to retain 3 factors from the analysis, the inclusion of these 3 factors would then account for 55.9% of the total variance. Details of the retained factors and factor loadings are given in Table 5, factor loadings were considered to be very good where they were 0.6 or above and moderate where they were 0.45–0.59[13]. The PCA therefore identified

Table 2. Maternal age and nutrition related variables.

	≤19		20–34		35≥		Total		
	N	%	N	%	N	%	N	%	p =
Used any vitamins or iron supplements in the last 4 weeks									
Yes	86	26.1	1606	39.1	318	50.1	2010	39.6	<0.001
No	244	73.9	2500	60.9	317	49.9	3061	60.4	
Used Pregnacare multivitamins at least twice per week									
Yes	21	6.4	553	13.4	114	18.0	688	13.5	<0.001
No	309	93.6	3565	86.6	521	82.0	4395	86.5	
Are you familiar with the 5 a day recommendations for fruit and vegetables?									
Yes	303	95.6	3279	95.5	500	97.1	4082	95.7	0.238
No	14	4.4	156	4.5	15	2.9	185	4.3	
Do you consume 5 portions of fruit and vegetables per day?									
Always	28	8.8	586	17.0	126	24.5	740	17.3	<0.001
Sometimes	259	81.7	2616	76.0	365	70.9	3240	75.8	
Never	30	9.5	238	6.9	24	4.7	292	6.8	
Where does most of your advice about healthy eating during pregnancy come from?									
Family members	124	37.6	845	20.5	83	13.1	1052	20.7	<0.001
Midwives/Health visitors	119	36.1	1175	28.5	155	24.4	1449	28.5	
Magazines/Newspapers	31	9.4	490	11.9	99	15.6	620	12.2	
GPs/Doctors	16	4.8	126	3.1	13	2.0	155	3.0	
Books	11	3.3	395	9.6	85	13.4	491	9.7	
Other	11	3.3	310	7.5	66	10.4	387	7.6	
Friends	5	1.5	96	2.3	13	2.0	114	2.2	
	N	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**N**	**Mean (95% CI)**	**p =**
Cups of regular (sugar sweetened) cola per day	330	0.9 (0.7 to 1.1)	4269	0.4 (0.4 to 0.4)	484	0.2 (0.1 to 0.2)	5083	0.4 (0.4 to 0.4)	<0.001
Cups of diet (artificially sweetened) cola per day	330	0.2 (0.1 to 0.2)	4269	0.1 (0.1 to 0.1)	484	0.1 (0.1 to 0.2)	5083	0.1 (0.1 to 0.1)	0.674

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three independent variables whose relationship to other variables in the data set could be considered.

Association between dietary pattern and maternal age

The analysis showed that there was an association between both the snacks and processed foods pattern and the grains and starches pattern and maternal age group (Table 6). The mean PCA score for snack and processed foods was highest in the adolescent group. The opposite was observed in the case of the grains and starches dietary pattern where women aged 35 and over had the highest mean PCA score. There were no statistically significant differences between groups relating to the meat and fish dietary pattern. The results of these analyses are shown in Table 6.

Discussion

The results show an association between two of the dietary patterns in this analysis and maternal age. Strongest associations were seen in the snack and processed foods pattern where

Table 3. Dietary behaviour by maternal age.

	Crude OR (95% CI)	aOR (95% CI)*	Crude OR (95% CI)	aOR (95% CI)*
	≤19 Years (n = 641)†		35≥ Years (n = 1427) †	
Used any vitamins or iron supplements in the last 4 weeks				
Yes	0.54 (0.42 to 0.70)	0.71 (0.55 to 0.92)	1.53 (1.27 to 1.85)	1.56 (1.29 to 1.89)
No	Ref	Ref	Ref	Ref
Used Pregnacare multivitamins at least twice per week				
Yes	0.44 (0.28 to 0.68)	0.44 (0.28 to 0.70)	1.49 (1.16 to 1.90)	1.33 (1.04 to 1.71)
No	Ref	Ref	Ref	Ref
Familiar with the 5 a day recommendations for fruit and vegetables				
Yes	1.01 (0.58 to 1.77)	0.62 (0.35 to 1.12)	1.46 (0.80 to 2.65)	1.26 (0.67 to 2.24)
No	Ref	Ref	Ref	Ref
Consume 5 portions of fruit and vegetables per day				
Always	0.37 (0.22 to 0.63)	0.35 (0.20 to 0.61)	1.96 (1.18 to 3.23)	1.68 (1.01 to 2.80)
Sometimes	0.77 (0.52 to 1.15)	0.68 (0.45 to 1.03)	1.20 (1.18 to 3.23)	1.11 (0.69 to 1.78)
Never	Ref	Ref	Ref	Ref
Where does most of your advice about healthy eating during pregnancy come from?				
Family members	4.26 (2.27 to 8.00)	5.65 (3.14 to 10.18)	0.49 (0.33 to 0.72)	0.56 (0.36 to 0.88)
Midwives/Health visitors	2.94 (1.56 to 5.51)	2.77 (1.54 to 4.99)	0.69 (0.49 to 0.99)	0.78 (0.53 to 1.16)
Magazines/Newspapers	1.76 (0.87 to 3.55)	1.70 (0.86 to 3.36)	0.84 (0.57 to 1.25)	0.83 (0.53 to 1.29)
GPs/Doctors	3.66 (1.65 to 8.10)	3.92 (1.86 to 8.25)	0.46 (0.22 to 0.97)	0.62 (0.31 to 1.24)
Books	0.79 (0.34 to 1.84)	1.09 (0.51 to 2.35)	1.05 (0.70 to 1.56)	1.03 (0.66 to 1.61)
Friends	1.49 (0.50 to 4.38)	1.61 (0.64 to 4.05)	0.60 (0.29 to 1.27)	0.71 (0.36 to 1.42)
Other	Ref	Ref	Ref	Ref
	Unadjusted β (95%CI)	Adjusted β (95%CI)*	Unadjusted β (95%CI)	Adjusted β (95%CI)*
Cups of regular (sugar sweetened) cola per day	0.49 (0.36 to 0.62)	0.46 (0.33 to 0.59)	-0.22 (-0.33 to -0.12)	-0.20 (-0.31 to -0.09)
Cups of diet (artificially sweetened) cola per day	0.03 (-0.04 to 0.09)	-0.02 (-0.09 to 0.05)	0.01 (-0.05 to 0.07)	0.94 (-0.06 to 0.05)

*Adjusted for index of multiple deprivation score and maternal ethnicity

†comparison to reference category women aged 20–34 years

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women aged ≤19 were found to have the highest mean PCA score reflecting a higher intake of foods that are typically viewed as snack items (including crisps, chocolate, biscuits and cake) and moderate intake of processed meat. Adolescent women also reported consuming higher levels of sugar sweetened cola compared to older women; no differences were observed in levels of consumption of artificially sweetened cola.

There were no differences by age group in women's awareness of recommendations to eat five portions of fruit and vegetables per day; however adolescent women were less likely to say

Table 4. Food groupings for principal components analysis.

Potatoes	Grains and Starches	Whole meat and fish	Meat in Sauce	Processed meat and fish	Cured Pork Products	Savoury Snacks	Sweet Snacks
Chips	Fibre or bran-rich wheat breakfast cereal	Beef	Chicken or turkey in sauce	Beef burgers	Bacon	Potato Crisps	Cakes, buns, gateaux, doughnuts, muffins
Roast or fried potatoes	Oat cereals	Lamb	Beef, lamb or goat in sauce	Kebabs	Ham	Other salted savoury snacks	Sweet pastries
	Crispbread	Pork	Pork in sauce	Meat pies and pastries	Cured sausage		Chocolate bars and chocolate coated biscuits
	Other breakfast cereals	Chicken or turkey	Gravy made with pan or meat juices (not instant)	Sausages			Sweet biscuits
	Pasta or noodles	White fish		Hotdogs			
	Savouries like Yorkshire pudding, pakoras etc.	Tinned tuna		Chicken or turkey nuggets			
		Fresh or tinned oily fish		White fish in batter or breadcrumbs			
		Smoked fish					
		Salted or dried fish					

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they achieve this recommendation. Adolescent women in the sample also reported the lowest use of nutritional supplements.

Adolescent women had a higher prevalence of underweight (BMI <18.5) and older women a higher prevalence of overweight or obesity (BMI >25).

These results are largely consistent with findings from the latest wave of the National Diet and Nutrition Survey (NDNS)[14]. Results from the 2012/13–2013/14 surveys found significantly fewer adolescent girls reported meeting 5-a-day recommendations and had higher intakes of sugar sweetened beverages compared to adult women. The prevalence of overweight and obesity in the NDNS was also in line with this cohort (58% among adult women and 38% among girls aged 11–19). Whilst the observation that a population with an overall poorer quality diet would have lower levels of overweight and obesity is counterintuitive, however the impact of poor diet on BMI status is cumulative meaning that the effects of poor diet on the adolescent population will be evident in time if dietary changes are not made[15]. These similarities suggest that the findings of the current study are likely to be reflective of the UK

Table 5. Dietary patterns identified by principal component analysis.

	Component		
	1 Snack and processed foods	2 Meat and fish	3 Grains and starches
Savoury Snacks	0.756		
Potatoes	0.691		
Sweet Snacks	0.666		
Processed meat and fish	0.510	0.480	
Whole meat and fish		0.794	
Meat in Sauce		0.729	
Cured pork products		0.470	
Grains and Starches			0.888

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Table 6. Differences in dietary pattern scores† by maternal age.

	≤19		20–34		35≥		Total		
	N	Mean PCA Score (95% CI)	N	Mean PCA Score (95% CI)	N	Mean PCA Score (95% CI)	N	Mean PCA Score (95% CI)	p =
Snack and Processed Foods	277	0.6 (0.4 to 0.8)	2949	-0.02 (-0.1 to 0.01)	320	-0.3 (-0.4 to-0.2)	3546	0.0 (-0.03 to 0.03)	<0.001
Meat and Fish	277	0.04 (-0.1 to 0.2)	2949	-0.01 (-0.04 to 0.03)	320	0.04 (-0.05 to 0.1)	3546	0.0 (-0.03 to 0.03)	0.55
Grains and Starches	277	-0.04 (-0.2 to 0.1)	2949	-0.01 (-0.05 to 0.02)	320	0.1 (0.03 to 0.3)	3546	0.0 (-0.03 to 0.03)	0.03

† Dietary pattern scores derived from Principal Component Analysis indicating the extent to which participants adhere to the dietary pattern

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population. Dietary patterns during pregnancy have been previously examined using similar methods. One UK study[16] found an association between dietary pattern and maternal age with the 'health conscious' pattern being associated with increasing age and the opposite being true of the 'processed' pattern identified in the study. A further study conducted in New Zealand[17] similarly found a positive association between increasing maternal age and 'health conscious' and 'fusion/protein' dietary patterns and the opposite association with 'junk' and 'traditional/white bread' patterns.

The findings of these studies are consistent with those of the present study however neither specifically addressed adolescent women or older women as distinct groups. As discussed in the introduction, the nutritional needs of adolescent women in particular may differ from those of older women due to the continued growth of the mother meaning that understanding the nutritional intake of young women during pregnancy is important. This study helps us to start to understand the dietary patterns associated with this group, however further work based on more robust dietary surveys is needed in order to improve understanding of this complex topic. A particular strength of this work is that it utilises well-established, ethnically diverse, UK based cohort data in a way which is unique to this study. This cohort includes a large number of participants meaning that analysis by maternal age including an adolescent group is both possible and robust.

There were limitations in the dietary data available for this study. The number of items included in the FFQ was limited meaning that there is potential for the dietary patterns identified to be lacking in detail, or that additional patterns which might be present in the population could have been missed. This issue also resulted in the distribution of dietary pattern scores being significantly skewed, meaning that it was not possible to use statistical modelling to predict the extent to which maternal age influences dietary pattern, only that there appears to be an association. There was also no definition of portion size in the collection of data meaning there is likely to be significant variation between participants self-defined portion sizes. The FFQ was completed at 26–28 weeks of pregnancy and related to the preceding 4 weeks, meaning that the dietary patterns identified are only reliably relevant to the second trimester of pregnancy. Women's diet may change over the course of pregnancy[18] meaning that these results may not be generalisable to the first and third trimesters.

This study assesses dietary patterns ascertained by principal component analysis. Dietary patterns have been defined as "foods that are actually consumed in various characteristic combinations"[19]. The study of dietary patterns as opposed to single foods or nutrients has the advantages of allowing for interactions between nutrients to be accounted for and reflecting more accurately that people do not eat single foods or nutrients, they eat meals comprising of many food types. Dietary patterns can be derived either theoretically as in the case of the Diet

Quality Index[20] where foods are ranked based on what current knowledge defines as healthy or less healthy or empirically using statistical methods to reduce collected dietary data into distinct patterns. A systematic review of the use of these methods in nutritional epidemiology has concluded that empirically derived eating patterns may improve our understanding of eating behaviour and therefore provide a stronger evidence base from which to provide dietary advice[21]. For these reasons this method of assessing dietary patterns is considered to be appropriate for this study.

The results suggest that there may be some cause for concern regarding the quality of adolescent pregnant women's diet, despite reporting similar levels of knowledge of recommendations to older women. This suggests that factors other than knowledge may be important in developing behaviour change interventions. There are a number of different theoretical models discussing the process of translating knowledge into action in public health. For example the health belief model[22] is based on the premise that individuals will make an assessment as to whether the benefits of a change in behaviour outweigh the perceived costs. This includes an assessment of both the risks associated with not changing behaviour, their belief in the potential benefits and the perceived barriers to taking action. Applied to this data therefore there are several avenues for further investigation with the aim of encouraging positive dietary changes.

The adolescent women in the sample also reported less use of nutritional supplements compared to the reference group. This suggests that any gaps in the nutritional profile of young women during pregnancy as a result of a sub-optimal diet may not be being filled by supplementary vitamins and minerals and may therefore leave women in this group with nutrient deficiencies.

Consumption of sugar and artificially sweetened cola in this cohort has previously been examined[23] with results showing that high intakes of sugar sweetened cola were associated with higher odds of preterm delivery in the cohort as a whole. This suggests sugar sweetened cola intake in adolescent women may be a cause for concern.

Energy intake was not available for analysis in this dataset meaning that maternal BMI at booking appointment is a useful indicator. Individual differences in total energy intake are largely determined by a combination of body size, physical activity and metabolic efficiency. Measurements of energy intake and physical activity in epidemiology are often crude and suffer from under or over reporting, and metabolic efficiency is essentially impossible to measure in this setting. For these reasons height and weight measurements are often considered a suitable alternative to measures of energy intake[24]. The results of this study suggest that for some adolescent women their overall energy intake during pregnancy may be insufficient while an association with overweight and obesity in older women suggests an excessive energy intake.

The results of this study are consistent with previous work assessing maternal obesity in the UK[25]. This work found that levels of maternal obesity (measured during the first trimester) increased as maternal age increased. Increases in maternal obesity impact significantly on the health of mothers and babies and increase the need for specialist and high dependency care, therefore having both health and economic implications.

Conclusions

There may be some cause for concern with regard to diet quality in adolescent women and obesity among older women during pregnancy. Further work using more comprehensive methods of dietary data collection would be advantageous in assessing the nature of these relationships.

The impact of dietary pattern on birth outcomes is also an important area for further work, particularly in light of evidence presented previously that there is a higher risk of extremely low birthweight babies and extremely pre-term delivery among adolescent women in this cohort[26].

Interventions targeted to specific age groups to facilitate behaviour change may be useful due to differences identified in the types of nutritional issues affecting pregnant women at different ages. There is a need to further understand the barriers to healthy eating during pregnancy in order to develop successful interventions.

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6.4 Summary and implications for thesis

The results of this study show significant differences between adolescents and adult women with regard to their diet. Adolescent women had higher intakes of snack and processed foods and sugar sweetened cola and lower intakes of fruit and vegetables compared to older women. This is an important finding as it clearly demonstrates differences by age group which are likely to result in differences in nutritional status which may impact upon the health of the pregnancy.

6.5 Development of qualitative research phase

The final study in this programme of work uses qualitative methods to gain a deeper understanding of the factors which contribute to the observed differences in outcomes and diet in pregnant adolescents. The qualitative phase uses semi-structured interviews following a topic guide, the formation of which being informed by the results of the quantitative analyses presented in chapters 5 and 6. The topic guide (appendix 9) therefore focuses on gathering information regarding what the participants believe to be the most important issues are for young women to have healthy pregnancies before asking questions which are specific to nutrition. This approach allows for data regarding other health issues to be collected before leading the participants to focus on nutrition as this is the primary focus of this program of research. The topic guide was also designed to investigate how youth support professionals viewed their own role in supporting healthy adolescent pregnancies. The findings of the qualitative research phase are presented in the following chapter.

Chapter 7 - Supporting Healthy Adolescent Pregnancies

7.1 Introduction

This chapter presents the third and final study in this programme of research which is a qualitative investigation into how adolescents may be supported to achieve a healthier diet during pregnancy from the perspectives of professionals who provide support for young women. A brief summary of the rationale for and key findings of this study is then followed by a copy of the full published research paper in its original form. The chapter also includes discussion of the contribution of this study to the thesis as a whole.

The work so far presented in this thesis has shown that there are differences between pregnant adolescents and older pregnant women, both in terms of their diet and the outcomes of their pregnancies for both mother and neonate. The quantitative data analysis does not however contextualise these findings by considering the factors which may affect young women's ability to eat well during pregnancy.

The views of young women and health care professionals on this topic have previously been reported[109] in a study which interviewed 34 young women (aged 16-19) and 20 healthcare professionals. The findings of this study suggested that young women did make small changed to their diet during pregnancy despite significant barriers such as lack of knowledge, financial concerns and social constraints. Young women reported that their primary consern was to have a healthy baby and so wanted to understand the benefits of dietary changes in those terms. Healthcare professionals reported that while they did provide information and advice regarding nutrition they often lacked the time and resources to focus on this message. This study therefore aims to explore the perspectives of youth support workers with a wider remit to investigate how they might contribute to improving the health and wellbeing of pregnant young women. . The development of the interview guide (appendix 9) was informed by the results of the quantitative analysis. In this sequential exploratory mixed methods design research this process is the first point of integration between the two phases of the study[99].

7.2 Publication and Impact

The manuscript describing this study is currently under review for publication in Evidence Based Midwifery.

7.3 Article D

The manuscript entitled *"Perspectives of youth support professionals on supporting healthy eating in adolescent pregnancies"* is reproduced here in the format in which it has been submitted for publication.

Title

Perspectives of youth support professionals on supporting healthy adolescent pregnancies

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Perspectives of youth support professionals on supporting healthy eating in adolescent pregnancies

Abstract

Background: Nutrition during pregnancy has been identified as an important modifiable factor to reduce adverse outcomes in adolescent pregnancies. Young women are supported during their pregnancies by a variety of professionals with both clinical and non-clinical roles. Professionals with a non-clinical support role provide practical and emotional support for young women and often have longer lasting professional relationships with their clients. For this reason this study aims to explore the perspectives of these professionals on how young women can be encouraged to improve their diet during pregnancy.

Methods: This exploratory, qualitative study purposefully sampled participants to take part in semi-structured interviews. Interviews were audio recoded and transcribed. Interview transcripts were then analysis thematically and emerging themes identified.

Results: Five overarching themes were identified from the data: Perceptions of dietary pattern; Connection with baby; Family and social stability; Building relationships and Service availability. Youth support professionals felt that young women often encountered numerous complex barriers to eating healthily during pregnancy. Their lives are often chaotic and lack stable partner and family relationships. They suggested that young women often needed specific practical support, such as being accompanied to health appointments, in order to make improvements. There was also some concern that increasing cuts to

services for this group would make it more difficult for vulnerable young women to access help.

Conclusions: A higher level of consistent, holistic support delivered by joined up networks of professionals is needed in order to help young women achieve healthier pregnancies. Further research is necessary to understand the context of young women's lives, how this relates to their experiences of pregnancy and what type of interventions or resources would have the biggest impact in supporting health behaviours.

Keywords: Adolescent; Pregnancy; Nutrition; Healthy eating; Youth work

Introduction

Pregnancy during the adolescent years has often been associated with higher rates of adverse outcomes for mother and child compared to women aged 20-35. This is the case both in terms of social issues such as isolation and poverty (Cook and Cameron, 2015) and clinical outcomes such as low birthweight and prematurity (Gilbert, Jandial and Field, 2004; Tyrberg, Blomberg and Kjolhede, 2013).

Work to assess the mechanisms by which early pregnancy increases the risk of poor outcomes has suggested that maternal nutrition may be an important modifiable factor. A systematic review by Gibbs et.al (2012) looking at the relationship between adolescent pregnancy and pregnancy outcomes found that very young maternal age had a negative effect on foetal growth and infant survival. The authors suggested that there may be competition between the

foetus and the mother who is still herself growing resulting in babies with low birthweight or who are small for their gestational age.

A further systematic review (Marvin-Dowle, 2016) of nutrient intakes and nutritional biomarkers in adolescent pregnancies found that intakes of energy, fibre and a number of key micronutrients were below recommended levels. Assessment of nutritional biomarkers also suggested there may be some cause for concern with regard to iron and selenium status.

Assessment of the dietary patterns of pregnant adolescents in the Born in Bradford cohort (Marvin-Dowle, 2018) has found that young women had higher intakes of snack and processed foods which were high in salt, sugar and saturated fats compared to older pregnant women. The study also found that adolescents had higher intakes of sugar sweetened cola and lower intakes of fruit and vegetables and nutritional supplements.

The evidence therefore suggests that pregnant adolescents are likely to have a diet which is nutritionally poor and also that this may have an impact on the health of their developing child. It is therefore important to understand more about the nature of young women's diets and how they can be supported to make positive changes during pregnancy.

One survey of young women and health care professionals regarding dietary habits and supplementation practices during pregnancy (Soltani et.al, 2017) found that young women did report making some positive changes to their diet during pregnancy. Participants reported increasing intake of fruit, vegetables and milk and the majority also reported taking nutritional supplements at some point during pregnancy. The young women taking part in the survey reported

that their reasoning for making improvements to their diet was the impact on foetal development. There were however also areas of concern in that young women reported consuming less red meat, eggs, oily fish and soft cheese, suggesting that there may be some confusion over foods which should be avoided during pregnancy. The same study also collected responses from health care professionals (HCPs) including midwives, family nurse practitioners and health visitors regarding their discussions with young women around diet and nutrition during pregnancy. Family nurse practitioners were more likely to discuss nutrition in greater depth with young women due to time constraints on midwife and health visitor appointments. Young women stated that they mostly prefer receiving advice and information from HCPs, with mixed responses for other sources including websites and apps, leaflets, family members or parenting classes. HCPs reported that young women often struggled to access Healthy Start vouchers or vitamins but that those who were most motivated would purchase supplements for themselves. It should be recognised however that these findings are restricted to those young women who have chosen to complete a survey on pregnancy nutrition, and so are likely to represent a more motivated group compared to the population as a whole.

Pregnant teenagers with otherwise uncomplicated pregnancies in the United Kingdom (UK) will receive standard National Health Service (NHS) antenatal care as a minimum. Additional services for this population are commissioned locally and therefore vary amongst NHS Trusts. The area in which this research has been conducted has previously had both teenage pregnancy specialist midwives and family nurse partnership services; however these services have been decommissioned at the time of writing.

HCPs are not the only group of professionals who have a role in supporting young women during pregnancy in the UK. Pregnant adolescents are at increased risk of being socially isolated or experiencing difficulties with housing or access to education and training (Cook and Cameron, 2015) . They are also more likely to have experienced being cared for by a local authority (Craine et.al, 2014). This means that a significant proportion of young women who become pregnant will have contact with professionals such as youth workers and support advisors who are likely to spend more time with young women than HCPs, whose appointment times are limited. These relationships are largely voluntary on the part of young people and some young women will have difficulties accessing support services, meaning that this type of additional support is far from universal. This said professionals who work in these roles have a unique insight into the experiences of young women during pregnancy and how they may be best supported to have healthy pregnancies. It is therefore this group who are the target for this study.

Aims

The research questions this study aims to address are:

What do youth support professionals perceive to be the barriers and facilitators to healthy pregnancies for young women?

How do youth support professionals think young women can be best supported to have a healthy diet during pregnancy?

Methods

Design

This exploratory, qualitative study used semi-structured interviews to gather information from professionals with a role in providing social or practical support to young women during pregnancy. Professionals whose main role was clinical such as midwives and health visitors were excluded, as the views of these professionals, alongside those of young women, have been sought previously (Rundle, Soltani and Duxbury, 2018). All participants worked in Sheffield which is a large city in Northern England. The interviews took place locally at a time and location convenient to the participants.

Characteristics of the research team

This study was undertaken as part of a PhD programme of work by Katie Marvin-Dowle (KMD), supervised by Prof. Hora Soltani (HS) and Dr Victoria Burley (VB). All of the recruitment and interviews were conducted by KMD during February 2017. KMD worked as a youth worker in sexual health and teenage pregnancy for a number of years before moving into public health epidemiology, she holds a Master's degree in Public Health and a post-graduate certificate in research methods as well as experience of working on numerous research projects and service evaluations, The interviewer was herself pregnant at the time of the research, however every effort was made to conceal the pregnancy until after interviews were completed in order not to influence the responses of participants.

Participants and recruitment

Participants were recruited following a purposive sampling strategy via email invitations sent to relevant agencies, physical flyers distributed to services, social media and word of mouth. As this was intended as an exploratory piece of work the planned sample size was 8-10 participants which was considered adequate to assess the issues considered to be most important by participants. Individuals were eligible to take part if they had a professional role supporting young people and had some experience of working with young women (aged ≤19) during pregnancy. Participants were contacted prior to the study after having expressed interest in taking part in order to arrange appointments to meet. Participants were aware that the study was part of a PhD programme and that the focus was on supporting healthy pregnancies in adolescents.

Information sheets and consent forms were sent out to individuals who expressed an interest in taking part and informed consent obtained before interviews took place. Ethical approval for the study was provided by Sheffield Hallam University Ethics Committee.

Data Collection

Semi-structured interviews were carried out either on a one to one basis or with two participants together who worked in the same agency (two interviews). Participants were also asked to complete a brief demographic questionnaire.

A topic guide was developed which was informed by previous quantitative work carried out during the PhD study. This work has been published elsewhere (Marvin-Dowle et.al 2018a, Marvin-Dowle et.al 2018b, Marvin-Dowle 2016) but

in brief the results suggested that the dietary patterns and nutritional status of pregnant adolescents is likely to be poorer than that of adult women. They are also more likely to experience higher levels of poverty, lower education and their babies may be at higher risk of adverse outcomes. The topic guide for this study therefore covered these main topic areas; subjects explored included issues faced by pregnant young women, perceptions of young women's attitudes to health behaviours (including, but not limited to, dietary behaviours), barriers for young women to making changes and facilitators for healthier pregnancies. Interviews were audio recorded with participants' consent.

Data analysis

Audio recordings of interview data were transcribed verbatim and transcripts anonymised with participants being allocated a participant number for identification purposes. Transcripts were loaded into NVivo 11 software to facilitate analysis. Data analysis was carried out inductively using thematic analysis which involved familiarisation with the data, generation of initial codes, assigning coded data into related categories and developing overarching themes (Braun and Clarke, 2008). Initial analysis was conducted by one researcher and codes and themes verified by a second researcher to enhance inter-reliability.

Results

Participant characteristics

A total of 8 participants took part in 6 interviews; four of the interviews were individual and two interviews took place with two colleagues from the same

agency at the same time. No participants withdrew from the study after agreeing to take part; interviews lasted between 20 and 40 minutes. Characteristics of the participants are shown in table 1.

Table 1. Participant characteristics

	Job role	Gender	Age group	Highest qualification	Number of children	Individual or shared interview
P1	Parenting support worker	Female	26-35	A Level or equivalent	0	Shared
P2	Parenting support worker	Male	Not reported	Not reported	Not reported	Shared
P3	Youth support worker	Female	26-35	Degree or equivalent	1	Shared
P4	Education officer	Female	36-45	Degree or equivalent	2	Shared
P5	Youth project manager	Female	46-55	Degree or equivalent	4	Individual
P6	Youth support advisor	Female	36-45	Degree or equivalent	2	Individual
P7	Youth support worker	Female	36-45	A Level or equivalent	1	Individual
P8	Perinatal support co-ordinator	Female	36-45	A Level or equivalent	3	Individual

Analysis of interview transcripts identified 5 over-arching themes within the data: Perceptions of dietary pattern; Connection with baby; Family and social stability; Building relationships and Service availability.

Perceptions of dietary pattern

Concerns over poor diet

All participants discussed the content of young women's diet during pregnancy and expressed concern over the dietary patterns they observed among their client group. Participants perceived the majority of young women were eating a large amount of fast/junk food, snacks that are high in salt, sugar and fat and sugary and/or highly caffeinated drinks and very little fresh produce or home cooked meals.

"And they're overeating, every pregnant girl we see has just got energy drinks and chocolate and you know their diet is so phenomenally bad, McDonalds and KFC and there's no proper food, even a jacket potato with cheese and beans is better than you know, McDonalds and energy drinks and rubbish like that"

Concern over poor dietary patterns was a common theme across all of the interviews. Some participants did speak about young women who did eat more healthily or made a particular effort to change their eating habits, however these young women were singled out as unusual or the exception to the rule.

"*I've got my lady who just had a baby a few weeks ago took the health of herself and the unborn child really seriously, she had low iron so made sure she went and bought really high iron foods, and really got that link, so it's really a bit hit and miss to be honest with you."*

Lack of sufficient knowledge or information

One participant mentioned that young women were often confused regarding which foods should be avoided during pregnancy, and that they did not have adequate knowledge or reliable information to be able to provide advice regarding this.

> *"then when they do come to places like this and they will ask, you know they're asking questions like can I eat mayonnaise? and I'm like I really don't know, you're going to have to ask your midwife, and they'll be like my midwife says I can after 38 weeks, and my midwife says something else and it's like, what?! There's still confusion"*

There was a sense that young women were less knowledgeable and less prepared for the pregnancy than older women in terms of diet and nutritional supplements to support the pregnancy. This was presented almost as a dichotomy by one participant who suggested the older women would have significantly more knowledge than adolescents.

> *"it's not like for older women getting pregnant and knowing exactly what you're supposed to be eating, what you're not supposed to be eating, take your folic acid and all of that"*

Connection with baby

All participants talked about their perceptions of young women's readiness or motivation to make changes to improve their own health and that of their baby. A key theme related to behaviour change was the importance young women

gave to healthy eating. The majority of participants reported that they didn't think the young women they worked with felt their nutrition was important.

> "*I don't feel I'm discussing with them that they feel that's [diet] important at all*"

There was a regular theme across the data which suggested that the participants felt that some young women struggled to see their baby as really there before the birth. This meant that these young women did not necessarily connect their behaviours with the health of their unborn child, particularly with reference to diet.

> *"It's a hard one cause we've come across mums who don't actually see baby as being there until the baby is actually in their arms, and it doesn't matter what I'm eating because they might not see it as it does affect the growing baby"*

This was linked to ideas put forward by several participants that the young women they worked with were not always emotionally mature enough to make decisive changes or to accept the significant changes that were happening to them as a result of the pregnancy. Similarly to the comments on diet content however there were exceptions where participants spoke of young women they had worked with who had made positive changes, but these were much less common than references to young women who either did not try to make changes or who struggled to do so.

"*There's some 17, 18 year old mums that we've worked with and I've worked with where you're like she's really switched on she's amazing and she could teach some of the older mums and people her own age sometimes where you think they could really learn something, but I think sometimes that's a big barrier to a healthy pregnancy is willingness and acceptance that things have to change.*"

Family and social stability

The majority of young women the participants were involved with face significant challenges, both in terms of their historical family situations and current living arrangements.

Family support and growing up in care

A number of the participants spoke about the difficult family backgrounds their clients had come from including high levels of poverty, unstable families and that a significant proportion of the young women they worked with had spent time being looked after in local authority care.

"A lot of the issues for our young people are because they've not had any positive parenting in their formative years, so they've not grown up with good routines, they've come from abused backgrounds, so they don't always understand actually what a good parent is and what they should do."

It was also suggested that experiences of being removed from families and being placed in local authority care may influence young women's willingness to

seek or accept support, particularly from social services, for fear that their own children may be removed from their care.

> *"Remember these young people have been removed from their families, their automatic fear is that you're there to do the same"*

It was also discussed how unstable family situations may have contributed to a lack of knowledge and skills around healthy eating and cooking, in that young women may not have had role models available to them or have been taught how to prepare and cook healthier meals.

> "*They've probably not built those skills up to care for themselves ... in that kind of way so in a heathy eating sort of way"*

Housing and poverty

Young women's current living situation was also a common theme with the majority of participants talking about young women living in poverty and experiencing housing issues. Being able to provide a safe and appropriate home for their baby was discussed as being clearly important to young women and a significant source of stress.

> *"I've just had a lady who gave birth about 4 weeks ago and she moved house 2 weeks before she gave birth, so I mean I was there 'til 7, 8 o'clock at night helping her get everything ready, and as soon as, she'd literally just moved in and got everything sorted and baby arrived"*

The situation of living in poverty was also considered a barrier to eating well by some participants, as healthy food was considered to be prohibitively expensive.

"How are they supposed to eat healthily if they've got no extra money, have you seen the price of fruit? You know, it's ridiculously overpriced."

One participant also suggested that promotions on less healthy foods made it difficult for young women to make healthier choices.

"Yeah our teenage parents will come in with all kinds of rubbish, donuts and you think geez, but when they're offering things like 4 donuts for a pound why wouldn't you? I do it, you know, there's a nice healthy sandwich or 4 donuts for a pound"

Social support and isolation

Difficult personal relationships, particularly with partners/baby's fathers were discussed by all of the participants. Young women were described as being very heavily influenced by their partners. Young fathers were described as either a negative, controlling influence or as absent.

"Their boyfriends are a massive influence on them, on the decisions they make about breastfeeding, stopping smoking, getting their figure back, starting to have sex again, you know, they're very dominated by their partners."

Similar issues were described with young women losing friends after having a baby as young women's priorities changed, leading young women to become isolated and without support.

"It's the age old you know, he's not going to go out with his friends anymore, he's going to stay in with me and the baby and all my friends are going to come round and visit, you know after 6 weeks it's, I could

write it down on a piece of paper and say there, 6 weeks' time I can guarantee your friends will disappear and so will your boyfriend, and they nearly always do, 99% of the time they do."

Isolation and mental health issues, compounded by this lack of support, were very prominent themes identified from the data. Some participants spoke about how many of their clients had mental health issues which were present before pregnancy and which clearly impacted on their wellbeing and ability to cope with a pregnancy.

"Most actually had complex needs in terms of their health and mental health already that weren't being addressed"

For others the stress and pressure of the pregnancy and parenthood, connected to the difficult living situations the young women were in meant that mental health issues were almost inevitable:

"so a lot of the ladies that I work with are single mums with no family, no support and are very isolated in the community on their own basically, and it's really difficult, really challenging, to think if you are pregnant at 16, 17, 18, 19 it's quite scary, I think, not having anybody there."

There was a sense that young women actually do incredibly well to cope with pregnancy and motherhood in the context of chaotic lives, and that often more is expected of young parents than is possible given the reality of their situation.

"I think we expect these young people that have got post-traumatic stress disorder or, you know, lots of really significant abuse in their life, to just function as an everyday parent in life. And a lot of them do don't get me

wrong, I've got loads of success stories, but sometimes they're tired and just need a break"

Building Relationships

The participants spoke extensively about their own roles in supporting young women, how they worked with other agencies and where they felt services were lacking or falling short of providing what is necessary. The participants generally saw their role as separate to that of clinical health professionals, but that didn't mean they were not concerned with the health of the pregnancy.

"We're not social workers, we're not midwives, we're youth workers and we come from a completely different perspective, but they know and we know that we've got their health and their baby's health at the forefront of everything we do"

Building relationships with young women was considered central to their work, and it was suggested that this may be more challenging due to young women's backgrounds.

"'cause they've got to build up that trust in professionals and people that are trying to support them, whereas they might be starting two steps behind someone else whose on a more secure base that can kind of go ok I've got to speak to A_____ about this and I know that I can trust A_____, whereas someone who's never had that ability to have a trusting relationship with an adult, you've got to build that trust."

Most of the participants also spoke about providing practical support, particularly in facilitating young women to attend health appointments which

were often missed, leading to potential consequences for the health of the pregnancy.

> *"We make assumptions that they've got access to services therefore they access them, so they've got midwives and social workers some of the young people but actually often it's about relationships, about hand holding, about transition, about actually getting to places, so some of those health needs we assume are being addressed but they're not because just on a basic level they're not accessing appointments, so they miss lots of appointments"*

Service Availability

There was also a significant amount of discussion in every interview about the need for more resources and the impact of cuts to existing services. All of the participants considered that cuts to services had had a detrimental effect on young women's health during pregnancy.

> *"They used to have, years ago, specialists that once a girl found out she was pregnant was put straight on to her so she would be given all the information and then directed to midwives and doctors and everything else. First round of cuts that was the first thing that went"*

When asked about whether additional resources would be helpful the majority agreed that an information resource which gave universal information and also provided local signposting would be useful, and that this would need to be provided in multiple formats.

"I think you'd need to cover all of those [formats], I mean definitely use technology, something they could easily download on their phone or they could come in here and have somebody sit and go through with them like a physical paper pack."

Overall, the overwhelming message from the data was that the participants recognised the importance of supporting healthy eating as part of a healthy pregnancy and supported young women to do their best in often particularly difficult circumstances. There are significant concerns, particularly around young women's mental health, and dedicated, specialised services are needed for any significant improvements to be made.

"Yeah if you could just ask to get a new service for pregnant teenagers back that'd be great, that's all we want, that'd be really good"

Discussion

This study is novel in that it seeks to gather the perspectives of a professional group which have not before been consulted on the topic of improving health in adolescent pregnancies. Integrated models of care which bring together social support services and primary health care in the UK are rare; one example of such a service is the Well Centre in South London (Hagell and Lamb, 2016), which is designed to be a 'one-stop-shop' specifically for adolescents. Evaluation has shown that young people were accessing the services who were not engaged with any other service, particularly those with mental health needs. This suggests that collaborative work between primary care services and youth

work providers may facilitate the most vulnerable young people to access and engage with the services they need, however the effectiveness of such services require robust independent evaluations.

In this research, nutrition was a topic that was generally considered to be important by youth support professionals, however they perceived that this view was not necessarily shared by the young women they worked with. Participants reported that the young women in their care ate large amounts of take away and processed food and sugary drinks and little fruit and vegetables. This is largely consistent with existing literature suggesting that adolescent's diet during pregnancy is often poor (Marvin-Dowle et.al, 2016; Marvin-Dowle et.al, 2018; Northstone, Emmett and Rogers, 2008; Scholl and Hediger, 1995). These findings are also consistent with evidence from the latest wave of the National Diet and Nutrition Survey (NDNS) produced by Public Health England (2018). Results from the 2014/15 - 2015/16 surveys found adolescent girls reported consuming an average of 2.8 portions of fruit and vegetables a day compared to 4.2 portions for adult women. Young women also consumed almost twice the amount of sugar sweetened beverages compared to adult women (183g and 100g respectively). This suggests that it is not just pregnant adolescents but in fact the majority of young women who have a poor diet. While the immediate consequences may be more apparent for young women who are pregnant this does suggest population wide interventions are needed to improve nutrition in all adolescents.

Reasons suggested for poor diet in pregnant young women were varied and included lack of interest or belief that nutrition makes a difference, lack of

knowledge and skills and the price of healthier choices. Participants spoke about how they believed young women often didn't make the connection between themselves and their baby until after the baby was born, particularly with reference to how what they ate might affect the developing foetus. Previous research has shown that a mother's emotional connection with her child during pregnancy can have a significant effect on her health behaviours. The theory of maternal-fetal attachment (MFA) proposed by Cranley (1981) is defined as “the extent to which women engage in behaviours that represent an affiliation and interaction with their unborn child” and the validated tool has been used to explore connections between attachment and maternal health behaviours. One study exploring correlations between MFA and comprehensive measure of pregnancy health behaviours (including balance of rest and exercise, safety measures, nutrition, avoiding use of harmful substances, obtaining health care, and obtaining information) in low-income urban women (Alhusen et.al, 2012) found an overall positive association between women's scores on the two measures. This suggests that improving women's emotional connection to the developing foetus may in turn improve health behaviours. There is little evidence in the existing literature regarding differences in MFA scores between adolescent and adult mothers, suggesting that this may be an important area for further study.

There is also a significant lack of evidence in the literature evaluating whether young women make connections between their diet during pregnancy and the health of their child, suggesting that this is an important area for further research. One small study (Whisner, Bruening and O'Brien, 2016) reporting survey data reported that the majority of pregnant teenagers recognised that

diet during pregnancy was important, but that this did not necessarily translate into making positive changes. A further recent study (Rundle, Soltani and Duxbury, 2018) found that the desire to deliver a healthy baby was a prime motivator for pregnant young women and therefore that the benefits of making dietary changes should be framed in those terms. This study also reports young women making some small positive changes to their diet despite barriers to doing so. Further insight into young women's understanding of how their diet impacts on the health of their baby and the factors which motivate positive changes is needed.

Psychosocial stability, lack of social support and isolation were themes which emerged clearly from this data set. Mental health needs in this population are likely to be high as these are associated with neglect or abuse during childhood (Mills et.al, 2013) (a likely contributor to young women being looked after in local authority care) and pregnant and parenting adolescents being at higher risk of experiencing mental health problems compared to older mothers (Siegel and Brandon, 2014). This is an important observation in the context of this study due to the impact that poor mental health may have on young women's ability to eat well and look after their own wellbeing. Poor diet has also been correlated with poor mental health in adolescents (Kulkarni, Swinburn and Utter, 2015; O'Neil et.al, 2014) meaning that improvements to young women's mental health may in turn help them to improve their diet.

The price of healthy food such as fruit was cited as a significant barrier to eating well and that young women favoured cheap, high energy density snack foods which were often subject to price promotions. There is significant evidence to

suggest that socioeconomic deprivation is associated with poorer nutritional status, particularly in adolescents. One study looking both at the attitudes and behaviours of adolescents towards healthy eating found that while participants had similar attitudes to healthy eating regardless of socio-economic position those from more deprived areas were more likely to report higher intakes of fast foods and sugar sweetened soft drinks (Utter et.al, 2011).

The main message regarding improving the health and wellbeing of young women during pregnancy gained from this study was that more targeted support services are needed to meet the needs of a vulnerable population. While physical resources were considered a useful tool for health promotion, having somebody to talk to with a holistic view of health and wellbeing was considered to be the key to making improvements. This, along with greater levels of consistency in the messages that young women receive regarding how to make positive changes to their diet, are key in developing practical strategies to support young women. There is a wealth of research addressing approaches to sexual health promotion and preventing teenage pregnancies (Mezey e.al, 2017; Oyedele, Wright and Maja, 2015; Sorhaindo et.al, 2016), including the prevention of second pregnancies (Aslam et.al, 2015), however evidence looking at strategies to support the health of young women during their pregnancy in the academic literature is severely lacking.

This study is limited somewhat by the small number of participants; however the use of qualitative methods means that the depth of the data is central to the research design and the intended number of participants was reached. Saturation of the data with regard to practical support to improve dietary habits

was achieved, however it is likely that longer interviews with more participants would yield more detailed insights regarding the myriad difficulties faced by young women during pregnancy Further work to include the perspectives of other professionals working with young people such as teachers and social workers would also be useful in order to develop a more complete picture of the available support for young women.

This study also does not include the perspective of pregnant young women themselves. This study was designed to complement a program of work in which the opinions of pregnant young women and young mothers have been explored (this has been reported elsewhere (Soltani et.al, 2016; Rundle, Soltani and Duxbury, 2018). Further, more in depth work to examine how young women view health during pregnancy and the factors which would support or motivate them is essential to our understanding of how to improve outcomes for young mothers and their children.

Conclusion

This study adds to the body of work exploring how young women's pregnancy outcomes could be improved through dietary changes. The findings do however suggest that for many young women in this population there are numerous, complex factors which impact on their ability to have healthier pregnancies. A higher level of consistent, holistic support delivered by joined up networks of professionals is needed in order to help young women achieve healthier pregnancies. Further research is necessary to understand the context of young women's lives, how this relates to their experiences of pregnancy and what type

of interventions or resources would have the biggest impact in supporting health behaviours.

List of abbreviations

FNP - Family Nurse Practitioner

HCP - Health Care Professional

MFA - Maternal-Foetal Attachment

NDNS - National Diet and Nutrition Survey

NHS - National Health Service

UK - United Kingdom

Declarations

Ethics approval and consent to participate

All participants gave their informed, written consent to participate in the study, ethical approval was granted by Sheffield Hallam University Ethics Committee on 19.07.16, proposal number 2015-16/HWB/HSC/35.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' Contributions

KMD - Primary responsibility for development of research question and study design, collection and analysis of data and writing the main body of the article

HS - Data analysis including verification of codes, advisory role in development of research question and study design, revisions to and approval of final article

VB - Advisory role in development of research question and study design, revisions to and approval of final article

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7.4 Summary and implications for thesis

The results of this study showed that there were numerous, complex factors which professionals perceive to impact negatively on young women's ability to achieve and maintain a healthy diet during pregnancy. The included both individual factors and social context and the availability of appropriate services. This work contributes to the narrative regarding how adolescent women can be best supported to have healthier pregnancies a potentially begin to reduce the disparities seen in adverse neonatal outcomes.

The following chapter synthesises the findings of all three studies in this programme of work and discusses the contribution of this thesis in the context of the existing field of academic literature. Recommendations for future work arising from this thesis will also be made and the strengths and limitations of the research discussed.

Chapter 8 - Integration of research Findings

8.1 Introduction

This thesis has presented a systematic review of current evidence followed by a programme of research composed of three original research studies. This program of research was undertaken as a mixed methods research project with sequential exploratory design. A key feature of this research design is the synthesis of research findings from the constituent parts of the programme of work to develop overarching themes. This chapter therefore completes this synthesis of findings from the quantitative and qualitative phases of data collection and analysis.

8.2 Integration of findings

As described in chapter four this thesis follows a sequential explanatory mixed methods design. As priority in the design was given to the quantitative phase, and this analysis was undertaken first in the sequence, the findings of the quantitative phases are used to inform the development of the qualitative phase which aims to explain and expand upon the previous findings[102]. The integration of methods therefore occurred at two points across the study; in the development of study materials for the qualitative phase, as described in chapter 7, and in this section where the findings of both quantitative and qualitative analysis will be integrated.

The key quantitative findings in this study show that pregnant adolescents are likely to not meet recommendations for intake of key nutrients to support pregnancy and eat higher quantities of nutrient poor snack and processed foods compared to older pregnant women. The results also show that babies born to adolescents have higher odds of being born extremely premature or at extremely low birth weights. The qualitative phase of the study therefore aimed to elaborate on these findings by gathering more in-depth information regarding possible influential factors on difficulties with eating well during pregnancy and disparities in neonatal health outcomes, by striving to understand the context of young women's lives. This section brings together the findings across the whole study in a series of overarching themes.

8.2.1 Social context

The social context of the population of young women who become pregnant during adolescence is an important consideration which impacts on both the health of the pregnancy and future life chances for mother and child. In this first overarching theme, results from the quantitative phase indicated that there were differences in social, cultural and economic indicators between age groups. Women in the adolescent group were, on average, from areas of higher socio-economic deprivation (as measured by index of multiple deprivation score), were more likely to be single parents and to have smoked or used recreational drugs during pregnancy. They were also more likely to describe their ethnicity as white British. The qualitative analysis phase supported and elaborated upon these findings; participants discussed young women often having experienced significant poverty and having difficulties with stable housing and maintaining relationships with the baby's father.

Together the findings of this study therefore suggest that the social situation of pregnant adolescents is likely to be less favourable than that of adult women, which is an important overarching theme from this research.

8.2.2 Dietary pattern

The second overarching theme identified from the research is regarding evidence of difference in dietary patterns between adolescents and adult women during pregnancy. Results from the quantitative analysis phase suggested that adolescent women showed higher adherence to the dietary pattern characterised by snack and processed foods which are high in fat, sugar and salt and low in vitamins and minerals. In addition, adolescent women reported consuming less fruit and vegetables and more sugar sweetened cola compared to adult women. This finding was supported by the results of the qualitative analysis phase which identified a perception that adolescent pregnant women consumed larger quantities of 'junk food' than was considered to be healthy and often did not consume enough of healthier alternatives such as fruit and vegetables or home cooked, balanced meals.

There were differences in BMI between adolescents and adult women identified in the quantitative analysis with adolescent women being more likely to be underweight and less likely to be overweight or obese. This finding may seem to

contradict the finding that adolescents consumed larger amounts of foods which are high in fat and sugar, and therefore with greater energy density. Evidence from the qualitative phase however suggests that young women in this population may have irregular eating patterns and be more likely to skip meals or eat less frequently than older women which may contribute to the lower BMI status among adolescents. Reasons for this include insufficient access to food due to cost or lack of skill in food preparation, which is maintained by the differences in socio-economic status observed in both phases of data analysis. Lower use of nutritional supplements was also seen amongst adolescent women in the quantitative data analysis. While specific discussion of supplement use was not a major theme from the qualitative work, significant issues with access to services for young women were reported. This, coupled with the cost of buying supplements from retailers, could in part explain why adolescents are less likely to access and use dietary supplements to support their nutrition in pregnancy.

8.2.3 Support

Need for, and ability to access support was highlighted as a significant issue in both phases of data collection. The quantitative results showed that adolescent women booked with a midwife significantly later in their pregnancy than adult women. The results also showed that adolescent women were likely to have higher support needs for issues likely to affect the health of the pregnancy such as smoking and poor nutritional status. It is also important to consider that the cohort utilised for the quantitative analysis includes only those women who were engaged with services during the second trimester of pregnancy, therefore potentially the most vulnerable women in terms of access to support are excluded from the analysis by virtue of not being engaged with services.
The qualitative analysis found significant concerns with young women's ability to access services for a number of reasons including existence of suitable services, knowledge of services, ability to travel to services and emotional capacity to engage with services. The data also revealed a perceived high level of mental health problems among pregnant adolescents and young mothers. A lack of family and social support was also recognised; adolescent women being more likely to be single parents was reflected across the data collection phases.

8.3 Summary

As described above, the findings from this programme of research have been integrated and three overarching themes have been identified. The following discussion chapter expands upon these key findings and situates them within the existing research literature. It also includes identification of the main strengths and any limitations of this programme of research and makes suggestions for future developments.

Chapter 9 - Discussion

9.1 Introduction

The primary research question in this thesis was '*Is there a need for additional nutritional support in adolescent pregnancies?'* which has been addressed through a program of mixed methods research. The research has identified three overarching themes which are presented in chapter 8. These overarching themes emerging from this program of research provide insight into the specific issues faced by adolescent women during pregnancy and the impacts these might have on their own health and that of their babies.

In this chapter the key findings are discussed, with reference to the existing academic literature, and the contribution to knowledge made by these new findings is explored. This chapter will also discuss the strengths and limitations of this program of work and present suggested avenues for future development.

9.2 Discussion of key findings

9.2.1 Social context

This study has identified that social context is of paramount importance when considering the health and wellbeing of adolescents during pregnancy and outcomes for their babies. The association between socio-economic status (SES) and the prevalence of adolescent pregnancy has been well documented with young women living in socially disadvantaged areas reported as being more likely to become pregnant as teenagers. The most recent under 18 conceptions data for England shows that the rate of conceptions among young women living in the most deprived decile (according to the 2015 index of multiple deprivation) was 24.8 per 1,000 young women aged 15-17 compared to 11.9 per 1,000 in the least deprived decile, meaning that the difference in conception rate due to deprivation is more than doubled[110]. There is little evidence to suggest that this situation is changing over time, rather inequalities

in the number of conceptions due to deprivation may indeed be widening. A Scottish study[111] assessing the social determinants of teenage pregnancy over a 60 year period found that despite a significant decrease in the overall teenage conception rate during the study period, the rate ratio between the most and least deprived areas increased significantly. They conclude that socio-economic deprivation is a significant and enduring predictor of teenage pregnancy.

It has also been established that socio-economic deprivation is a risk factor for both physical and mental health problems in populations, including among children and young people.

Particularly relevant here is the association between socio-economic status and a number of adverse neonatal outcomes including low birthweight and pre-term delivery, with women living in areas of higher deprivation being at increased risk. One review[112] of the research evidence suggested that these associations may be due at least in part to differences in cigarette smoking and lower gestational weight gain, issues which are also independently associated with young maternal age. The review also acknowledged that there was some evidence that psychosocial factors may have an important role to play but that more research in this area was needed.

It is also important to consider that the Born in Bradford cohort utilised for the quantitative analysis in this study is somewhat unique in terms of its demographic make-up. Born in Bradford was established in 2007 in response to concerns about the high rates of childhood morbidity and mortality in the city of Bradford with the aim of examining how genetic, nutritional, environmental, behavioural and social factors may influence health and development through childhood and into adult life. Approximately 20% of the population of Bradford are South Asian, of whom approximately 90% are of Pakistani origin. Due to the relative youth and high fertility rates among this population almost half of the babies born in Bradford at the time of recruitment to the cohort had parents of Pakistani origin. Bradford also has significant areas of socio-economic deprivation with approximately 60% of the babies born in Bradford being born into the poorest 20% of the population of England and Wales. Further details regarding features of the cohort which were not relevant to the work presented in this thesis are available in the cohort profile[103].

As discussed in chapter 5, the population of women aged under 20 years in the cohort is demographically significantly different to the cohort as a whole. The analysis in this study was restricted to primiparous women with singleton pregnancies in order to control for the impact of parity and multiple births on outcomes, particularly as the average parity increased with maternal age. While over 37% of women in the study population as a whole were of Pakistani ethnicity the proportion was only just over 16% among the adolescent women in the sample. The adolescent women in the sample were also more likely to have smoked during pregnancy, be single parents, have booked for antenatal care later in their pregnancy and live in more deprived areas. While recent national statistics regarding the ethnicity of pregnant adolescents are not available, the demographic profile of the young women included in this study is reflected elsewhere in the literature[111,113, 114] .

9.2.2 Maternal weight status

Pre-pregnancy BMI and gestational weight gain and their association with maternal age and socio-economic status are important considerations in this study. As discussed in chapter 2, evidence of BMI status among women in England showed that, while incidence of overweight and obesity in the UK overall is high, younger women were more likely to be underweight and less likely to be overweight or obese than older women and this pattern was also reflected in the results of the present study. There is also evidence to suggest that pre-pregnancy BMI is associated with gestational weight gain with adolescent women with a lower BMI gaining less during their pregnancy[115]. Guidelines for gestational weight gain from the institute of medicine vary by pre-pregnancy BMI with recommendations stating that women with lower BMIs should aim to gain more weight during pregnancy than their heavier counterparts[116]. A recent systematic review[117] aiming to assess the association of adverse outcomes with gestational weight gain either above or below these recommendations confirmed their efficacy. The results showed that weight gain below recommendations to be associated with small for gestational age and pre-term birth while weight gain above recommendations was associated with

large for gestational age, macrosomia and caesarean section. A further study[118] has however highlighted a potential issue with the use of these guidelines in adolescent pregnancies as BMI category is assessed based on adult criteria as opposed to centile based growth charts as would otherwise be used for assessing adolescent BMI categories. This BMI classification disparity may therefore lead to weight gain recommendations for pregnant adolescents which are in fact inappropriate.

Low gestational weight gain is associated with pre-term delivery and low birthweight[119], outcomes which were also observed to be associated with young maternal age in the analysis of the Born in Bradford data presented in chapter 5. Unfortunately it was not possible to examine the impact of gestational weight gain on outcomes in this cohort as no further information on gestational weight changes was available for the women at the end of their pregnancy. This may therefore be an important avenue for consideration in exploring the causal mechanisms of poorer outcomes among adolescent women. High pre-pregnancy BMI and high gestational weight gain have also been associated with adverse outcomes including increased risk of caesarean section, macrosomia and large for gestational age infants[120]. While high BMI and high gestational weight gain are not necessarily associated with young maternal age, maternal obesity is associated with low socio-economic status[121] meaning that this could be a consideration for women in this population in future pregnancies, especially in the context of poor diets.

9.2.3 Mental health

Mental health was identified in the qualitative enquiry presented in chapter 7 as a key factor influencing the health and wellbeing of pregnant young women. Mental health has been reported to account for a large proportion of the disease burden among young people globally, and is strongly related to other health issues including poor sexual and reproductive health[122]. A systematic review addressing the association between socio-economic inequalities and mental health problems in children and adolescents (aged 4-18 years) concluded that children and adolescents with low SES are at higher risk of mental health problems. The review included examination of 55 published studies, all of which

reported at least one marker of SES and at least one identified mental health problem using validated instruments. Further to this an American study[123] assessing internalising behaviour problems (depression, anxiety, withdrawal and somatic problems) in almost 3,000 children aged 5-11 years found a linear relationship between neighbourhood socio-economic status and the percentage of children above the clinical threshold for diagnosis. The study also found that areas of concentrated disadvantage were associated with higher prevalence of mental health problems among children. Having established that socio-economic deprivation is a significant predictor of both adolescent pregnancy and mental health issues, it is perhaps no surprise that poor mental health and unstable family backgrounds were identified in this study as significant issues for pregnant adolescents, as reported in chapter 7.

These findings are further supported in the existing academic literature; One USA based study[124] which looked specifically at the association between adverse childhood experiences (ACEs) and teenage pregnancy found that as ACE scores on a validated tool increased so did the likelihood of becoming pregnant during adolescence. The same study also found that while teenage pregnancy was not independently associated with foetal death, ACE score was associated with increased foetal death after first pregnancy.

Mental health issues have also been independently associated with less healthy diets in adolescents. A study of almost 3,000 socially deprived young people in East London[125] found that poor diet quality was significantly associated with mental health difficulties as assessed using two validated assessment tools (strengths and difficulties questionnaire and the short mood and feelings questionnaire). Nutrition has also been suggested as an important modifiable factor in the treatment and management of mental health conditions. One review[126] of the impact of nutrition on depression in women of childbearing age found significant support for dietary interventions including fish oil and folic acid supplementation in supporting management of major depressive disorders and that deficiencies in folate, vitamin B12, iron, zinc and selenium tend to be more prevalent among those suffering with depression. The direction of the relationship between mental health difficulties and poor diet is not clear, and it is likely that it is somewhat cyclical. This suggests that further work is needed to

explore the complex relationships between adverse childhood experiences, mental health issues, socio-economic deprivation, nutritional deficiencies conceptions to young women and outcomes for pregnant adolescents and their children.

9.2.4 Diet quality

There is also a significant body of evidence supporting an association between socio-economic status and poorer quality diets in various populations. One review[127] of the family and social-determinants of children's eating patterns and diet quality found that the amount and type of foods eaten by children are dependent on both the physical and social environment, much of which is dictated by the behaviours, attitudes and feeding styles of the adults with whom they live. A more quantitative approach assessed the nutrient intake of 250 pregnant women in Sheffield[128] and found that participants living in the 40% most deprived wards had significantly lower nutrient intakes compared to more affluent women in the study.

The findings of the research presented in this thesis suggest that adolescent age may be an independent predictor of poorer quality diets during pregnancy when compared to those of adult pregnant women. The systematic review of the available evidence presented in chapter 3 found that pregnant adolescents were not meeting the recommended intakes for energy, fibre and a number of key micronutrients. As discussed previously, under reporting of energy intake is common in epidemiological studies and this is unlikely to be of serious concern given the adequate gestational weight gain also reported in the studies included in the systematic review. Micronutrient intake and subsequent status is however more likely to be an issue for this population given the evidence presented both by the systematic review and the analysis of dietary patterns presented in chapter 6.

The team involved with supervising and advising on this program of research have recently published two studies which are closely aligned with the work presented in this thesis. These papers seek to explore the perspectives of

young women and health care professionals through the use of an online survey and qualitative interviews. The results of the survey phase of this project showed that there were some difficulties with access to nutritional supplements and many young women reported low compliance, largely due to forgetting to take them. Young women did report some positive dietary changes but also reported unnecessary food avoidances which may be due to misunderstanding of recommendations.

The qualitative phase of this study[109] interviewed young women who were aged 16-19 during pregnancy and who were either currently pregnant or had given birth in the preceding 6 months. The study interviewed 34 young women with a focus on dietary habits and supplementation practices. Young women in this study reported high consumption of processed snack foods and take away meals and often irregular meal patterns with long gaps between eating. The study also reported that young women's social circumstances and living arrangements had an impact on food availability and food choices, with those who lived alone being least likely to cook for themselves. The study also identified that young women's understanding of the impact of nutrition on their baby was key to making changes. Small changes in diet during pregnancy were reported by some young women, some healthier changes and some for other reasons such as cravings or aversions to certain foods or beliefs about food safety. Young women in this study also reported confusion over the role of nutritional supplements in pregnancy. Despite this, most reported taking some sort of supplements at some point in their pregnancy but reported poor adherence, often simply because they forgot to take them. The results showing poorer quality diet and lower adherence to supplements, accentuated by lower socio-economic status are consistent across both the previously published work and the research presented in this thesis. Due to the close relationship between these papers and the work presented in this thesis the published manuscripts are available in full in appendices 10 and 11.

While the work presented in this thesis uses a mixture of established methods in order to evaluate nutritional issues in adolescent pregnancies it is also

accepted that accurate dietary assessment of populations is incredibly difficult to achieve, particularly in marginalised and hard to reach populations such as this. There is a significant risk of underestimation of portion sizes in dietary recall methods, particularly among adolescents[129]. As discussed in chapter 2, assessment of under reporting in the national diet and nutrition survey using the doubly labelled water technique revealed a significant level of under reporting of energy intake across the sample[77,78]. A systematic review which also included studies using the doubly labelled water method of assessing energy intake to assess the validity of dietary assessment methods in children[130] found that the accuracy of data collection methods altered by the age of children and adolescents and concluded that for young people aged 16-18 diet history taking provided a better estimate than other methods.

While acknowledging that dietary assessment in pregnant adolescents is difficult, particularly in terms of collecting data which is accurate on an individual level, the use of dietary assessment can give important insights into the nutritional status of populations. As reported in the systematic review included in chapter 3 of this thesis, a number of studies have successfully used 24hr dietary recalls[131, 133,134,135, 136] or food diaries[137,138, 139] to assess dietary intake in this population. In addition to this, assessment of nutritional biomarker status also provides important information in terms of assessing the risk of harm due to nutrient deficiencies[61,140,141, 142,143, 144,145,146,147,].

It has been shown that improving nutritional status in adolescent women during pregnancy is likely to be beneficial to both the young woman and her child. One review looking at interventions to improve diet and weight gain among pregnant adolescents[148] found that positive effects on birth outcomes were evident in interventions which focused on multidisciplinary teams who supported the psychosocial needs of young women including the provision of individual education and counselling. These findings are consistent with the results of this program of research suggesting that interventions which are multifaceted and consider young women's lives in context are most likely to be effective.

Increasing micronutrient intake by supplementation is also a useful method of improving nutritional status in populations. A further review focusing on the impact of nutritional interventions in adolescent pregnancies[149] found that micronutrient supplementation had a positive effect on mean birthweight and the rates of low birthweight and preterm births. There is a lack of research regarding barriers to supplementation in pregnant adolescents and the efficacy of interventions to improve adherence. As discussed previously the results of the study by Rundle et.al[109] show that limited access to appropriate supplements and not remembering to take them were reasons given for low adherence, suggesting these may be avenues for further research into potential interventions. In the UK women who are pregnant and under 18 or in receipt of certain benefits can claim Healthy Start vouchers, which can be exchanged for fruit and vegetables, and vitamins to help support their nutrition. An evaluation[150] of this scheme has found that women reported that receiving health start vouchers improved the quality and diversity of fruit and vegetables consumed and they believed their diet quality to be improved. There were however issues with access to the scheme including complex eligibility criteria and low levels of awareness among families and practitioners. These issues were echoed in a survey of pregnant adolescents who reported that access to healthy start vitamins was patchy and ease of access was dependent on geographical area[151]. Systems which offer reminders for behaviours such as supplement use may also be useful in improving adherence in this population. Text messaging reminder services to mobile phones have been shown to be effective in paediatric and adolescent populations[152] for improving healthy behaviours across demographic groups, however evidence for more complex mobile based intervention requires further research. There is also some evidence to suggest that the use of mobile technology for nutritional behaviour change interventions may be useful[153,154]. To date these have largely focused on weight loss interventions so further work to explore the feasibility and efficacy for mobile application based interventions for improving diet quality and adherence to supplement use would be useful.

There is also evidence to suggest that the routine fortification of grain based products with folic acid may have a significant effect on the prevalence of neural tube defects. A review of data from 19 population-based birth defects surveillance programs since the introduction of mandatory folic acid fortification in the USA[155] concluded that this is an effective public health strategy in the prevention of neural tube defects. At the time of writing, ministers in the UK have very recently approved plans to begin mandatory fortification of flour, with a public consultation on the proposals due to launch in early 2019[156].

9.2.5 Supporting adolescent pregnancies

It has been established both in the findings of this program of research and the relevant research literature that the young women most vulnerable to adolescent pregnancy are also at higher risk of other issues which affect their health and wellbeing such as poverty, unstable living arrangements and poor mental health. The research findings also highlighted a concern that these young women may also be struggling to access appropriate support to improve their situation either due to lack of knowledge of services and how to access them or because services are over-subscribed or simply don't exist. Many teenage pregnancy services are focused on prevention, with clinical services encouraging long-acting reversible contraceptives, as these have been shown to be significantly associated with a reduction in conceptions[157]. Less is available to support young women once they become pregnant, particularly since the decommissioning of family nurse partnerships (FNP) in many areas across the country. Under the FNP services first-time young parents (aged 24 and under) would receive personal support from a dedicated family nurse who would visit regularly from early pregnancy until their child's second birthday. Many local authorities have however decommissioned this service and the offer of support for young parents varies significantly depending on geographical location. In many areas, at the time of writing, there is no specialist support for pregnant teenagers or young parents, neither is there any additional support to facilitate access to universal midwifery and health visiting services.

As identified in this study, adolescent women on average book with a midwife later than older women meaning that they are less likely to be supported well through the first trimester. These findings are consistent with evidence from other parts of the world in that pregnant adolescents often receive a lower level of prenatal care which is relative to local standards. In a report by the World Health Organisation it is noted that evidence from the USA suggests that among unmarried adolescents 16.4% receive inadequate care compared to only 2% of "non-poor", married, white, adult women[158]. The pattern of care is also similar in developing countries, which is a particular concern where the national standard of prenatal care is already insufficient[159]. Cost of care[160] and being unmarried were reported as significant barriers to care in this context. This is particularly important as there is robust evidence presented by a Cochrane systematic review[161] to show midwife-led continuity models of care have beneficial effects in improving clinical outcomes as well as enhancing women's experiences. The most significant and relevant findings from this review is that the risk of preterm birth and foetal/neonatal mortality was lower in mothers who received midwife-led continuity care models compared to other (non-midwife led) models of care. While the benefits of this specific intervention have not been investigated in this particular group of women, given the observed higher risks of extremely preterm birth for adolescent pregnancies in this cohort, further investigation of the benefits of applying the principles identified in this review including building trusting relationships and providing compassionate care with full respect and dignity in this population would be advantageous.

In addition to the advantages of midwife-led continuity of care there is also evidence to suggest that lay health workers may have a role to play in improving social support and ultimately improving outcomes for marginalised groups. A randomised control trial[162] comparing the addition of pregnancy outreach workers to usual maternity care in disadvantaged women in the West Midlands found that women with two or more risk factors saw improvements in mean Edinburgh post-natal depression scores and that mother-to-infant bonding was improved among all women receiving the intervention. Further work arising from this trial has sought to theorise lay health worker interventions

and presents the concept of 'synthetic social support'[163]. This is support which is provided by either paid workers or peer or volunteer supporters and encompasses emotional, appraisal, instrumental and informational support. This differs from other types of social support in that the support provided is not reciprocal and is time limited, meaning that some of the benefits of social support previously identified may not apply. This said, this work provides an important framework for future investigation into the role of youth support professionals in supporting adolescent pregnancies, given that the value of the support offered by pregnancy support workers to women in other marginalised groups has already been evidenced.

9.3 Contributions of this research

There are a number of ways in which this program of research makes positive contributions to the field of study. Firstly, this research provides a unique analysis of an important existing cohort therefore increasing the breadth of what is known about pregnancy health in the UK. The Born in Bradford cohort has produced a wide variety of important and informative research; however the data had not previously been examined for differences due to maternal age. This is also the first time that the maternal food frequency questionnaire data has been used to investigate dietary patterns.

The identification of significant differences in extremely pre-term and extremely low birthweight babies predicted by maternal adolescent age is also an important and novel finding for a relatively recent, UK based study.

Previous to this program of research there was a severe lack of evidence regarding the nature of adolescent women's diet during pregnancy; this study has provided both a systematic review and an original research study in order to begin to bridge this gap.

In addition to the new quantitative analysis, the qualitative phase of this study sought to gain the perspectives of a professional group who have not previously been consulted on this topic. As previously discussed, there is existing work documenting the views of young women and health care professionals regarding supporting healthy eating in pregnancy, however professionals whose role is to provide a wider range of support to young people encompassing psychosocial support and practical assistance have been overlooked. Taking

into account the perspectives of these professionals is important as they often have enduring relationships with young people which last beyond the pregnancy period, and are in a unique position to be able to offer support.

9.4 Strengths and limitations

A significant strength of this program of research was the ability to utilise a large and diverse existing cohort to create new knowledge. The Born in Bradford cohort is unique in terms of its diverse population, meaning it presents the opportunity for new research which would not be possible elsewhere. The large number of participants made for a robust analysis and made it possible to investigate relatively rare events; however the study was limited by very low numbers of younger adolescents (aged under 16 in particular) and low occurrences of some rarer outcomes such as stillbirth. There were also a relatively small number of adolescent south Asian women in the cohort, meaning that the potential for examining the impact of ethnicity on outcomes was limited.

It should also be considered that the sample for this study consisted only of women who were engaged with services during the second trimester, meaning that those young women accessing services much later in their pregnancy are not included in the cohort. Adolescent age was identified as a key determinant of late presentation to antenatal care and poor foetal outcomes in a retrospective study of almost 60,000 records in a large UK based maternity hospital[164], suggesting that this cohort may not include some of the most hard to reach young women.

The availability of data from a food frequency questionnaire was also a major strength of this study as it enabled investigation of the types of food eaten in the assessment of dietary patterns, which is more useful than assessment of nutrients in terms of real world applicability. This said the food frequency questionnaire included in the Born in Bradford baseline questionnaire is limited by brevity and inability to characterise whole diets. This is due to the original intention of the FFQ being to categorise women according to their intakes of a small range of agents with potential genotoxic and/or immunotoxic properties, including polycyclic aromatic hydrocarbons, heterocyclic amines, nitrosamines,

acrylamide, the mycotoxin deoxynivalenol, dioxin and polychlorinated biphenyls, alcohol and DNA-reactive aldehydesotential[165]. This therefore means that more robust analysis may have been possible had a questionnaire been developed specifically for this study with the intention of characterising the whole diets of pregnant women. This was a pragmatic decision to investigate the limits of the existing available data and provide a baseline for future developments.

The qualitative data in this program of research was collected from professionals with a wide variety of roles; however all had the common feature of providing social, emotional and practical support to young women. This is a strength of the study in that this strategy allowed for a wide range of perspectives to be heard. The study was however limited by a small overall number of participants, meaning that further insights may be gained by additional work with professionals in similar roles.

9.5 Recommendations for future work

9.5.1 Research Recommendations

This study has highlighted a number of important avenues for the development of future research. Mental health and social factors have emerged as an important theme impacting on the health and wellbeing of pregnant adolescents. Variables relating to these topics have yet to be evaluated in the Born in Bradford cohort. A project to evaluate differences in indicators of social and emotional wellbeing in the Born in Bradford cohort and their relationship to maternal age and maternal and neonatal outcomes would be useful to further explore their implications for the health of adolescent mothers and their babies.

In addition to more detailed evaluation of differences between adolescent and adult women in the Born in Bradford cohort this study has identified the need for a more in depth evaluation of young women's diets during pregnancy in the UK compared to that of adult women. Research based on a comprehensive assessment of young women's diets during pregnancy would provide a more solid framework for the development of interventions to support young women to make changes.

Further work is also needed with this population to investigate young women's perspectives on what would help them to have healthier pregnancies more

holistically and to consult them on their views of the themes emerging from the data provided by health and social care professionals.
While this program of research has focused on adolescent women there is a significant body of evidence to suggest that maternal and neonatal outcomes among older women (aged 35 years or over) may also be of concern[166,167,167,168,168]. Older women in the Born in Bradford cohort have not previously been the focus of any investigation into pregnancy and birth outcomes meaning this may be an important area for further research.

9.5.2 Practice recommendations

As previously discussed, recent work has been carried out with young women during or after pregnancy to ascertain their views on healthy eating and supplement use. Young women reported that they value the support of midwives and generally trust their advice, particularly on health related topics. Investigation of the feasibility of brief interventions which could be successfully delivered to adolescent pregnant women within existing midwifery appointments would help to capitalise on this relationship and maximise the effectiveness of the support young women already have during their pregnancies. Additional training for midwives both as continuing professional development and as part of midwifery education addressing the specific nutritional issues associated with adolescent pregnancies would be useful in giving midwives the tools to provide support in time pressured consultations.
Consultation regarding or, ideally, co-production of any interventions to improve pregnancy health for young women is essential in order to ensure that any interventions are useful and relevant to the population they aim to support. It is also important that those young women who may be particularly vulnerable within this population, for example due to very young maternal age, poverty and homelessness or mental health conditions, are considered specifically in the development of future work to ensure that those young women with the highest need are central to the development of interventions.

9.6 Summary

This section has discussed the key findings of this program of research and situated them within the existing academic literature. It has also considered the particular strengths and limitations of this study and highlighted the original contributions to knowledge made by this work. Recommendations for further research to build upon the findings have also been suggested.

Chapter 10 - Conclusions

10.1 Introduction

This thesis provides details of a program of mixed methods research presented in an article based format consisting of three papers published in reputable peer reviewed scientific journals and a further paper which is currently under review. In this chapter, the aims and objectives are reviewed and the contribution and impact of this work discussed.

10.2 Review of aims and objectives

The primary aim of this work was to answer the research question "*Is there a need for additional nutritional support in adolescent pregnancies?".* This question has been addressed through investigation of three research objectives:

Establish what is known in the current research literature regarding the nutritional status of pregnant adolescents

This objective was met through a systematic review of the available research literature presented in chapter 3. The review concluded that the nutritional status of adolescents during pregnancy is likely to be sub-optimal, particularly with reference to a number of key micronutrients.

Examine differences in dietary intake and birth outcomes between adolescent and adult mothers in a large cohort data set

This objective was addressed through two separate analyses of the Born in Bradford cohort data set. The first, presented in chapter 5, looks at differences in maternal and neonatal outcomes by maternal age. This study concluded that adolescent mothers had higher odds of delivering babies who were extremely preterm and/or of extremely low birthweight. This study also found that adolescent mothers had lower odds of instrumental deliveries, caesarean section and gestational diabetes.

The second analysis of the Born in Bradford data is presented in chapter 6 and uses principal component analysis alongside assessment of questionnaire responses to consider differences in dietary pattern by maternal age. The study concludes that the adolescent women in the cohort had a poorer quality diet with lower intake of fruit and vegetables, lower intake of nutritional supplements and higher intake of sugar sweetened cola compared to adult women.

Explore the perspective of health and social care professionals of providing nutritional support for pregnant adolescents

This objective was met through qualitative interviews with professionals, which were analysed thematically. This study, presented in chapter 7 in the format submitted for review, concluded that in order to improve the nutritional status of young women during pregnancy it is necessary to consider the impact of psychosocial factors such as access to services, social support, poverty and homelessness and mental health difficulties. Consistent, holistic support delivered by networks of professionals is needed in order to support young women to make changes that benefit their own health and that of their babies.

10.3 Impact to date

This program of work has produced three research papers which have been published in peer reviewed journals. At the time of printing this thesis on 20.01.19 the metrics for theses research outputs were:

Marvin-Dowle, K., Burley, V. J., & Soltani, H. (2016). Nutrient intakes and nutritional biomarkers in pregnant adolescents: a systematic review of studies in developed countries. *BMC pregnancy and childbirth*, *16*(1), 268.

Accessed 2,109 times, cited 6 times

Marvin-Dowle, K., Kilner, K., Burley, V. J., & Soltani, H. (2018). Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort. *BMJ open*, *8*(3), e016258.

Accessed 1220 times, cited 3 times

Marvin-Dowle, K., Kilner, K., Burley, V., & Soltani, H. (2018). Differences in dietary pattern by maternal age in the Born in Bradford cohort: A comparative analysis. *PloS one*, *13*(12), e0208879.

Accessed 109 times

10.4 Summary

This thesis has presented a comprehensive program of mixed methods research which has produced an original contribution to knowledge in the fields of maternal and neonatal health, nutrition and adolescent health and wellbeing. The research has also identified a number of areas where additional research would be likely to further enhance understanding of the issues affecting young women's health and wellbeing and ultimately inform interventions to improve the health of young mothers and their children.

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practitioners of the healthy start programme in england. *BMC Public Health*. 2014;14(1):148.

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Appendix 1.

Supplementary tables published alongside systematic review

Supplementary Table 1. Characteristics of Excluded Studies

Reference	Reason for exclusion
Briggs, M. M., Hopman, W. M., & Jamieson, M. A. (2007). Comparing pregnancy in adolescents and adults: obstetric outcomes and prevalence of anemia. *Journal of obstetrics and gynaecology Canada: JOGC= Journal d'obstetrique et gynecologie du Canada: JOGC*, *29*(7), 546-555.	Anaemia is the only relevant outcome measure and is only reported as a binary measure
O'Brien, K. O., Donangelo, C. M., Ritchie, L. D., Gildengorin, G., Abrams, S., & King, J. C. (2012). Serum 1, 25-dihydroxyvitamin D and calcium intake affect rates of bone calcium deposition during pregnancy and the early postpartum period. *The American journal of clinical nutrition*, *96*(1), 64-72.	No baseline nutritional measures and no control group intakes
De Vienne, C. M., Creveuil, C., & Dreyfus, M. (2009). Does young maternal age increase the risk of adverse obstetric, fetal and neonatal outcomes: a cohort study. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *147*(2), 151-156.	Anaemia is the only relevant outcome measure and is only reported as a binary measure
Dean, S. V., Lassi, Z. S., Imam, A. M., & Bhutta, Z. A. (2014). Preconception care: nutritional risks and interventions. *Reprod Health*, *11*(Suppl 3), S3.	Review - considers preconception nutritional interventions
Garikapaty, V. P., Feyerharm, R., & Zhu, B. (2007). Folic acid consumption among Missouri women in the periconceptional period. *Missouri medicine*, *105*(6), 504-509.	Peri-conceptional period only
Gupta, N., Kiran, U., & Bhal, K. (2008). Teenage Pregnancies: Obstetric characteristics and outcome. *European Journal of Obstetrics & Gynecology*	Anaemia is the only relevant outcome measure and is only reported as a binary

and Reproductive Biology, *137*(2), 165-171.	measure
Jones, R. L., Cederberg, H. M. S., Wheeler, S. J., Poston, L., Hutchinson, C. J., Seed, P. T., ... & Baker, P. N. (2010). Relationship between maternal growth, infant birthweight and nutrient partitioning in teenage pregnancies. *BJOG: An International Journal of Obstetrics & Gynaecology*, *117*(2), 200-211.	Data is split into 'growers' and 'non-growers', same data as Baker 2009 which is included
Oliveira, O. R., Santana, M. G., Santos, F. S., Conceição, F. D., Sardinha, F. L., Veiga, G. V., & do Carmo, M. G. T. (2012). Composition of fatty acids in the maternal and umbilical cord plasma of adolescent and adult mothers: relationship with anthropometric parameters of newborn. *Lipids in health and disease*, *11*(1), 1.	Country of origin excluded - Brazil
Tsikouras, P., Dafopoulos, A., Trypsianis, G., Vrachnis, N., Bouchlariotou, S., Liatsikos, S. A., ... & Von Tempelhoff, G. F. (2012). Pregnancies and their obstetric outcome in two selected age groups of teenage women in Greece. *The Journal of Maternal-Fetal & Neonatal Medicine*, *25*(9), 1606-1611.	Anaemia is the only relevant outcome measure and is only reported as a binary measure
Wheeler, S. J., Poston, L., Thomas, J. E., Seed, P. T., Baker, P. N., & Sanders, T. A. (2011). Maternal plasma fatty acid composition and pregnancy outcome in adolescents. *British journal of nutrition*, *105*(04), 601-610.	Oily fish is the only intake variable reported, data is from the same study as Baker 2009 which is included
Wise, N. J., & Arcamone, A. A. (2011). Survey of adolescent views of healthy eating during pregnancy. *MCN: The American Journal of Maternal/Child*	Does not report a valid comparable measure of dietary intake or nutritional status

Nursing, *36*(6), 381-386.	
Young, B. E., McNanley, T. J., Cooper, E. M., McIntyre, A. W., Witter, F., Harris, Z. L., & O'Brien, K. O. (2012). Vitamin D insufficiency is prevalent and vitamin D is inversely associated with parathyroid hormone and calcitriol in pregnant adolescents. *Journal of Bone and Mineral Research*, *27*(1), 177-186.	Focus on effect of hormone changes, reports same data Young 2012 which is included
Finkelstein, J. L., Pressman, E. K., Cooper, E. M., Kent, T. R., Bar, H. Y., & O'Brien, K. O. (2014). Vitamin D status affects serum metabolomic profiles in pregnant adolescents. *Reproductive Sciences*, 1933719114556477.	Reports same data as Young 2012 which is included
Whisner, C. M., Young, B. E., Witter, F. R., Harris, Z. L., Queenan, R. A., Cooper, E. M., & O'Brien, K. O. (2014). Reductions in heel bone quality across gestation are attenuated in pregnant adolescents with higher prepregnancy weight and greater increases in PTH across gestation. *Journal of Bone and Mineral Research*, *29*(9), 2109-2117.	Reports same data as Young 2012 which is included
Lenders, C. M., McElrath, T. F., & Scholl, T. O. (2000). Nutrition in adolescent pregnancy. *Current opinion in pediatrics*, *12*(3), 291-296.	Not a primary study, questionnaire/quiz to determine knowledge
Burchett, H., & Seeley, A. (2003). Short Report: Good Enough to Eat? The Diet of Pregnant Teenagers. *International Journal of Health Promotion and Education*, *41*(2), 59-61.	Not a primary study, short review article
COMA (2002) Scientific review of the Welfare Food Scheme, *Reports on health and social subjects,* 51, i	Not a primary study, service review

Wallace, J. M., Luther, J. S., Milne, J. S., Aitken, R. P., Redmer, D. A., Reynolds, L. P., & Hay, W. W. (2006). Nutritional modulation of adolescent pregnancy outcome–a review. *Placenta*, *27*, 61-68.	Not a primary study, news brief relating to an included article
ANUMBA, D. (2009). SESSION 2-MATERNAL MEDICINE. *Journal of Obstetrics and Gynaecology*.	Conference papers, not relevant
Anderson, N. E., Smiley, D. V., Flick, L. H., & Lewis, C. Y. (2000). Missouri rural adolescent pregnancy project (MORAPP). *Public Health Nursing*, *17*(5), 355-362.	Does not report a valid comparable measure of dietary intake or nutritional status
Aston, G. (1995). Building a healthy community. *AHA News*, *31*(15), 7	Not a primary study, news article
Barda, G., Arbel-Alon, S., Bernstein, D., Zakut, H., & Menczer, J. (1997). Pregnancy and delivery in a group of Israeli teenagers. A case-controlled study. *Clinical and experimental obstetrics & gynecology*, *25*(1-2), 32-35.	Country of origin excluded - Israel
Berenson, A. B., Wiemann, C. M., & McCombs, S. L. (1997). Adverse perinatal outcomes in young adolescents. *The Journal of reproductive medicine*, *42*(9), 559-564.	Does not report a valid comparable measure of dietary intake or nutritional status
Berenson, A. B., Wiemann, C. M., Rowe, T. F., & Rickert, V. I. (1997). Inadequate weight gain among pregnant adolescents: risk factors and relationship to infant birth weight. *American journal of obstetrics and gynecology*, *176*(6), 1220-1227.	Does not report a valid comparable measure of dietary intake or nutritional status

Bergmann, R. L., Gravens-Müller, L., Hertwig, K., Hinkel, J., Andres, B., Bergmann, K. E., & Dudenhausen, J. W. (2002). Iron deficiency is prevalent in a sample of pregnant women at delivery in Germany. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *102*(2), 155-160.	Wrong age group
Bonnette, R. E., Caudill, M. A., Boddie, A. M., Hutson, A. D., Kauwell, G. P., & Bailey, L. B. (1998). Plasma homocyst (e) ine concentrations in pregnant and nonpregnant women with controlled folate intake. *Obstetrics & Gynecology*, *92*(2), 167-170.	Intervention group given measured folate, controls not pregnant
Boult, B. E., & Cunningham, P. W. (1995). Some aspects of obstetrics in black teenage pregnancy: a comparative analysis. *Med. & L.*, *14*, 93.	Does not report a valid comparable measure of dietary intake or nutritional status
Cong, K., Chi, S., & Liu, G. (1995). Calcium supplementation during pregnancy for reducing pregnancy induced hypertension. *Chinese medical journal*, *108*(1), 57-59.	Wrong age group
Covington, D. L., Peoples-Sheps, M. D., Buescher, P. A., Bennett, T. A., & Paul, M. V. (1998). An evaluation of an adolescent prenatal education program. *American Journal of Health Behavior*.	Does not report a valid comparable measure of dietary intake or nutritional status
Cunnington, A. J. (2001). What's so bad about teenage pregnancy?. *Journal of Family Planning and Reproductive Health Care*, *27*(1), 36-41.	Not a primary study, review
Dunn, P. C., Kolasa, K., & McKee, A. (1998). Nutrition education materials for pregnant teens. *Journal of Nutrition Education*, *30*(6), 414-415.	Not a primary study, resource review

Erkkola, M., Karppinen, M., Järvinen, A., Knip, M., & Virtanen, S. M. (1998). Folate, vitamin D, and iron intakes are low among pregnant Finnish women. *European Journal of Clinical Nutrition*, *52*(10), 742-748.	Wrong age group
Goonewardene, I. M. R., & Waduge, R. P. K. (2009). Adverse effects of teenage pregnancy. *Ceylon Medical Journal*, *50*(3).	Does not report a valid comparable measure of dietary intake or nutritional status
Howell, S. R., Barnett, A. G., & Underwood, M. R. (2001). The use of pre-conceptional folic acid as an indicator of uptake of a health message amongst white and Bangladeshi women in Tower Hamlets, east London. *Family Practice*, *18*(3), 300-303.	Supplement use only, does not report a valid comparable measure of dietary intake or nutritional status
Howie, L. D., Parker, J. D., & Schoendorf, K. C. (2003). Excessive maternal weight gain patterns in adolescents. *Journal of the American Dietetic Association*, *103*(12), 1653-1657.	Does not report a valid comparable measure of dietary intake or nutritional status
Hunt, D. J., Stoecker, B. J., Hermann, J. R., Kopel, B. L., WILLIAMS, G. S., & Claypool, P. L. (2002). Effects of nutrition education programs on anthropometric measurements and pregnancy outcomes of adolescents. *Journal of the American Dietetic Association*, *102*(3), S100-S102.	Does not report a valid comparable measure of dietary intake or nutritional status
Koenig, J., & Elmadfa. (2000). Status of Calcium and VitaminD of Different Population Groups in Austria. *International journal for vitamin and nutrition research*, *70*(5), 214-220.	No pregnant adolescents included in the sample

Kondo, A., Kamihira, O., Shimosuka, Y., Okai, I., Gotoh, M., & Ozawa, H. (2005). Awareness of the role of folic acid, dietary folate intake and plasma folate concentration in Japan. *Journal of Obstetrics and Gynaecology Research*, *31*(2), 172-177.	Wrong age group
Lake, R. S., & Drake, L. M. (1995). Nutrition Intervention Program for Pregnant Girls [Abstract]. *Public Health Reports (1974-)*, 208-208.	Does not report a valid comparable measure of dietary intake or nutritional status
Lenders, C. M., McElrath, T. F., & Scholl, T. O. (2000). Nutrition in adolescent pregnancy. *Current opinion in pediatrics*, *12*(3), 291-296.	Does not report a valid comparable measure of dietary intake or nutritional status
Loto, O. M., Ezechi, O. C., Kalu, B. K. E., Loto, A. B., Ezechi, L. O., & Ogunniyi, S. O. (2004). Poor obstetric performance of teenagers: is it age-or quality of care-related?. *Journal of obstetrics and Gynaecology*, *24*(4), 395-398.	Country of origin excluded -Nigeria
Mahfouz, A. A., El-Said, M. M., Al-Erian, R. A., & Hamid, A. M. (1995). Teenage pregnancy: are teenagers a high risk group?. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *59*(1), 17-20.	Does not report a valid comparable measure of dietary intake or nutritional status
Malviya, M. K., Bhardwaj, V. K., Chansoria, M., & Khare, S. (2003). Anthropometric profile and perinatal outcome of babies born to young women (< 18 years). *Indian pediatrics*, *40*(10), 971-976.	Country of origin excluded - India
Mathews, F., Yudkin, P., & Neil, A. (1998). Folates in the periconceptional period: are women getting enough?. *BJOG: An International Journal of Obstetrics & Gynaecology*, *105*(9), 954-959.	Does not report a valid comparable measure of dietary intake or nutritional status

Mathews, F., Yudkin, P., Smith, R. F., & Neil, A. (2000). Nutrient intakes during pregnancy: the influence of smoking status and age. *Journal of Epidemiology and Community Health*, *54*(1), 17-23.	Wrong age group
Perry, R. L., Mannino, B., Hediger, M. L., & Scholl, T. O. (1996). Pregnancy in early adolescence: Are there obstetric risks?. *Journal of Maternal-Fetal Medicine*, *5*(6), 333-339.	Does not report a valid comparable measure of dietary intake or nutritional status
Ruppel, K. J. (2001). *Health beliefs and health behaviors of pregnant adolescents*.	Not a primary study, dissertation
Stang, J., Story, M., & Feldman, S. (2005). Nutrition in adolescent pregnancy. *International Journal of Childbirth Education*, *20*(2), 4.	Not a primary study, review article
Story, M., & Alton, I. (1995). Nutrition Issues and Adolescent Pregnancya. *Nutrition Today*, *30*(4), 142-151.	Not a primary study, review article
Wrieden, W. L., & Symon, A. (2003). The development and pilot evaluation of a nutrition education intervention programme for pregnant teenage women (food for life). *Journal of Human Nutrition and Dietetics*, *16*(2), 67-71.	Does not report a valid comparable measure of dietary intake or nutritional status
Whisner, C. M., Young, B. E., Pressman, E. K., Queenan, R. A., Cooper, E. M., & O'Brien, K. O. (2015). Maternal diet but not gestational weight gain predicts central adiposity accretion in utero among pregnant adolescents. *International Journal of Obesity*, *39*(4), 565-570.	Reports same data as Young 2012 which is included
Symon, A. G., & Wrieden, W. L. (2003). A qualitative study of pregnant teenagers' perceptions of the acceptability of a nutritional education	Does not report a valid comparable measure of dietary intake or nutritional status

intervention. *Midwifery*, *19*(2), 140-147.	
Dubois, S., Coulombe, C., Pencharz, P., Pinsonneault, O., & Duquette, M. P. (1997). Ability of the Higgins Nutrition Intervention Program to improve adolescent pregnancy outcome. *Journal of the American Dietetic Association*, *97*(8), 871-873.	Characteristics of participants at the time of data collection are not given. A paper where these can be found is referenced; however this is not available in English language.
Pope, J. F., Skinner, J. D., & Carruth, B. R. (1997). Adolescents' self-reported motivations for dietary changes during pregnancy. *Journal of Nutrition Education*, *29*(3), 137-144.	Does not report a valid comparable measure of dietary intake or nutritional status

Supplementary Table 2. Pooled, Weighted Mean Nutrient Intakes Expressed as Percentages of Dietary Reference Values by Stage of Pregnancy

	Percentage of UK Dietary Reference Value												Percentage of US Dietary Reference Value											
	Total			Second Trimester			Third Trimester			Mean over pregnancy			Total			Second Trimester			Third Trimester			Mean over pregnancy		
Nutrient	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval
Energy kcal/day[1]	9	91.0	30, 153	4	81.9	34.1, 129.8	7	83.0	37, 129	4	93.0	37, 149	9			4			7			4		
Protein grams/day[2]	9	224.0	99.9, 348.1	4	126.4	44.2, 208.5	6	134.8	44.4, 225.1	4	174.1	137.9, 210.3	9	129.2	40.1, 218.4	4	90.8	31.8, 149.8	6	96.8	31.9, 161.7	4	125.1	17.0, 233.1
Calcium mg/day[3]	8	107.3	0, 232	2	164.9	1.7, 328.1	5	117.6	9.9, 225.2	4	101.5	0, 233.7	8	66.0	0, 147.6	2	101.5	1, 201.9	5	72.4	6.1, 138.6	4	62.4	0, 194.7
Phosphorous mg/day [4]	4	208.2	30.1, 386.2	1			2	195.1	47.2, 343	3	208.7	31.3, 386	4	104.1	30.7, 177.4	1			2	97.6	23.6, 171.5	3	104.3	15.6, 193
Iron mg/day[5]	10	119.1	0, 259.9	4	111.0	29.7, 192.3	7	118.2	0, 268.3	4	125.1	0, 251	10	65.3	0, 139.5	4	60.8	16.3, 105.4	7	64.8	0, 147.1	4	68.6	0, 137.6
Magnesium mg/day[6]	6	84.2	15.6, 152.8	1			4	79.4	27.3, 131.4	3	86.3	39.1, 133.6	6	63.2	20.1, 106.3	1			4	59.5	20.4, 98.6	3	64.7	7.6, 121.9
Potassium mg/day[7]	2	83.2	43.6, 122.7	1			2	84.3	43.6, 125	0			2	61.9	32.6, 91.2	1			2	62.8	32.5, 93.1	0		0, 0
Zinc mg/day[8]	10	145.7	0, 297.2	4	118.7	21.5, 215.9	7	128.4	21.9, 234.9	4	178.0	0, 385.6	10	85.0	0, 189.7	4	69.3	12.6, 126	7	74.9	12.8, 137	4	103.8	0, 224.9
Vitamin D µg/day[9]	5	34.8	0, 83.1	1			4	31.2	0, 81.9	2	54.6	0, 114.3	5	23.2	0, 58.2	1			4	20.8	0, 54.6	2	36.4	0, 96.1
Vitamin E[10]	5			1			4			2			5	55.0	0, 148.9	1			4	56.8	0, 129.2	2	51.4	0, 0
Vitamin C[11]	7	309.2	0, 894.9	1			4	297.3	0, 753.6	4	294.9	0, 916.8	7	193.2	0, 524.6	1			4	185.8	0, 471	4	184.3	0, 573
Folate[12]	6	125.1	0, 487.3	1			4	146.9	0, 374	3	142.6	0, 580.1	6	62.6	0, 256	1			4	73.4	0, 187	3	71.3	0, 290
Riboflavin[13]	4	200.3	0, 405.7	1			4	225.9	29.9, 421.9	4	199.1	0, 404.9	4	157.4	5.9, 308.9	1			4	177.5	23.5, 331.5	4	156.4	0, 319.3
B12[14]	5	224.0	0, 1011.1	1			3	162.9	0, 758.1	3	365.5	0, 1205.8	5	129.2	0, 488.1	1			3	207.3	0, 550.7	3	210.8	0, 685
Vitamin A[15]	7	162.5	0, 583	1			4	141.5	0, 456.8	4	164.2	0, 578.3	7	130.0	0, 571.1	1			4	113.2	0, 365.5	4	131.4	0, 462.6

1.UK EARs, First and Second Trimester requirement (Average UK EAR for Females aged 11-19) 2355kcal/d, Third Trimester requirement 2546 kcal/d, Mean over pregnancy requirement (average of three trimester values) 2419kcal/d 2.UK RNI 51 g/day and US RDA 71g/day 3.UK RNI 800mg/day and US RDA 1300mg/day 4. UK RNI 625mg/day and US RDA 1250mg/day 5. UK RNI 14.8mg/day and US RDA 27mg/day 6. UK RNI 300mg/day and US RDA 400mg/day 7. UK RNI 3500mg/day and US RDA 4700mg/day 8. UK RNI 7mg/day and US RDA 12mg/day 9.UK RNI 10µg/day and US RDA 15µg/day 10. US RDA 15mg/day 11. UK RNI 40mg/day and US RDA 80mg/day 12.UK RNI 200µg/day and US RDA 600µg/day 13. UK RNI 1.1mg/day and US RDA 1.4mg/day 14. UK RNI 1.5µg/day and US RDA 2.6µg/day 15.UK RNI 600µg/day and US RDA 750µg/day

Supplementary Table 3. Pooled, Weighted Mean Nutrient Intakes Expressed as Percentages of Dietary Reference Values by Study Country of Origin

	Percentage of UK Dietary Reference Value						Percentage of US Dietary Reference Value					
	UK studies			US studies			UK studies			US studies		
Nutrient	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval
Energy kcal/day[1]	2	89.1	39.2, 139.1	5	100.4	24.2, 176.6	2			5		
Calcium mg/day[2]	2	106.3	20.8, 191.9	5	107.0	0, 239.9	2	65.4	12.8, 118.1	5	65.8	0, 147.6
Iron mg/day[3]	2	112.9	0, 331	5	131.9	0, 273.1	2	61.9	0, 181.5	5	72.3	0, 149.7
Magnesium mg/day[4]	2	78.8	30.3, 127.4	4	86.8	10.5, 163	2	59.1	22.7, 95.5	4	65.1	7.9, 122.3
Zinc mg/day[5]	2	115.8	36.2, 195.3	5	186.8	0, 399	2	67.5	21.1, 113.9	5	109.0	0, 232.8
Vitamin D µg/day[6]	2	21.4	0, 54.4	3	53.2	0, 116.7	2	14.3	0, 36.3	3	35.4	0, 77.8
Vitamin E[7]	2			3			2	58.8	0, 124.5	3	53.1	0, 151.2
Vitamin C[8]	2	317.2	0, 791.3	4	309.6	0, 924.8	2	198.2	0, 494.6	4	193.5	0, 578
Folate[9]	2	93.8	4.3, 183.2	4	139.3	0, 459.1	2	46.9	2.1, 91.6	4	69.7	0, 229.5
Vitamin A[10]	2	124.3	0, 422.7	4	179.9	0, 658.3	2	99.4	0, 338.2	4	143.9	0, 526.7

1.UK EARs, First and Second Trimester requirement (Average UK EAR for Females aged 11-19) 2355kcal/d, Third Trimester requirement 2546 kcal/d, Mean over pregnancy requirement (average of three trimester values) 2419kcal/d 2.UK RNI 800mg/day and US RDA 1300mg/day 3. UK RNI 14.8mg/day and US RDA 27mg/day 4. UK RNI 300mg/day and US RDA 400mg/day 5. UK RNI 7mg/day and US RDA 12mg/day 6.UK RNI 10µg/day and US RDA 15µg/day 7. US RDA 15mg/day 8. UK RNI 40mg/day and US RDA 80mg/day 9.UK RNI 200µg/day and US RDA 600µg/day 10.UK RNI 600µg/day and US RDA 750µg/day

Supplementary Table 4. Pooled, Weighted Mean Biological Markers of Nutritional Status by Stage of Pregnancy

	Total			First Trimester			Second Trimester			Third Trimester		
Nutrient	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval
Haemoglobin (g/dL)[1]	11	114.6	95.4, 133.8	2	121.8	100.2, 143.4	8	114.9	97.7, 132	11	109.2	90.3, 128.1
Haematocrit (g/L)[2]	4	33.7	28, 39.4	1			2	33.0	27.1, 38.9	4	32.3	26.5, 38
Ferritin (µg/L)[3]	5	18.2	0, 48.3	0			5	21.8	0, 60.8	4	16.5	0, 40.8
Zinc (µmol/L-1)[4]	5	11.5	5.9, 17.1	2	11.8	5.1, 18.5	0			5	11.0	5.6, 16.5
Selenium (µg/L)[5]	4	61.8	39.2, 84.4	0			2	46.8	29.1, 64.5	4	64.8	41.8, 87.7
25_OH_D (nmol/L)[6]	6	55.9	6.2, 105.7	0			1			5	55.9	8.9, 103

1. Target value 110 g/L 2. Target value33 g/L 3. Target value 15 µg/L 4. Target value 6.12µmol/L-1 5. Target value 90 µg/L 6. Target value 25 nmol/L

Supplementary Table 5. Pooled, Weighted Mean Biological Markers of Nutritional Status by Study Country of Origin

	Non-US Studies			US studies		
Nutrient	Number of studies	Mean	Confidence Interval	Number of studies	Mean	Confidence Interval
Haemoglobin (g/dL)[1]	3	109.2	88.6, 129.8	8	114.3	96.1, 132.6
Haematocrit (g/L)[2]	2	26.2	20.2, 32.2	2	33.6	27.7, 39.4

1. Target value 110 g/L 2. Target value33 g/L

Appendix 2.

Born in Bradford baseline questionnaire

Appendix 3.

Born in Bradford Data transfer agreement

Study ID | 1 | 2 | 0 | 0 | 1 | P | 1 |

Born in Bradford - Mothers' Questionnaire

To be completed by interviewer:

Interviewer's Number | | | - | | | (*2 initials - 2 numbers e.g. AN 01)*

1. Date Completing this questionnaire?

		/			/	2	0		
d	d		m	m		y	y	y	y

***2. What language(s) was used for administering the questionnaire?**

☐ English ☐ Mirpuri/Punjabi ☐ Urdu

Any other language (please write in)

***3. Was an Interpreter used?**

☐ No ☐ Hospital/Study Interpreter ☐ Family Member/Friend

(To be measured by interviewer)

4. Height (Cms) | | | | . | |

5. Weight | | | | . | | (Kilos) (Grms)

***6. Triceps** (Cms) | | | . | | ☐ Not able to take

***7. Arm circumference** (Cms) | | | . | | ☐ Not able to take

8. How old were you when you had your first period?

				☐ Don't Know
y	y	m	m	

9. Will this be your first child? ☐ Yes ☐ No

9a) If no:- what month and year were each of your previous children born in ?
- starting with the eldest:

	Month	Year
First child		
Second child		
Third child		
Fourth child		
Fifth child		
(add birth dates of all other children)		

Section A - Where you live

These questions relate to where you are living at present.

***A1. How long have you lived at your current address?**

y	y	m	m

***A2. In which of these ways does your household occupy this address?**
(Cross ONE box ONLY)

If answers yes to any of the three * questions, please go to A2a). If not go to A3

- ☐ Buying it with the help of a mortgage or loan
- ☐ Owns outright
- ☐ *Rents it
- ☐ *Lives here rent free (including rent free in relatives/friends property excluding squatting)
- ☐ *Pays part rent and part mortgage (shared ownership)
- ☐ Don't know
- ☐ Squatting

***A2a) If A2 was answered - Rents it: Lives rent free or pays part rent and part mortgage - ask who is your landlord?**
(Cross ONE box ONLY)

- ☐ Private Landlord or Letting Agency, Another individual
- ☐ Housing Association, Housing Co-operative, Charitable Trust
- ☐ Local Authority/Council
- ☐ Relative or friend (before you lived here) of a household member
- ☐ Employer (individual) of a household member
- ☐ Employer (organisation) of a household member
- ☐ Another Organisation
- ☐ Don't Know

A3) How many bedrooms does your household have, including bedsitting rooms and spare bedrooms?

Enter number of bedrooms | | |

Section B - Who you live with?

B1. What ages are those, including yourself, who live in your household or accommodation? [If age not known, please give best estimate]

Is there anybody:-

Age	Number of males	Number of females
Under 2 years		
between 2 -15 years		
between 16 - 17 years		
between 18 - 64 years		
65 years and over		

B2. Are you: (Cross ONE box ONLY)

- ☐ Married (first marriage)
- ☐ Re-married
- ☐ Single (never married)
- ☐ Separated (but still legally married)
- ☐ Divorced
- ☐ Widowed

B3. Are you: (Cross ONE box ONLY)

- ☐ Living with baby's father
- ☐ Living with another partner
- ☐ Not living with a partner – but in a relationship (eg. partner living abroad or in another propery)
- ☐ Not living with a partner and not in a relationship

Section C - About you, your family and your baby's father and his family

C1. What country were you and your baby's father born in?

(Cross ONE box ONLY in each column).

Country	You	Country	Baby's father
England	☐	England	☐
Northern Ireland	☐	Northern Ireland	☐
Scotland	☐	Scotland	☐
Wales	☐	Wales	☐
Channel Islands	☐	Channel Islands	☐
Isle of Man	☐	Isle of Man	☐
Republic of Ireland	☐	Republic of Ireland	☐
Czech Republic	☐	Czech Republic	☐
Poland	☐	Poland	☐
Slovakia	☐	Slovakia	☐
Bangladesh	☐	Bangladesh	☐
India	☐	India	☐
Pakistan	☐	Pakistan	☐
Sri Lanka	☐	Sri Lanka	☐
Philippines	☐	Philippines	☐
Don't know	☐	Don't know	☐

You - Other (Please write in)

Baby's father - Other (Please write in)

***C2. To be asked if not born in the UK**
How old were you when you moved to the UK?

Age in Years | | | | | |
y y m m

If answered Pakistan for you and/or baby's father in C1 go to C3.
If not Pakistan for either person then go to C4.

C3) Were you and/or baby's father born in Mirpur District?
(Cross ONE box ONLY in each row)

You	☐ Yes	☐ No	☐ Don't Know
Baby's father	☐ Yes	☐ No	☐ Don't Know

***C3a) If yes, which town or village?**

You (Please write in) ☐ Don't Know

Baby's father (Please write in) ☐ Don't Know

***C3b) Do you know the name of your's and baby's father's Biraderi?**
(Interviewer - consult list of Biraderi if necessary).

You (Please write in) ☐ Don't Know

Baby's father (Please write in) ☐ Don't Know

*C4. What country were your mother and father born in?

(Cross ONE box ONLY in each column).

Country	Your Mother	Country	Your Father
England	☐	England	☐
Northern Ireland	☐	Northern Ireland	☐
Scotland	☐	Scotland	☐
Wales	☐	Wales	☐
Channel Islands	☐	Channel Islands	☐
Isle of Man	☐	Isle of Man	☐
Republic of Ireland	☐	Republic of Ireland	☐
Czech Republic	☐	Czech Republic	☐
Poland	☐	Poland	☐
Slovakia	☐	Slovakia	☐
Bangladesh	☐	Bangladesh	☐
India	☐	India	☐
Pakistan	☐	Pakistan	☐
Sri Lanka	☐	Sri Lanka	☐
Philippines	☐	Philippines	☐
Don't know	☐	Don't know	☐

Your mother - Other (Please write in)

Your father - Other (Please write in)

If answered Pakistan for your mother or father in C4 go to C5 if not Pakistan then go to C6

C5) Were your mother and father born in Mirpur district?

(Cross ONE box ONLY)

Your mother	☐ Yes	☐ No	☐ Don't Know
Your father	☐ Yes	☐ No	☐ Don't Know

C5a) If yes, which town or village?

Your mother - (Please write in) ☐ Don't Know

Your father - (Please write in) ☐ Don't Know

C5b) Do you know the name of your mother's and father's Biraderi?

Your mother - (Please write in) ☐ Don't Know

Your father - (Please write in) ☐ Don't Know

C6 What country were your grandparents born in?

(Cross ONE box ONLY in each column).

Country	Your mother's mother	Your mother's father	Your father's mother	Your father's father
England	☐	☐	☐	☐
Northern Ireland	☐	☐	☐	☐
Scotland	☐	☐	☐	☐
Wales	☐	☐	☐	☐
Channel Islands	☐	☐	☐	☐
Isle of Man	☐	☐	☐	☐
Republic of Ireland	☐	☐	☐	☐
Czech Republic	☐	☐	☐	☐
Poland	☐	☐	☐	☐
Slovakia	☐	☐	☐	☐
Bangladesh	☐	☐	☐	☐
India	☐	☐	☐	☐
Pakistan	☐	☐	☐	☐
Sri Lanka	☐	☐	☐	☐
Philippines	☐	☐	☐	☐
Don't know	☐	☐	☐	☐

Your mother's mother - Other (Please write in)

Your mother's father - Other (Please write

Your father's mother - Other (Please write in)

Your father's father - Other (Please write in)

If answered Pakistan in C6 for where any of your grandparents were born ask C7:
If not go to C8.

Answer this if your grandparents were born in Pakistan If not go to C8.

C7. Were your grandparents born in Mirpur district? (Cross ONE box ONLY in each row)

Your mothers mother	☐ Yes	☐ No	☐ Don't Know
Your mother's father	☐ Yes	☐ No	☐ Don't Know
Your father's mother	☐ Yes	☐ No	☐ Don't Know
Your father's father	☐ Yes	☐ No	☐ Don't Know

C7a) If yes, which town or village ?

Your mother's mother - (Please write in) ☐ Don't Know

Your mother's father - (Please write in) ☐ Don't Know

Your father's mother - (Please write in) ☐ Don't Know

Your father's father - (Please write in) ☐ Don't Know

C7b) Do you know the name of your grandparent's Biraderies?

Your mothers mother - (Please write in) ☐ Don't Know

Your mothers father - (Please write in) ☐ Don't Know

Your fathers mother - (Please write in) ☐ Don't Know

Your fathers father - (Please write in) ☐ Don't Know

C8. What country were the parents of your baby's father born in?

(Cross ONE box ONLY in each column).

Country	Mother of baby's father	Country	Father of baby's father
England	☐	England	☐
Northern Ireland	☐	Northern Ireland	☐
Scotland	☐	Scotland	☐
Wales	☐	Wales	☐
Channel Islands	☐	Channel Islands	☐
Isle of Man	☐	Isle of Man	☐
Republic of Ireland	☐	Republic of Ireland	☐
Czech Republic	☐	Czech Republic	☐
Poland	☐	Poland	☐
Slovakia	☐	Slovakia	☐
Bangladesh	☐	Bangladesh	☐
India	☐	India	☐
Pakistan	☐	Pakistan	☐
Sri Lanka	☐	Sri Lanka	☐
Philippines	☐	Philippines	☐
Don't know	☐	Don't know	☐

Mother of baby's father - Other (Please write in)

Father of baby's father - Other (Please write in)

If answered Pakistan in C8 for where the mother of the baby's father or father of the baby's father was born ask C9: If not then go to C10.

Answer this if the mother of the baby's father or father of the baby's father was born in Pakistan

C9. Was the mother of the baby's father / father of the baby's father born in Mirpur ? (Cross ONE box ONLY in each row)

Mother of baby's father	☐ Yes	☐ No	☐ Don't Know
Father of baby's father	☐ Yes	☐ No	☐ Don't Know

C9a) If yes, which town or village ?

Mother of baby's father - (Please write in) ☐ Don't Know

Father of baby's father - (Please write in) ☐ Don't Know

C9b) Do you know the name of your baby's father's parents' Biraderies?

Mother of baby's father - (Please write in) ☐ Don't Know

Father of baby's father - (Please write in) ☐ Don't Know

Returning to you;

C10. To which of these groups do you consider you belong? (Cross ONE box ONLY)

☐ White ☐ Asian or Asian British

☐ Mixed ethnic group ☐ Chinese

☐ Black or Black British ☐ Other

C10a) If Answered C10 as White what do you consider your cultural background? (Cross ONE box ONLY)

☐ British ☐ Irish

Any other white background (please write in)

C10b) If Answered C10 as Mixed ethnic group what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Indian
- ☐ White and Pakistani
- ☐ White and Bangladeshi
- ☐ White and Indian Caribbean
- ☐ White and African-Indian

Any other mixed background (please write in)

C10c) If answered C10 as Black or Black British what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Caribbean
- ☐ African

Any other Black background (please write in)

C10d) If answered C10 as Asian or Asian British what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Indian
- ☐ Pakistani
- ☐ Bangladeshi
- ☐ Indian Caribbean
- ☐ African-Indian

Any other Asian background (please write in)

C10e) If answered C10 as Chinese what do you consider your cultural background? (Cross ONE box ONLY)

- ☐ Chinese
- ☐ Japanese
- ☐ Filipino
- ☐ Vietnamese

Any Chinese or other background (please write in)

C10f) If answered C10 as Other what do you consider your cultural background? (please write in)

Section D - Your Family

These questions are about you and your family and about baby's father and his family.

D1. Are you related to the father of your baby other than by marriage? For example are you cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D1a) If yes, how are you related to the father of your baby? e.g. 1st cousin, 2nd cousin (Cross ONE box ONLY)

☐ 1st Cousin
☐ 1st Cousin, once removed
☐ Second Cousin
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

D2. Were your parents related? For example were they cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D2a) If yes, how were your parents related? (Cross ONE box ONLY)

☐ 1st Cousins
☐ 1st Cousins, once removed
☐ Second Cousins
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

D3. Were the parents of the father of your baby related? For example were they cousins? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

D3a) If yes, how were they related? (Cross ONE box ONLY)

☐ 1st Cousins
☐ 1st Cousins, once removed
☐ Second Cousins
☐ Other related by blood
☐ Other related by marriage
☐ Don't know

Interviewer: If answered yes in D1, please complete a family tree (on a separate form after you have completed this section. Do not change questions D1 to D3 after the family tree is completed).

D4. Was a family tree completed? ☐ Yes ☐ No

Section E Education

E1. What is the highest educational qualification you have? (Cross ONE box ONLY)

- ☐ 1 + 0 levels/CSEs/GCEs (any grades)
- ☐ 5 + 0 levels, 5+ CSEs (grade 1) 5 + GCSEs (grades A-C), School Certificate
- ☐ 1 + A levels/AS levels
- ☐ 2 + A levels, 4 + AS levels, Higher School Certificate
- ☐ NVQ Level 1, Foundation GNVQ
- ☐ NVQ Level 2,Intermediate GNVQ
- ☐ NVQ Level 3, Advanced GNVQ
- ☐ NVQ Levels 4-5, HNC, HND
- ☐ First Degree (e.g. BA, BSc)
- ☐ Higher Degree (e.g. MA, PhD, PGCE Post-graduate certificates/diplomas)
- ☐ Other qualifications (e.g. City and Guilds, RSA/OCR, BTEC/Edexcel)
- ☐ Overseas qualification ***(If obtained in Pakistan go to E1a, If obtained in another country go to E1b)***
- ☐ No Qualifications
- ☐ Don't know

E1a) If your highest educational qualification was obtained in Pakistan please indicate: (Cross ONE box ONLY)

- ☐ Second School Certificate (SSC) Matriculation (Metric)
- ☐ Diploma in Commerce
- ☐ Higher Secondary (HSC) Cert/Intermediate Humanities, Pre-Eng or Pre-Medical/Science Streams
- ☐ Certificate from Board of Technical Education
- ☐ Diploma from Board of Technical Education
- ☐ Final Apprenticeship Certificate/Grade 2 Skilled
- ☐ Vocational Institute Diploma/Grade 3 Skilled Worker Certificate
- ☐ Batchelor Degree (4 year) in generally professional fields (excluding Bachelor of Education)
- ☐ Batchelor of Arts/Commerce/Engineering/Science/Technology (Pass and Honours)
- ☐ Postgraduate Eg Masters degree/PhD
- ☐ Don't know

E1b) If your highest educational qualification was not obtained in the UK or in Pakistan, please specify what that qualification was and which country it was obtained in.

Qualification

Country

E2. What is baby's father's highest educational qualification? (Cross ONE box ONLY)

- ☐ 1 + 0 levels/CSEs/GCEs (any grades)
- ☐ 5 + 0 levels, 5+ CSEs (grade 1) 5 + GCSEs (grades A-C), School Certificate
- ☐ 1 + A levels/AS levels
- ☐ 2 + A levels, 4 + AS levels, Higher School Certificate
- ☐ NVQ Level 1, Foundation GNVQ
- ☐ NVQ Level 2,Intermediate GNVQ
- ☐ NVQ Level 3, Advanced GNVQ
- ☐ NVQ Levels 4-5, HNC, HND
- ☐ First Degree (e.g. BA, BSc)
- ☐ Higher Degree (e.g. MA, PhD, PGCE Post-graduate certificates/diplomas)
- ☐ Other qualifications (e.g. City and Guilds, RSA/OCR, BTEC/Edexcel)
- ☐ Overseas qualification ***(If obtained in Pakistan go to E2a, If obtained in another country go to E2b)***
- ☐ No Qualifications
- ☐ Don't know

E2a) If his highest educational qualification was obtained in Pakistan please indicate (Cross ONE box ONLY)

- ☐ Second School Certificate (SSC) Matriculation (Metric)
- ☐ Diploma in Commerce
- ☐ Higher Secondary (HSC) Cert/Intermediate Humanities, Pre-Eng or Pre-Medical/Science Streams
- ☐ Certificate from Board of Technical Education
- ☐ Diploma from Board of Technical Education
- ☐ Final Apprenticeship Certificate/Grade 2 Skilled
- ☐ Vocational Institute Diploma/Grade 3 Skilled Worker Certificate
- ☐ Batchelor Degree (4 year) in generally professional fields (excluding Bachelor of Education)
- ☐ Batchelor of Arts/Commerce/Engineering/Science/Technology (Pass and Honours)
- ☐ Postgraduate Eg Masters degree/PhD
- ☐ Don't know

E2b) If his highest educational qualification was not obtained in the UK or Pakistan, please specify what the qualification was and which country it was obtained in.

Qualification

Country

Section F Your Current Employment

F1. Are you currently a full time student? ☐ Yes ☐ No

F2. Are you currently employed? ☐ Yes ☐ No (If Yes, go to F3)

F2a) If No - Have you ever worked? ☐ Yes ☐ No (If No, go to F12)

F2b) If yes to F2a - how long ago did you stop working?

Years ☐☐ Months ☐☐

If stopped less than one month ago record weeks - (round up to nearest week) Weeks ☐☐

F3. Are you currently on Maternity/Sick Leave? ☐ Yes ☐ No

F4. Were/are you self employed? ☐ Yes ☐ No

F4a) If no to F4 - If an employee, what type of industry/company do/did you work for?

F5. What was/is your job title?

F5b) How many people work at the place that you usually work?

☐ 1-2 ☐ 3-24 ☐ 25-499 ☐ 500+ (Cross ONE box ONLY)

F5c) Are/were you a: (Cross ONE box ONLY)

☐ Manager ☐ Supervisor ☐ Other Employee

F6. Please list the 2 or 3 main tasks you perform/performed at work?

F7. How many hours do/did you work in a typical week?

Indicate number of hours ☐☐.☐

Only answer F8-F11 if currently working or stopped working less than one year ago.

F8. How long have/had you done this job?

Years ☐☐ Months ☐☐

F9. Where is/was your main place of work? (Cross ONE box ONLY)

☐ Work mainly at or from home ☐ No regular place of work

If neither of the above ask 10 and 10a. Everyone should be asked F11.

F10. What is/was your main place of work?

Street

Town

Postcode

F10a. How do/did you usually travel to work?

Cross ONE box ONLY indicating what is/was the longest part, by distance, of your usual journey to work.

☐ Work mainly at or from home
☐ Train
☐ Bus, minibus or coach
☐ Motor cycle, scooter or moped
☐ Driving a car or van
☐ Passenger in a car or van
☐ Taxi
☐ Bicycle
☐ On foot
☐ Other

Other - (please write in)

F11. How many days in a typical week do/did you go to work?

(Enter 0 if works mainly at or from home)

Days ☐☐

About baby's father

*F12. Which best describes the sort of work the baby's father does?

If not in work now, please **cross ONE box ONLY** to show what work he did in his last main job.

- ☐ Modern professional occupations
- ☐ Clerical and intermediate occupations
- ☐ Senior managers or administrators
- ☐ Technical and craft occupations
- ☐ Semi-routine manual and service occupations
- ☐ Routine manual and service occupations
- ☐ Middle or junior managers
- ☐ Traditional professional occupations
- ☐ Self Employed
- ☐ Student/in training
- ☐ Does not work – long term unemployed/ill health (one year or over).
- ☐ Don't know

***F13. Can you tell me which of these credits/allowances/benefits you and your husband/partner receive?**

(Please cross ALL that apply)

- ☐ Child Benefit
- ☐ Child Tax Credit
- ☐ Working Tax Credit (Formerly Working Family Tax Credit and Disabled Person's Tax Credit)
- ☐ Income Support
- ☐ Disability Living Allowance (including Disabled Person's Tax Credit)
- ☐ Income tested Job Seekers Allowance (Unemployment)
- ☐ Housing Benefit/Rent Rebate/Council Tax Benefit
- ☐ Incapacity Benefit (Replaces Invalidity and NI Sickness Benefit)
- ☐ Pension Credit
- ☐ Carer's allowance (was Invalid Care Allowance)
- ☐ None
- ☐ Don't know
- ☐ Does not wish to answer

Any Other State Benefit Please specify below

***F14. This table shows income in weekly, monthly and annual amounts.**

Which of the amounts on this list represents you and your husband/partner's, total income from all jobs, (full and part time), all tax credits, all benefits and all other sources and earnings after tax when all income is added together. (Cross ONE box ONLY)

Weekly Income after Tax	Monthly Income after tax	Annual Income after Tax	
Less than £25	Less than £108	less than £1,299	☐
£25 - £39	£109 - £175	£1,300 - £2,099	☐
£40 - £59	£176 - £259	£2,100 - £3,099	☐
£60 - £79	£260 - £350	£3,100 - £4,199	☐
£80 - £99	£351 - £433	£4,200 - £5,199	☐
£100 - £124	£434 - £542	£5,200 - £6,499	☐
£125 - £149	£543 - £650	£6,500 - £7,799	☐
£150 - £179	£651 - £775	£7,800 - £9,299	☐
£180 - £209	£776 - £917	£9,300 - £10,999	☐
£210 - £259	£918 - £1,125	£11,000 - £13,499	☐
£260 - £299	£1,126 - £1,333	£13,500 - £15,999	☐
£300 - £379	£1,334 - £1,667	£16,000 - £19,999	☐
£380 - £479	£1,668 - £2,083	£20,000 - £24,999	☐
£480 - £577	£2,084 - £2,500	£25,000 – £29,999	☐
£578 - £769	£2,501 - £3,333	£30,000 - £39,999	☐
£770 - £962	£3,334 - £4,167	£40,000 - £49,999	☐
£963 - £1,154	£4,168 - £5,000	£50,000 - £59,999	☐
£1,155 - £1,346	£5,001 - £5,833	£60,000 - £69,999	☐
£1,347 - £1,538	£5,834 - £6,667	£70,000 - £79,999	☐
£1,539 or more	£6,668 or more	£80,000 or more	☐
Does not wish to answer ☐		Don't know	☐

The next few questions are about the sorts of things that some people have but which many people have difficulty finding the money for.

***F15. Do you or you and your husband/partner have?**
(Cross ONE box ONLY in each row)

	Yes	I/we would like this but can't afford it at this moment	I/we do not want/need this at the moment	Does not wish to answer	Don't know
a) A holiday from home for at least one week once a year (not including staying with relatives in their home)	☐	☐	☐	☐	☐
b) Friends or family who call for a drink or meal at your house at least once a month	☐	☐	☐	☐	☐
c) Two pairs of all weather shoes	☐	☐	☐	☐	☐
d) Enough money to keep your home in a decent state of decoration	☐	☐	☐	☐	☐
e) Household contents Insurance	☐	☐	☐	☐	☐
f) Money to make regular savings of £10 a month or more for rainy days or retirement	☐	☐	☐	☐	☐
g) Money to replace any worn out furniture	☐	☐	☐	☐	☐
h) Money to replace or repair major electrical goods such as a refrigerator or a washing machine when broken	☐	☐	☐	☐	☐
i) A small amount of money to spend each week on yourself (not on your family)	☐	☐	☐	☐	☐
j) A hobby or leisure activity	☐	☐	☐	☐	☐
k) In winter are you able to keep your home warm enough	☐	☐	☐	☐	☐

***F16. Sometimes people are not able to pay every bill when it falls due. May I ask, are you up to date with the bills on this list or are you behind with any of them?**

Interviewer: Show card with list of bills

F16a) Are you up to date with all these bills? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know ☐ Does not wish to answer

F16b) If no, which ones are you behind with? (Cross ALL that apply)

- ☐ Electricity Bill
- ☐ Gas
- ☐ Other fuel bills like coal or oil
- ☐ Council tax
- ☐ Insurance Policies
- ☐ Telephone Bill
- ☐ Television/video/DVD rental or hire purchase
- ☐ Other hire purchase payments
- ☐ Water rates

***F17. These questions apply if you have any children living in your household now.** (Cross ONE box ONLY in each row)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
a) Are there enough bedrooms for every child of 10 or over of a different sex to have their own bedroom.	☐	☐	☐	☐

The following questions apply to your children living with you

b) Does your child/children have leisure equipment or a bicycle	☐	☐	☐	☐
c) Does your child/children have celebrations on special occasions such as birthdays, or religious festivals	☐	☐	☐	☐
d) Does your child/do your children go swimming at least once a month	☐	☐	☐	☐
e) Does your child/children do A hobby or leisure activity	☐	☐	☐	☐
f) Does your child/children have friends round for tea or a snack once a fortnight	☐	☐	☐	☐

F18. If you have any children age under 6 who are not in School

(Cross ONE box ONLY)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
Does your child/children go to a toddler group/nursery/playgroup at least once a week	☐	☐	☐	☐

F19. If your child/children is/are over age 6 or in school.

(Cross ONE box ONLY)

	Yes	Would like to have this but cannot afford this at the moment	Children do not want/need this at the moment	Does not apply
Does your child/children go on school trips	☐	☐	☐	☐

F20. For children of all ages (Cross ONE box ONLY)

	Yes	No	Does not apply
Does your child/children have an outdoor space or facilities nearby where they can play safely	☐	☐	☐

F21. How well would you say you or you and your husband/partner are managing financially these days. Would you say you are? (Cross ONE box ONLY)

- ☐ Living comfortably
- ☐ Doing alright
- ☐ Just about getting by
- ☐ Finding it quite difficult
- ☐ Finding it very difficult
- ☐ Does not wish to answer

F22. Compared to a year ago, how would you say you and your husband/partner are doing financially now? (Cross ONE box ONLY)

- ☐ Better off
- ☐ About the same
- ☐ Worse off
- ☐ Does not wish to answer

Section G - Smoking/Alcohol/Drug Use

We apologise if any questions in this section cause offence - we are asking everyone the same questions but we realise some religions do not permit certain things.

SMOKING

G1. Have you ever regularly smoked cigarettes; that is at least one cigarette a day? (Cross ONE box ONLY)

☐ Yes for more than 1 year ☐ Yes for less than 1 year ☐ No

If NO, go to question G4

G1a) How old were you when you started smoking cigarettes?

Age: ☐☐ Years old ☐ Don't Remember

G2. Do you smoke cigarettes nowadays? ☐ Yes ☐ No (Cross ONE box ONLY)

G2a) If no, when did you stop smoking?

Age: ☐☐ Years old ☐ Don't Remember

G3. How many cigarettes do/did you smoke during pregnancy, or in the three months before pregnancy? (Cross ONE box ONLY in each row)

	None	1-5 a day	6-10 a day	11-20 a day	Over 20 a day
a) 3 months before	☐	☐	☐	☐	☐
b) First 3 months of pregnancy	☐	☐	☐	☐	☐
c) Since the beginning of 4th month	☐	☐	☐	☐	☐

G4. During pregnancy have you been exposed to other peoples' cigarette smoke at work or at home and if Yes, for how many hours per day approx? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Less than 1 hour per day/occasionally

If yes - Hours ☐☐

G5. Have you used any other tobacco products like Paan during pregnancy, or in the 3 months before pregnancy? Interviewer: please show list of possible products.
(Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

If No, Don't Know or you don't remember go to question G6

***G5a) If yes please identify which ones and how many you smoke/chew etc., (relevant to point in pregnancy)**

	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
3 Months before pregnancy					
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
First 3 months of pregnancy					
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
From beginning of 4th month to now					
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	

G6. Have you used any drugs like marijuana or ecstasy during pregnancy or in the three months before pregnancy? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know If No, Don't Know or you don't remember go to question G7

***G6a) If yes please identify which ones and how often you have taken them (relevant to point in pregnancy)**

3 Months before pregnancy	Daily	Weekly	Monthly	Rarely	If 1+ per week, how many per week
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
First 3 months of pregnancy					
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
From beginning of 4th month to now					
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	
	☐	☐	☐	☐	

ALCOHOL

G7. Did you drink any alcohol during your pregnancy or in the 3 months before? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Remember If NO or don't remember go to Section H

G7a) Did you drink any alcohol in the 3 months before pregnancy?
(Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

If NO or don't remember go to question G7d)

G7b) If once per week or more, what is the weekly average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

G7c) In the 3 months before pregnancy how often did you consume 5 or more units of alcohol on one occasion? (Cross ONE box ONLY)

☐ Everyday ☐ 1-3 times a month

☐ Nearly every day ☐ Rarely

☐ 1-4 times/week ☐ Never

G7d) Did you drink any alcohol in the first 3 months of pregnancy?
(Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

If NO or don't remember go to section G7g)

G7e) If once per week or more, what is the average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

G7f) In the first 3 months of pregnancy how often did you consume 5 or more units of alcohol on one occasion? (Cross ONE box ONLY)

- ☐ Every day or more often
- ☐ Nearly every day
- ☐ 1-4 times/week
- ☐ 1-3 times a month
- ☐ Rarely
- ☐ Never

G7g) Did you drink any alcohol from the beginning of the 4th month until now of your pregnancy? (Cross ONE box ONLY)

☐ Yes, Once per week or more ☐ Yes, occasionally ☐ No ☐ Don't remember

If NO or don't remember go to section H

G7h) If once per week or more, what is the average and maximum number of units in a week?

	Average number of units per week	Maximum units at one time
Beer/Lager	☐☐	☐☐
Wine	☐☐	☐☐
Spirits	☐☐	☐☐
Other	☐☐	☐☐
Don't remember	☐	☐

G7i) Since the beginning of the 4th month of your pregnancy how often did you consume 5 or more units of alcohol on one occasion?
(Cross ONE box ONLY)

- ☐ Every day or more often
- ☐ Nearly every day
- ☐ 1-4 times/week
- ☐ 1-3 times a month
- ☐ Rarely
- ☐ Never

Section H Your diet

BREADS AND BREAD PRODUCTS

H1. During the last 4 weeks, on average how many slices/pieces of the following did you eat per week?

	Total Slices/Pieces	No. eaten as toast
a) White bread incl baguette		
b) Brown bread incl granary, multiseed, best of both. 50/50.		
c) Baps/rolls/teacake		
d) Crumpets		
e) Pizza (1 slice)		
f) Roti/Chappatis		
g) Naan, pitta bread, bagel		
h) Paratha		
Other bread products e.g. wraps, croissants, pancakes, flatbreads, English muffin		

Other please write in

CAFFEINATED DRINKS

H2. During the last 4 weeks of pregnancy, on average, how many cups or mugs of the following drinks would you have per day or per week?

(Glass is 200 ml Cup is 200 ml 1 Mug = 2 cups.
If less than 1 per day enter weekly average)

How many cups of: ?	Per day	Per Week
a) Instant coffee (Caffeinated)		
b) Instant coffee (De-caffeinated)		
c) Filter/cafetiere coffee (Caffeinated)		
d) Filter/cafetiere coffee (De-caffeinated)		
e) Tea (Caffeinated)		
f) Tea (De-caffeinated)		
g) Kashmiri tea (Caffeinated)		
h) Kashmiri tea (De-caffeinated)		
i) Herbal/fruit teas (Caffeinated)		
j) Herbal/fruit teas (De-caffeinated)		
k) Cola (regular, with sugar Caffeinated)		
l) Cola (regular, with sugar De-caffeinated)		
m) Diet or sugar free cola (Caffeinated)		
n) Diet or sugar-free cola (De-caffeinated)		

SUPPLEMENTS/VITAMINS

H3. Have you taken any dietary supplements including vitamins or iron tablets in the last 4 weeks of pregnancy? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Remember

H3a) If Yes, which:

	Daily	5-6 per week	2-4 per week	Once a week	Less Often
Vitamin C	☐	☐	☐	☐	☐
Vitamin D	☐	☐	☐	☐	☐
Vitamin E	☐	☐	☐	☐	☐
Iron	☐	☐	☐	☐	☐

Other vitamins and dietary supplements, please write in below:

Don't Know ☐

If multivitamins:

Pregnacare	☐	☐	☐	☐	☐
Sanatogen prenatal	☐	☐	☐	☐	☐

Other multivitamins, please write in below:

Don't Know ☐

Section I Water Consumption

***I1. On a typical day how much of the following do you drink?**

		At home	At work/study	Elsewhere
a) Tap water	Glasses per day:			
b) Bottled water (Includes water cooler)	Glasses per day:			
c) Tea (any sort)	Cups per day:			
d) Coffee	Cups per day:			
e) Squash (Including any other drinks made with tap water)	Glasses per day:			

I2. Do you filter the water you drink at home? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know

I3. Do you filter the water you drink at work? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Don't Know ☐ N/A

I4. In a typical week while you have been pregnant how often and for how long do you undertake the following?

(if you do not do any then fill in 0)

	Times per week	Minutes each time
Shower		
Bath		
Swim		

Section J General Health

Interviewer to give questionnaire for this section to be self-completed.

We should like to know if you have had any medical complaints and how your health has been in general, over the past few weeks. Please answer ALL the questions on the following pages simply by putting a cross by the answer which you think most nearly applies to you. Remember that we want to know about present and recent complaints, not those that you had in the past. It is important that you try to answer ALL the questions.

Cross ONE box ONLY for each question - have you:

J1a. Been feeling perfectly well and in good health?

☐ Better than usual ☐ Same as usual ☐ Worse than usual ☐ Much worse than usual

J1b. Been feeling in need of a good tonic?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1c. Been feeling run down and out of sorts?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1d. Felt that you are ill?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1e. Been getting any pains in your head?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1f. Been getting a feeling of tightness or pressure in your head?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J1g. Been having hot or cold spells?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2a. Lost much sleep over worry?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2b. Had difficulty in staying asleep once you are off?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2c. Felt constantly under strain?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2d. Been getting edgy and bad- tempered?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2e. Been getting scared or panicky for no good reason?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2f. Found everything getting on top of you?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J2g. Been feeling nervous and strung-up all the time?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J3a. Been managing to keep yourself busy and occupied?

☐ More so than usual ☐ Same as usual ☐ Rather less than usual ☐ Much less than usual

J3b. Been taking longer over the things you do?

☐ Quicker than usual ☐ Same as usual ☐ Longer than usual ☐ Much longer than usual

J3c. Felt on the whole you were doing things well?

☐ Better than usual ☐ About the same as usual ☐ Less well than usual ☐ Much less well

J3d. Been satisfied with the way you've carried out your tasks?

☐ More satisfied ☐ About the same as usual ☐ Less satisfied than usual ☐ Much less satisfied

J3e. Felt that you are playing a useful part in things?

☐ More so than usual ☐ Same as usual ☐ Less useful than usual ☐ Much less than usual

J3f. Felt capable of making decisions about things?

☐ More so than usual ☐ Same as usual ☐ Rather less so than usual ☐ Much less capable

J3g. Been able to enjoy your normal day-to-day activities?

☐ More so than usual ☐ Same as usual ☐ Less so than usual ☐ Much less than usual

J4a. Been thinking of yourself as a worthless person?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4b. Felt that life is entirely hopeless?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4c. Felt that life isn't worth living?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4d. Thought of the possibility that you might make away with yourself?

☐ Definitely not ☐ I don't think so ☐ Has crossed my mind ☐ Definitely have

J4e. Found at times you couldn't do anything because your nerves were too bad?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4f. Found yourself wishing you were dead and away from it all?

☐ Not at all ☐ No more than usual ☐ Rather more than usual ☐ Much more than usual

J4g. Found that the idea of taking your own life kept coming into your mind?

☐ Definitely not ☐ I don't think so ☐ Has crossed my mind ☐ Definitely has

Section K Exercise

Interviewer to give questionnaire for this section to be self-completed

K1. Please tell us about the type and amount of physical activity involved in your paid work.
(Cross ONE box ONLY)

- ☐ I am not in paid employment
- ☐ I spend most of my time at work sitting (such as in an office)
- ☐ I spend most of my time at work standing or walking. However my work does not require much intense physical effort (e.g. shop assistant; hairdresser; childminder)
- ☐ My work involves definite physical effort including handling of heavy objects and use of tools (e.g. cleaner; hospital nurse; gardener, postal delivery worker)
- ☐ My work involves vigorous physical activity including handling of very heavy objects.

K2. During the last week how many hours did you spend on each of the following activities?
(Cross only one box in each row)

	None	Some but less than one hour	1 hour but less than 3 hours	3 hours or more
a) Physical exercise such as swimming, jogging, aerobics, tennis, gym workout etc	☐	☐	☐	☐
b) Cycling, including cycling to work and during leisure time	☐	☐	☐	☐
c) Walking, including walking to work, shopping, for pleasure etc	☐	☐	☐	☐
d) Housework/childcare	☐	☐	☐	☐
e) Gardening/DIY (Do it Yourself)	☐	☐	☐	☐

K3. How would you describe your usual walking pace?

- ☐ Slow pace
- ☐ Steady average pace
- ☐ Brisk pace
- ☐ Fast pace

Please return to the interviewer' - 'Thank you for completing this questionnaire

Section Interviewer's feedback

L1. Was anyone present with Mother during the interview? (Cross ONE box ONLY)

☐ Yes ☐ No ☐ Part of interview

L1a) If yes or part of interview: who was present? (Cross ALL that apply)

☐ Baby's father ☐ Mother's friend

☐ Mother's mother ☐ Relative

☐ Mother's father ☐ Child

Other (please write in)

L2 Was a transliteration used to administer the questionnaire? ☐ Yes ☐ No ☐ Partially
(Cross ONE box ONLY)

L3 Were there any problems in completing this interview? ☐ Yes ☐ No

L3a) If yes, what were the problems

L4 Do you feel confident with the answers provided? ☐ Yes ☐ No

L4a) If no, why are you not confident?

COMPLETED QUESTIONNAIRE - CHECKED BY STUDY ADMINISTRATOR ☐ Yes

ALSO CHECKED: ☐ M Diet ☐ J General Health ☐ K Exercise

BY: Name

Interviewer Number
(if applicable)

-

Section M Your diet

Questionnaire about your diet

This short questionnaire asks you about the food you have eaten over the last four weeks of your pregnancy. You may not eat all the foods given or you may find that some of the foods you eat are not included – please do not worry but complete all of the question asked.

Please do not leave any of the lines blank and answer every question even if you are uncertain.

INSTRUCTIONS ABOUT HOW TO COMPLETE THE QUESTIONS

Please put a cross in each box to show how often you have eaten each food item. E.g. if you eat 4 slices of white bread a day – cross the box as shown below

FOOD ITEM	HOW OFTEN HAVE YOU EATEN THIS IN THE LAST 4 WEEKS?							
	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ a Day
White bread	0	1	2	3	4	5	X 6	7

If you make a mistake and cross the wrong box, just cross out and enter the cross in the correct box.

E.g. If you cross you had fruit juice 3 times a day when you meant 3 times a week just cross out the '3-4 times a day' answer and cross the '2-3 times a week' box.

FOOD ITEM	HOW OFTEN HAVE YOU EATEN THIS IN THE LAST 4 WEEKS?							
	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ a Day
Fruit juice (not cordial or squash)	0	1	2	X 3	4	5	~~X~~	7

M1. The following questions ask about some food and drinks you might have consumed during the last 4 weeks of your pregnancy. Do not be concerned if some things you eat or drink are not mentioned.

Please cross how often you eat at least ONE portion of the following foods & drinks: (a portion includes: a packet of crisps, a serving of chips, one bowl of cereal). **(Please cross ONE box ONLY, but answer EVERY line even if you don't eat that food)**

	Rarely or never	Less than 1 a Week	Once a Week	2-3 times a Week	4-6 times a Week	1-2 times a Day	3-4 times a Day	5+ Times a Day
a) Chips	☐	☐	☐	☐	☐	☐	☐	☐
b) Roast or fried potatoes, hash browns or potato waffles	☐	☐	☐	☐	☐	☐	☐	☐
c) Fibre or bran-rich wheat breakfast cereal, like Weetabix, Fruit 'n Fibre, Bran flakes	☐	☐	☐	☐	☐	☐	☐	☐
d) Oat cereals including muesli, porridge, crunchy oats, instant hot oats	☐	☐	☐	☐	☐	☐	☐	☐
e) Other breakfast cereals like cornflakes, rice krispies, Cheerios	☐	☐	☐	☐	☐	☐	☐	☐
f) Crispbread, like Ryvita	☐	☐	☐	☐	☐	☐	☐	☐
g) Pasta or noodles (also pot noodles, tinned spaghetti)	☐	☐	☐	☐	☐	☐	☐	☐
h) Savouries like Yorkshire puddings, dumplings, pakoras or bhajia	☐	☐	☐	☐	☐	☐	☐	☐
i) Potato crisps	☐	☐	☐	☐	☐	☐	☐	☐
j) Other salted savoury snacks like tortilla chips, Wotsits, Quavers, Bombay mix	☐	☐	☐	☐	☐	☐	☐	☐
k) Cakes, buns, gateaux, doughnuts, muffins	☐	☐	☐	☐	☐	☐	☐	☐
l) Sweet pastries like fruit pies, Danish pastries, custard/curd tarts, croissants	☐	☐	☐	☐	☐	☐	☐	☐
m) Chocolate bars and chocolate coated biscuits e.g. Twix, Kit-Kat, Dairy milk bar	☐	☐	☐	☐	☐	☐	☐	☐
n) Sweet biscuits like digestive, custard creams, gingernut, shortbread	☐	☐	☐	☐	☐	☐	☐	☐

M2. The following questions ask about types of meat and fish you might have consumed over the last 4 weeks of your pregnancy. Please cross how often you eat at least ONE portion of the following:

	Rarely or never	Less than 1 a Week	2-3 times a Week	4-6 times a Week	7+ times a week
Whole meats					
a) Beef - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐
b) Pork - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐
c) Lamb, mutton or goat	☐	☐	☐	☐	☐
d) Chicken or Turkey - steaks, roasts, joints, portions (not in batter, sauce or breadcrumbs)	☐	☐	☐	☐	☐
Processed meats/meat					
e) Meat sausages e.g. Walls or chipolata	☐	☐	☐	☐	☐
f) Beef burgers, either home cooked or takeaway	☐	☐	☐	☐	☐
g) Kebabs	☐	☐	☐	☐	☐
h) Hot dog, frankfurter or saveloy	☐	☐	☐	☐	☐
i) Bacon rashers	☐	☐	☐	☐	☐
j) Meat pies and pastries (sausage roll, pasties, meat samosa, steak/meat pie)	☐	☐	☐	☐	☐
k) Chicken/turkey nuggets, Kiev, turkey or chicken burgers, chicken pies, or in batter or breadcrumbs	☐	☐	☐	☐	☐
l) Ham	☐	☐	☐	☐	☐
m) Cured/dried sausage e.g. Chorizo, Salami	☐	☐	☐	☐	☐
Meat dishes					
n) Chicken or turkey with sauce e.g. curry, stir-fry, casserole	☐	☐	☐	☐	☐
o) Beef, lamb or goat in sauce e.g. curry, stew, Shepherd's pie, Bolognese sauce, Chilli con carne, Lasagne	☐	☐	☐	☐	☐
p) Pork in sauce e.g. stew, casserole or stir-fry	☐	☐	☐	☐	☐
q) Gravy made with pan or meat juices (not instant)	☐	☐	☐	☐	☐
Fish					
r) White fish in batter or breadcrumbs, like 'fish 'n chips'	☐	☐	☐	☐	☐
s) White fish not in batter or breadcrumbs e.g. cod in parsley sauce, fish curry (marsala fish), fish pie	☐	☐	☐	☐	☐
t) Tinned tuna	☐	☐	☐	☐	☐
u) Fresh or tinned oily fish like sardines, mackerel, salmon, trout (not tuna)	☐	☐	☐	☐	☐
v) Smoked fish, like smoked mackerel, kippers or smoked salmon	☐	☐	☐	☐	☐
w) Salted/dried fish e.g. 'Bombay duck'/bummalo	☐	☐	☐	☐	☐

M3. If eaten in the last 4 weeks of pregnancy how did you mainly cook the following?
Please enter only one cross on each line for cooking method. Cross yes if mainly eaten very well done, crispy or heavily browned as shown.

	Did not eat	Don't know or take-away	Grill	Fry	Roast	BBQ	Well done? Yes	No
a) Beef - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
b) Beef burgers, either home cooked or takeaway	☐	☐	☐	☐	☐	☐	☐	☐
c) Pork - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
d) Lamb, mutton or goat - steaks, roasts, joints, or chops (not in sauce)	☐	☐	☐	☐	☐	☐	☐	☐
e) Chicken or Turkey-steaks, roasts, joints, portions (not in batter, sauce or breadcrumbs)	☐	☐	☐	☐	☐	☐	☐	☐
f) Meat Sausages e.g. Walls or chipolata	☐	☐	☐	☐	☐	☐	☐	☐
g) Bacon rashers, chops or bacon ribs	☐	☐	☐	☐	☐	☐	☐	☐
h) White fish fillets or steaks e.g. cod or haddock NOT in batter	☐	☐	☐	☐	☐	☐	☐	☐
i) Oily fish fillets or steaks e.g. salmon, mackerel, trout	☐	☐	☐	☐	☐	☐	☐	☐

M4. a. Are you familiar with the "5 a day" recommendations for fruit and vegetables?

☐ Yes ☐ No

b. Do you consume 5 portions of fruit and vegetables per day?
(Please place a CROSS in ONE box ONLY)

☐ Always ☐ Sometimes ☐ Never

(Please place a CROSS in ONE box ONLY)
M5. Where does most of your advice about healthy eating during pregnancy come from?

☐ Family members ☐ GPs/Doctors

☐ Friends ☐ Midwife/Health Visitor

☐ Magazines/Newspapers ☐ Other

☐ Books

Thank you for completing this questionnaire - please leave it in the place indicated.

Born in Bradford Data Transfer Agreement

This agreement is between the Born in Bradford study and

Recipient of data	**Katie Marvin-Dowle**
Institution	**Sheffield Hallam University**
Data request number/ study number	**119**
Study title	A comparative study of demographic and nutritional factors in relation to birth outcomes among pregnant adolescents and adult pregnant women

1. All investigators and other relevant employees involved in the research have read and will abide by the "Born in Bradford Guidance for Collaborators"

2. The data remains the property of the Born in Bradford study. This agreement does not restrict the rights of Born in Bradford to distribute the data to other institutions or to publish any document relating to the data.

3. The recipient will retain the data in a secure location on its premises and will not permit the data or any part of it to come into the possession or control of any other organisation or any individual other than those employees who are involved in the research study specified above under direct supervision of the recipient.

4. The recipient will not transfer the data in whole or in part to third parties without the relevant third party entering into a separate data transfer agreement with Born in Bradford.

5. The recipient will use the data only to carry out the research described in approved proforma relating to the study specified above and only for research that has appropriate ethnical approval. The recipient will not use the data or any parts thereof for any commercial purposes or any purpose that is subject to consulting or licensing obligations to third parties.

6. The recipient will use all reasonable endeavours to ensure that the data in its possession or under the control of the recipient shall as soon as possible be returned or destroyed upon (i) the reasonable request of Born in Bradford, (ii) on termination of this agreement, (iii) in the event that the recipient is in breach of any of the conditions of this agreement or (iv) the withdrawal of consent of the relevant study participant. If the recipient is required to destroy the data then it will confirm in writing to Born in Bradford that the data has been destroyed.

7. All information (including the results of chemical and biological analyses and cleaned or derived variables) relating directly to study participants will be

incorporated into Born in Bradford study and shall be owned by the Born in Bradford study.

8. The recipient will provide Born in Bradford with a fully documented electronic copy of the full results before its publication in any form or within 6 months of the completion of the research whichever is sooner.

9. The recipient will keep the data confidential and will not try to identify study participants.

10. The recipients will not try to link the data provided by Born in Bradford to other Born in Bradford data held by different recipients or by the same recipient for different projects.

Signed for on behalf of the Born in Bradford study
Signature:

Name:

Date:

Signed on behalf of the recipient
Signature: 

Name: Katie Marvin-Dowle

Date: 20.04.2015

We require two signed original copies (not photocopies) one for our records and the other we will return to you

Please return to
Born in Bradford Data and Research Team
Bradford Institute for Health Research
Bradford Royal Infirmary
Duckworth Lane
Bradford
BD9 6RJ

Appendix 4.

Born in Bradford letter of ethics approval

NHS

National Research Ethics Service

Bradford Research Ethics Committee
Top Floor
Extension Block
St Lukes Hospital
Little Horton Lane
Bradford
BD5 0NA

Chairman: **Professor Alan C Roberts**
OBE TD DL MPhil PhD DSc DTech LLD FLS FIBiol
Administrator: Susan Jude

Tel: 01274 365508
Fax: 01274 365509
Email: susan.jude@bradfordhospitals.nhs.uk
Email: alan.roberts@bradfordhositals.nhs.uk

01 April 2008

Professor John Wright
Director of Bradford Institute for Health Research
Bradford Teaching Hospitals NHS Foundation Trust
Bradford Institute for Health Research
Bradford Royal Infirmary

Dear Professor Wright

Full title of study: **Born in Bradford: A longitudinal cohort study of babies born in Bradford and their mothers and fathers**
REC reference number: **07/H1302/112**

Thank you for your letter of 30 January 2008, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered at the meeting of the Sub-Committee of the REC held on 10 March 2008. A list of the members who were present at the meeting is attached.

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.

Ethical review of research sites

The favourable opinion applies to the research sites listed on the attached form.

Conditions of approval

The favourable opinion is given provided that you comply with the conditions set out in the attached document. You are advised to study the conditions carefully.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	*Version*	*Date*
Application		04 December 2007
Investigator CV		

Protocol	4	01 December 2007
Covering Letter		07 December 2007
Letter from Sponsor		29 March 2007
Questionnaire: Mothers	41	14 September 2007
GP/Consultant Information Sheets	1	19 April 2006
Participant Information Sheet: Part 2	1	27 July 2006
Participant Information Sheet: Parents	3	24 July 2007
Participant Consent Form: Mothers	6	10 July 2007
Participant Consent Form: Fathers	6	10 July 2007
Response to Request for Further Information		30 January 2008
Data Collection Schedule	9	12 January 2007
DVD		
Recruitment Flow Chart	6	26 October 2007
Husband/Partner Registration/Sample	1.1	11 September 2007
DVD Script		
Advertising material		

R&D approval

All researchers and research collaborators who will be participating in the research at NHS sites should apply for R&D approval from the relevant care organisation, if they have not yet done so. R&D approval is required, whether or not the study is exempt from SSA. You should advise researchers and local collaborators accordingly.

Guidance on applying for R&D approval is available from http://www.rdforum.nhs.uk/rdform.htm.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Website > After Review

Here you will find links to the following

a) Providing feedback. You are invited to give your view of the service that you have received from the National Research Ethics Service on the application procedure. If you wish to make your views known please use the feedback form available on the website.
b) Progress Reports. Please refer to the attached Standard conditions of approval by Research Ethics Committees.
c) Safety Reports. Please refer to the attached Standard conditions of approval by Research Ethics Committees.
d) Amendments. Please refer to the attached Standard conditions of approval by Research Ethics Committees.
e) End of Study/Project. Please refer to the attached Standard conditions of approval by Research Ethics Committees.

We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nationalres.org.uk .

With the Committee's best wishes for the success of this project

Yours sincerely

Professor A C Roberts
Chairman

Enclosures: *Standard approval conditions*
Site approval form

e-mailed copy to: R & D Department, BRI

Bradford Research Ethics Committee

Attendance at Sub-Committee of the REC meeting on 10 March 2008

Committee Members:

Name	*Profession*	*Present*	*Notes*
Dr MI Busby	Consultant Neurologist Bradford Teaching Hospital Foundation	Yes	
Dr Caroline Plews	Research Nurse	Yes	
Professor Alan Roberts	Chairman	Yes	

Bradford Research Ethics Committee

LIST OF SITES WITH A FAVOURABLE ETHICAL OPINION

For all studies requiring site-specific assessment, this form is issued by the main REC to the Chief Investigator and sponsor with the favourable opinion letter and following subsequent notifications from site assessors. For issue 2 onwards, all sites with a favourable opinion are listed, adding the new sites approved.

REC reference number:	07/H1302/112	**Issue number:**	0	**Date of issue:**	01 April 2008
Chief Investigator:	Professor John Wright				
Full title of study:	Born in Bradford:A longitudinal cohort study of babies born in Bradford and their mothers and fathers				

This study was given a favourable ethical opinion by Bradford Research Ethics Committee on 10 March 2008. The favourable opinion is extended to each of the sites listed below. The research may commence at each NHS site when management approval from the relevant NHS care organisation has been confirmed.

Principal Investigator	*Post*	*Research site*	*Site assessor*	*Date of favourable opinion for this site*	*Notes* [1]
Professor John Wright	Consultant in Clinical Epidemiology and Public Health	Research and Development Unit, Bradford Teaching Hospitals NHS Foundation Trust	Bradford Research Ethics Committee	01/04/2008	

Approved by the Chair on behalf of the REC:

..... (Signature of Chair/Co-ordinator)

(delete as applicable)

..... (Name)

(1) *The notes column may be used by the main REC to record the early closure or withdrawal of a site (where notified by the Chief Investigator or sponsor), the suspension of termination of the favourable opinion for an individual site, or any other relevant development. The date should be recorded.*

Appendix 5.

Ethical approval for Born in Bradford analysis from Sheffield Hallam University

Sheffield Hallam University | Centre for Health and Social Care Research

Date 01042015

Research proposal number: HWB-HSC-29

Dear Katie Marvin-Dowle

This letter relates to your research proposal:

A comparative study of demographic and nutritional factors in relation to birth outcomes among pregnant adolescents and adult pregnant women

This proposal was submitted to the Faculty Research Ethics Committee with a standard SHREC 1 form. It has been added to the register of projects and given a reference number. You do not need any further review from the Ethics Committee. You will need to ensure you have all other necessary permission in place before proceeding, for example, from the Research Governance office of any sites outside the University where your research will take place. This letter can be used as evidence that the proposal has been registered within Sheffield Hallam University.

The documents reviewed were:

MARVIN DOWLE 2015Binder1.pdf

Good luck with your project.

Yours sincerely

Peter Allmark

Peter Allmark
Chair Faculty Research Ethics Committee
Faculty of Health and Wellbeing
Sheffield Hallam University
32 Collegiate Crescent
Sheffield
S10 2BP
0114 224 5727
p.allmark@shu.ac.uk

Appendix 6.

Participant information sheet

Version 2 November 2016

Sheffield Hallam University

Participant information sheet

Study title:	Exploring the Need for Support in Adolescent Pregnancies
Chief investigator	Katie Marvin-Dowle
Telephone number	07816424950

Study Sponsor: Sheffield Hallam University

We would like to invite you to take part in our research study which forms part of a PhD project. 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.
The purpose of this research is to find out whether young women need extra support to have healthy pregnancies, and if so gets some ideas about what the best ways to offer this might be.

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 find out if young women (under 20 years old) need, or would like, extra support with having a healthy pregnancy. We are also interested in finding out how the professionals who support them might be able to help with this.

2. Why have I been invited?

You have been asked to take part in this study because your job role includes supporting the health and wellbeing of young people. You should also have some experience of working with young women during pregnancy.

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 wish to withdraw would not have any consequences for you.

4. What will happen to me if I take part?

If you participate in the study you will be either asked to attend a focus group with other professionals whose job role is similar to yours or a one to one interview with a researcher. You will be asked to discuss questions relating to how you see the role of your profession in supporting young women to have healthy pregnancies.

5. Expenses and payments

You will not be paid for taking part in this study. Travelling expenses to and from the research venue can be reimbursed.

6. What are the possible disadvantages and risks of taking part?

There are no physical risks from taking part in this study; the main disadvantage is that we are asking you to give up some of your time. Sometimes people might find talking about health or pregnancy upsetting. We will try to make sure this doesn't happen by only asking for your opinions about things and not asking for any personal details. We will also make sure there is plenty of time for you to ask questions both before and after the focus group or interview and make sure more support is available if needed.

7. What are the possible benefits of taking part?

The main benefit to taking part in this research is being able to put forward your views and help inform the development of strategies or interventions to improve pregnancy health in young women. You might also find having time to discuss and reflect upon these issues with other professionals useful for your practice or professional development.

8. What if there is a problem or I want to complain?

If you have any queries or questions please contact:

Principal investigator:

Katie Marvin-Dowle

katie.marvin-dowle@student.shu.ac.uk

07816424950

Sheffield Hallam University, Faculty of Health and Wellbeing

Alternatively, you can contact my supervisor:

Prof. Hora Soltani

h.soltani@shu.ac.uk

If you would rather contact an independent person, you can contact Peter Allmark (Chair Faculty Research Ethics Committee) p.allmark@shu.ac.uk; 0114 225 5727

9. Will my taking part in this study be kept confidential?

The focus group or interview will be recorded and then written up word for word. The researcher will check that the recording and the written transcript are the same. She will then erase the recording. The transcript will be kept on a password-protected computer. Identifying details will be taken out of any final report and any publication so people reading these will not be able to identify you. The written transcripts will have all links to you removed at the end of the study and will then be kept for as long as they might be useful in future research.

It might be that in the interviews something of concern arises relating to young women's care. If that happens, the researcher will consult with her supervisor to discuss what to do. She will act in accordance with her professional Code of Conduct.

The 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. The documents will be destroyed seven years after the end of the study.

13. What will happen to the results of the research study?

The results of the study will be written up and included in the researchers doctoral thesis, which may then be available in the University library. The results may also be written up as a research article and published in an academic journal.

14. Who is sponsoring the study?

The sponsor of the study has the duty to ensure that it runs properly and that it is insured. In this study, the sponsor is Sheffield Hallam University.

15. Who has reviewed this study?

All research based at Sheffield Hallam University is looked at by a group of people called a Research Ethics Committee. This Committee is run by Sheffield Hallam University but its members are not connected to the research they examine. The Research

Ethics Committee has reviewed this study and given a favourable opinion.

16. Further information and contact details

If you have any queries or questions please contact:

Principal investigator:

Katie Marvin-Dowle

katie.marvin-dowle@student.shu.ac.uk

07816424950

Sheffield Hallam University, Faculty of Health and Wellbeing

Alternatively, you can contact my supervisor:

Prof. Hora Soltani

h.soltani@shu.ac.uk

If you would rather contact an independent person, you can contact Peter Allmark (Chair Faculty Research Ethics Committee) p.allmark@shu.ac.uk; 0114 225 5727

Appendix 7.

Participant consent form

Version 2 November 2016

Sheffield Hallam University

Participant consent form

Study title:	Exploring the Need for Support in Adolescent Pregnancies
Chief investigator	Katie Marvin-Dowle
Telephone number	07816424950

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 dated November 2016 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 give any reason and without my legal rights being affected.	
3	I understand that data collected during the study may be looked at by responsible individuals from the Sponsor and the Research Ethics Committee, where it is relevant to this research. I give permission for these individuals to have access to my records.	
4	I agree to take part in this study	

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)

Appendix 8

Ethical approval for qualitative interviews from Sheffield Hallam University

Sheffield Hallam University | Centre for Health and Social Care Research

19 July 2016

Katie Marvin-Dowle
Sheffield Hallam University
Centre for Health and Social Care Research

Research proposal number: 2015-16/HWB/HSC/35

Dear

This letter relates to your research proposal:

Professional perspectives on supporting adolescent pregnancies

This proposal was submitted to the Faculty Research Ethics Committee with a standard SHUREC1 form. This indicates that your project does not require formal ethics and scientific review. As such, it has been added to the register of projects and given a reference number. You do not need any further review from the Ethics Committee. You will need to ensure you have all other necessary permission in place before proceeding, for example, from the Research Governance office of any sites outside the University where your research will take place. This letter can be used as evidence that the proposal has been registered within Sheffield Hallam University.

The documents reviewed were:

Binder1.pdf

Good luck with your project.

Yours sincerely

Peter Allmark

Peter Allmark
Chair Faculty Research Ethics Committee
Faculty of Health and Wellbeing
Sheffield Hallam University
32 Collegiate Crescent
Sheffield
S10 2BP
0114 224 5727
p.allmark@shu.ac.uk

Appendix 9.

Interview Topic Guide

What do you think are the main issues for pregnant young women in relation to their health?

Describe how you see your role in supporting young women to have healthy pregnancies

What do you think are the key barriers for young women?
What do you think are motivating factors?

How important do you think nutrition is to pregnancy health?

How important do you think young women feel what they eat is?

How confident do you feel giving advice to young women on health topics? On nutrition?

Are there any areas you would like additional training/information on to improve your confidence?

What format would you like to receive information in?

Do you have anything to add?

Appendix 10

Dietary habits and supplementation practices of young women during pregnancy: an online cross-sectional survey of young mothers and health care professionals.

Soltani et al. BMC Nutrition (2017) 3:19
DOI 10.1186/s40795-017-0137-3

BMC Nutrition

RESEARCH ARTICLE Open Access

Dietary habits and supplementation practices of young women during pregnancy: an online cross-sectional survey of young mothers and health care professionals

Hora Soltani[1*], Alexandra Duxbury[1], Rachel Rundle[2] and Katie Marvin-Dowle[3]

Abstract

Background: Nutrition is a modifiable factor affecting birth outcomes, particularly in adolescent pregnancies. This study explores diet and supplementation practices, information and advice before, during and after pregnancy from the perspectives of pregnant or new young mothers and healthcare professionals.

Methods: Two cross-sectional surveys used online questionnaires for young women who were currently pregnant or who had recently given birth, and health care professionals providing antenatal care. The surveys utilised a combination of question types including free text and multiple choice. Recruitment was conducted via the Tommy's website, online forums for young mothers and professional networks.

Results: A total of 205 young women and 146 health care professionals were included in the study.
Most young women reported taking supplements at some stage of pregnancy (93.2%), with 54.6% taking it on a daily basis. Those who reported taking supplements less than 7 days a week stated it was mainly due to forgetting. Health care professionals however reported that some young women had difficulties accessing healthy start supplements. Young women reported positive dietary changes; however a significant proportion of participants indicated that they avoided some foods unnecessarily. Avoiding or reducing foods such as red meat (22.7%), eggs (40.6%), oily fish (60.4%) and soft cheese (36.2%) is of concern. Midwife/family nurse (38.0%) was young women's current favourite information source; smartphone applications (apps) and recipe booklets were suggested by over 50% of participants as a new addition to existing services. Health care professionals reported they included nutritional information and support as part of their role; however they felt there were some gaps in knowledge and confidence. Midwives in particular suggested a lack of sufficient time and resources as a main challenge in providing adequate support.
(Continued on next page)

* Correspondence: h.soltani@shu.ac.uk
[1]Maternal and Infant Health, Centre for Health and Social Care Research, Sheffield Hallam University, Sheffield, UK
Full list of author information is available at the end of the article

(Continued from previous page)

Conclusions: Avoiding or reducing major food groups was reported which can indicate a poor dietary pattern. A positive change in dietary intake reported by the majority of young women in this survey indicates willingness to adopt a healthy lifestyle. This, in addition to their trust in health professionals particularly midwives, provides an opportunity for health interventions which support behaviour change to improve birth outcomes. Identified gaps in knowledge and confidence by health professionals in providing dietary advice highlight the need for some additional training for health professionals in delivering dietary and lifestyle behaviour change interventions. Independent and trustworthy online resources for women and their health professionals which can be accessed at any time to provide up to date information in between appointments are also required.

Keywords: Nutrition, Supplements, Adolescent pregnancy, Midwives, Healthy eating information sources, Young mother, Digital

Background

A healthy diet and lifestyle during pregnancy is essential to ensure fetal growth and development is optimised. This is of a particular importance for young adolescent mothers in whom poor nutrition [1] and adverse outcomes such as stillbirth, preterm birth and low birthweight have been frequently reported [2–4]. Adolescent pregnancy (birth among women aged 15–19 when the pregnancy ended) has been considered a major contributor to maternal and child mortality worldwide [5] and is a major public health concern in United Kingdom (UK) with a rate of 19.7 births per 1000 women [6].

Young or adolescent mothers have specific requirements for macro- and micronutrients to support fetal development in addition to their own growing needs [7]. Systematic evidence [1] in addition to the recent UK 'National Diet and Nutrition Survey' (NDNS) [8] highlight that many adolescents' diets do not provide the recommended intakes for iron, zinc, calcium and folate and that those with the lowest incomes had significantly lower mean intakes than those from the highest income groups. Spending money on healthy food is often a lower priority compared to other fixed financial pressures such as housing, transport and utility bills [9]. With many competing priorities, it can be a challenge for health professionals to support women in making positive dietary changes and providing practical advice such as guiding on recipes that are suitable for circumstances with limited budget, cooking skills or facilities.

The Department of Health guidance and National Health Service (NHS) Choices [10] website provide standard healthy eating and food safety information for pregnant women in the UK. However most of the routinely provided information is not tailored to the specific nutritional requirements of adolescent mothers or in an adolescent friendly format. Midwives traditionally give every pregnant woman 'The NHS Pregnancy Guide', but the 200 page printed book can now only be read online so is likely to be only read by the most motivated of mothers with internet access. Tommy's, a UK baby charity, has produced the 'Young Woman's Guide to Pregnancy' which provides dietary advice in a booklet format more accessible to adolescents, but distribution of this free resource by midwives is variable [11]. It is therefore paramount to explore where and how young women access information and their preferences so that future resources are more appropriate to their needs.

Young mothers in the UK are entitled to standard antenatal care, although they are more likely to present for their first appointment later and miss appointments [12]. Various models of care are provided for adolescent pregnant mothers. In some areas, specialist teenage pregnancy midwives provide all or some of their care which may involve slightly longer appointment times and signposting to other services such as parenting classes. The Family Nurse Partnership (FNP) scheme provides intensive support for the young pregnant mother from 14 weeks and family for up to 2 years postnatal but only the most vulnerable are eligible and it is not available nationally. Understanding how young women are supported and guided regarding nutrition and healthy eating during pregnancy, and how they would like to be supported in future is essential to optimise care and enhance birth outcomes for this vulnerable group of women.

A previous study surveying adolescent's views of healthy eating during pregnancy in the USA [13] found that while young women reported that they considered healthy eating to be important the majority of their snacks consisted of unhealthy foods. The results from this study are however unclear in terms of the foods eaten at meal times and the frequency of consuming fruit and vegetables. There are no previous studies of this type undertaken in the UK, nor have any studies been conducted which include exploring the views of health professionals' dietary advice and support for this particular vulnerable group of women.

In an in-depth qualitative study [11] we have explored dietary patterns and supplementation adherence, and the facilitators and barriers in achieving a healthy diet and

lifestyle during adolescent pregnancy. This qualitative study suggested that many young mothers have a dietary pattern consisting of high fat snacks, carbonated drinks and occasional meals, but their diet often depends on their living arrangements with those still at home more likely to have more traditional eating habits. A larger study was required to verify these provisional findings with a specific focus on what, if any, changes young women made to their diets during pregnancy; what motivated them to make such changes; where they obtained information and how in future they would like to receive information and support regarding diet and supplements during pregnancy. This study therefore aimed to explore diet and supplementation practices, information and advice during pregnancy from the perspectives of adolescent pregnant or new mothers and their health care professionals.

Methods

Two cross-sectional surveys were developed, one using a questionnaire which was specifically designed, piloted and administered for young women and the other for health care professionals. The questionnaires were informed by the findings from our previous qualitative study on exploring views of adolescent pregnant women and their health care professionals on pregnant adolescents' dietary pattern and, facilitators and barriers for improvement [11].

Ethical approval was obtained from Sheffield Hallam University Research Ethics Committee. An information sheet was provided at the beginning of the questionnaires, providing information about the study, contact details for further information. Young women were invited to participate if they were aged between 16–20 years of age at the time of their pregnancy, with a recent pregnancy experience. Health care professionals were invited to participate if their role included providing antenatal care to adolescent pregnant women. Consent was assumed inherent for the respondents who completed the questionnaire voluntarily.

Survey design: Questions were drafted and formatted in SurveyMonkey and results downloaded for analysis into SPSS (Version 23). The young women's questionnaire was designed to gather data from young women who were currently pregnant or those who had been pregnant recently, so care was taken to word the questions and question logic in order to capture all possibilities. There were a total of 26 questions in the young women's survey and 25 in the survey for health care professionals both using a mixture of question types, including some free text questions and some where participants selected one from a list of options and matrices. Demographic data was collected from the young women including the first part of their postcode, age and number of pregnancies and, job role, grade and year of qualification were collected from health care professionals.

Questions for young women focussed around changes to their diet and supplement use, beliefs about why they made changes, current information sources and suggestions for future resources or services. Questions for health care professionals focused on when and how information and advice on diet, nutrition and supplements was offered to young women and their confidence in giving this advice.

Piloting

The surveys were developed in consultation with the young women at the local Young Men Christian Association (YMCA: a global organisation aiming to put principals into practice in order to promote healthy body, mind and spirit) training centre and health professionals at their place of work. The questionnaire was also sent to the project steering group including experts in the field whose comments and suggestions were used to further refine the survey. The survey was updated based on the feedback received such as providing examples where terms identified as complex (e.g. for the term red meat we provided examples for clarity) and reduced the length of time required for questionnaire completion to 10–15 min.

Sampling/Recruitment

Tommy's (the UK based baby charity) facilitated dissemination of the online survey through its well-established networking systems with a wide range of organisations and support groups for young women and their professionals in the UK. The survey was distributed by email and website links on the 23rd of November 2013 from which participants were invited to the study. Implicit consent was presumed by participants following a link and completing the questionnaire.

Data analysis

Descriptive statistics are reported for all demographic data and for closed answer questions including proportions, means, standard deviation (SD) and ranges as appropriate. Average score or proportions in percent are presented for individual survey items. A simple content analysis was used for the open ended questions to establish categories.

Results

Young Women's Questionnaire.

Respondent characteristics

The sample consisted of 212 young women who started the survey with 162 completing it (76%), most within

48 h of it being posted online. Of 212 original participants, five were excluded as they indicated they have never been pregnant and two because they were under 16 years of age. Characteristics of participants in the survey are presented in Table 1. About 74% of the respondents were over 20 years and 26% aged 16–20 years.

The majority of respondents (94.6%) described their ethnicity as White British and a small proportion identified themselves as Black, Asian or Mixed race (Table 1).

About 60% of participants had only one pregnancy and the remaining had two or more pregnancies. Fifty-eight women were currently pregnant, ranging from 3 to 40 weeks (mean 25.6, SD10.2) with 30 as their first pregnancy.

Valid postcode district data was available for 180 participants, of whom 141 were resident in England, 20 in Scotland, 15 in Wales and 4 in Northern Ireland [14].

Use of supplements

Young women were asked if they had taken any supplements before, during and/or after their pregnancy, with 93.2% reporting taking supplements at any stage of pregnancy and 5.8% stated they have never taken supplements during pregnancy. Folic acid was the most commonly used supplement with 75.1% stated having taken it at some stage in their pregnancy, followed by pregnancy multivitamins (42.9%) and iron supplements (40.0%) also being prevalent (Fig. 1).

Table 1 Characteristics of young women participating in the study ($N = 205$)

	Number	Percent
Age		
16–19 years	23	11.2
20 years	31	15.1
Over 20 years	151	73.7
Ethnicity		
White	194	94.6
Black	2	1.0
Asian	4	2.0
Chinese/other	0	0.0
Mixed	2	1.0
Not stated	3	1.5
Gravida		
Gravida 1	124	60.5
Gravida 2	50	24.4
Gravida 3 or more	29	14.1
Missing	2	1.0
Living arrangements		
Living with partner	131	63.9
Living with my family	36	17.6
Living with my partner's family	8	3.9
Living alone	26	12.7
Living in shared accommodation/hostel	2	1.0
Missing	2	1.0

A total of 84.5% took a folic acid supplement before or during their pregnancy, although the remainder might be getting their folic acid from Healthy Start (18.6%), a combined form of iron and folic acid (19.0%) or pregnancy multivitamins (48.3%) in this period.

Out of 205 participants, 54.6% stated that on average they took supplements daily, 24.9% took it 5–6 days a week, 12.2% 1–4 days a week, 4.4% never and 1% didn't know. Of 87 (out of 205) who reported taking supplements less than 7 days a week, 88.5% said it was mainly due to 'forgetting' and only a few stated it to be because of other reasons such as making them feel unwell, being too expensive, not liking to take tablets or not knowing what they are for.

Food choices and dietary changes

When young women were asked if they made changes to their diet during pregnancy 78.0% indicated yes, 17.6% said no, 0.5% (1 participant) said don't know and the remaining (3.9%) did not answer this question. As presented in Fig. 2, the respondents reported consumption of more fruit (53.2%), vegetables (51.2%), milk (41.5%) and breakfast cereal (33.7%). However a considerable proportion of participants indicated that they ate less or never ate red meat (22.9%), eggs (52.2%), oily fish (61.0%) and soft cheese (68.8%).

Table 2 shows that for many young mothers, the main contributing factor for changing to a healthier diet and supplement intake during pregnancy is the connection between healthy diet, supplementation and its impact on foetal growth and development.

Sources of information and support

As presented in Fig. 3, a great majority of young women remembered receiving information on food to avoid (76.6%) but only around a third or less of them stated that they received information on increasing calcium intake, safe intake of oily fish or weight gain. When they were asked about the main current sources of healthy eating information, they identified midwives (68%), Bounty pack (50%), family (39%) and websites (e.g. Baby Centre, YouTube) (37%) which reflected the state of practice.

When asked to rank their favourite sources of information from a list of 6 (Fig. 4), midwives and family nurse practitioners were the most popular with 38.0% selecting it as their favourite and parenting classes were the least popular (2.9%).

The average rating scores are also calculated from the proportion of respondents who ordered the 6 information

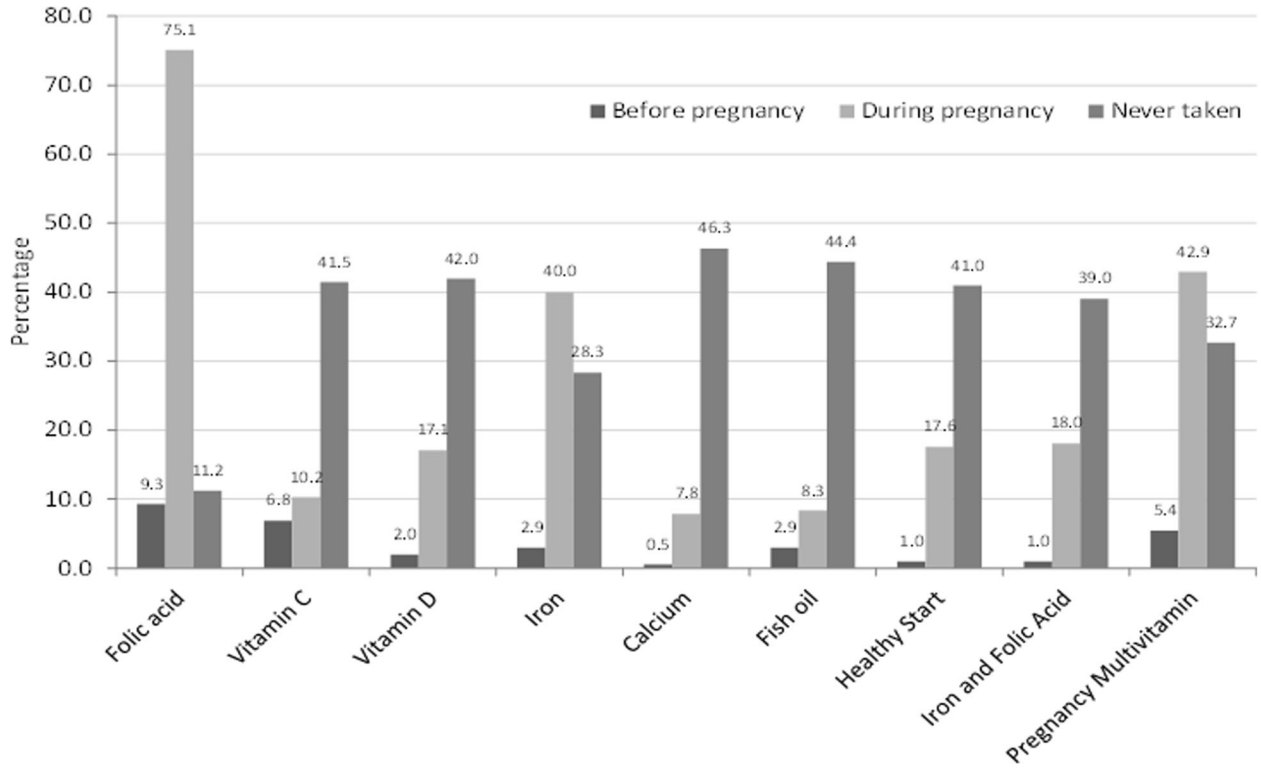

Fig. 1 Supplement intake before and during pregnancy by adolescent mothers ($N = 205$)

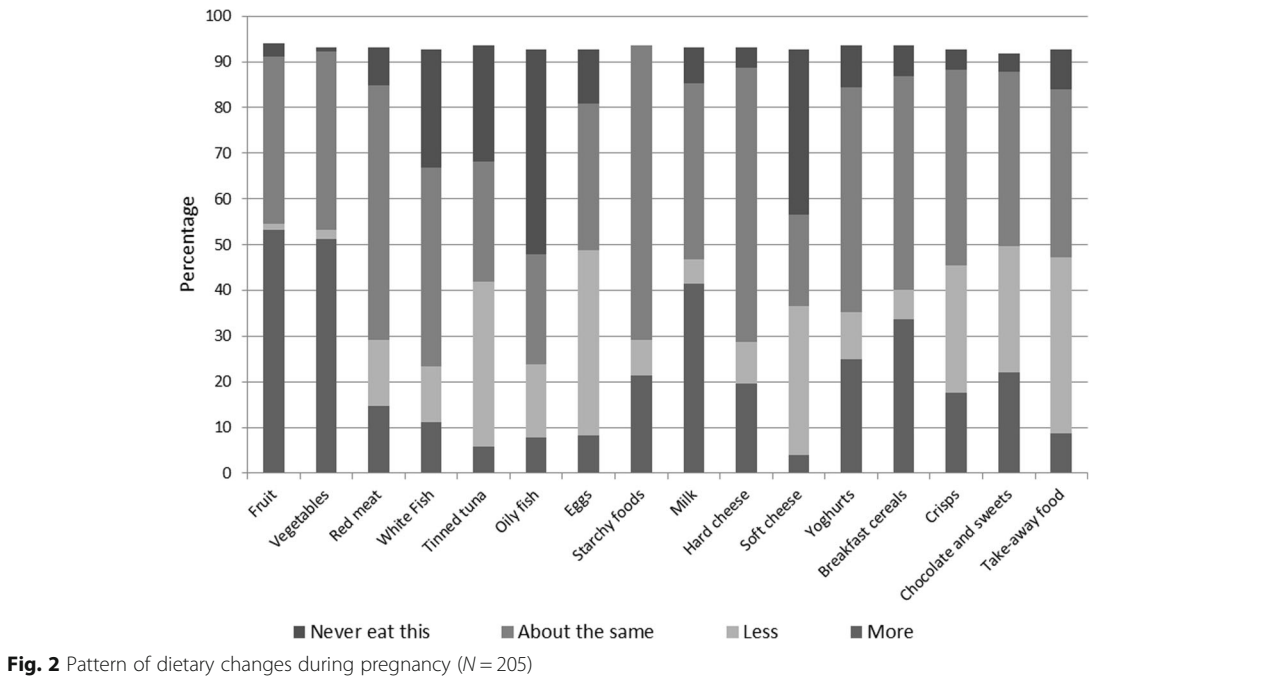

Fig. 2 Pattern of dietary changes during pregnancy ($N = 205$)

Table 2 Participants who agree to each statement regarding their reasons for eating a healthy diet or supplement use during pregnancy ($N = 205$)

	Eating well during pregnancy will…	Taking supplements during pregnancy will…
Help me to gain less weight	51.7%	3.9%
Help my baby grow properly	77.6%	71.7%
Help my baby to be healthier after it is born	76.1%	69.8%
Help my baby be more intelligent	20.5%	22.9%
Please my midwife/family nurse	51.2%	59.5%
Please my partner/family	39.0%	45.4%
Cost a fortune	25.9%	31.7%
Be hard work	23.4%	14.6%
Prepare my body for breastfeeding	62.4%	56.1%

source options based on their preferences (Fig. 5), confirming midwives/FNPs as the highly popular source of information (2.1), theoretical sources of information (Bounty pack, leaflets and websites) in the middle with an average score around 3, followed by partner/family and antenatal classes (scored around 4) to be the least favourite options for this group of women.

The free text responses about participants' views on favourite information sources are summarised in Table 3 under major categories relating to two major themes of advantages and disadvantages. The main advantages of receiving information from health care professionals were indicated to be related to its trustworthiness, reliability, being face to face and that it is through building relationship. The respondents however, highlighted issues such as lack of sufficient information or time as disadvantages for health care professionals to be able to communicate information effectively. There were also those who liked books or websites where they could access information in their own time or Bounty pack free samples. Some had concerns about the accuracy of information on websites or lack of a universal access to internet. Least popular information sources included

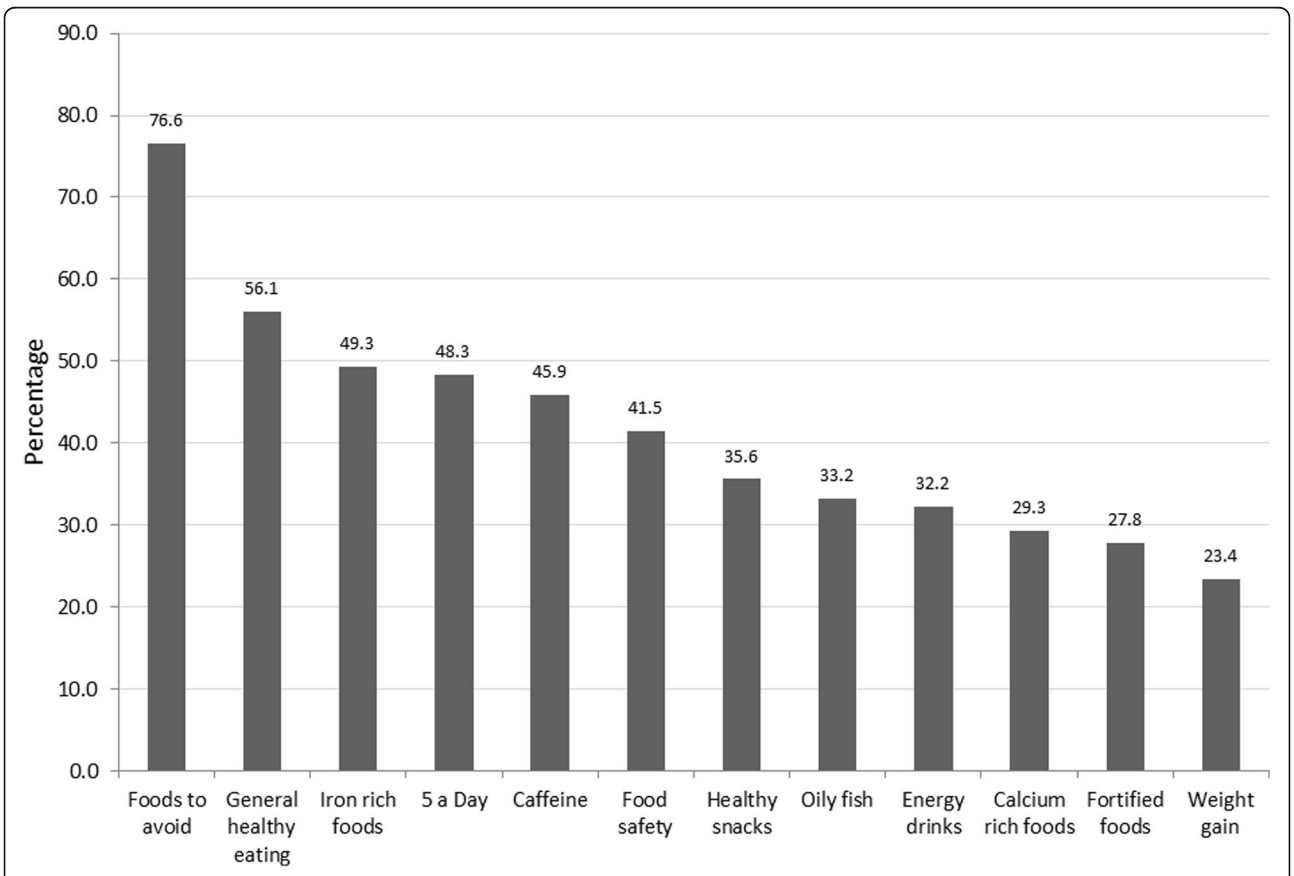

Fig. 3 Types of nutrition related information received by young pregnant women during pregnancy ($N = 205$)

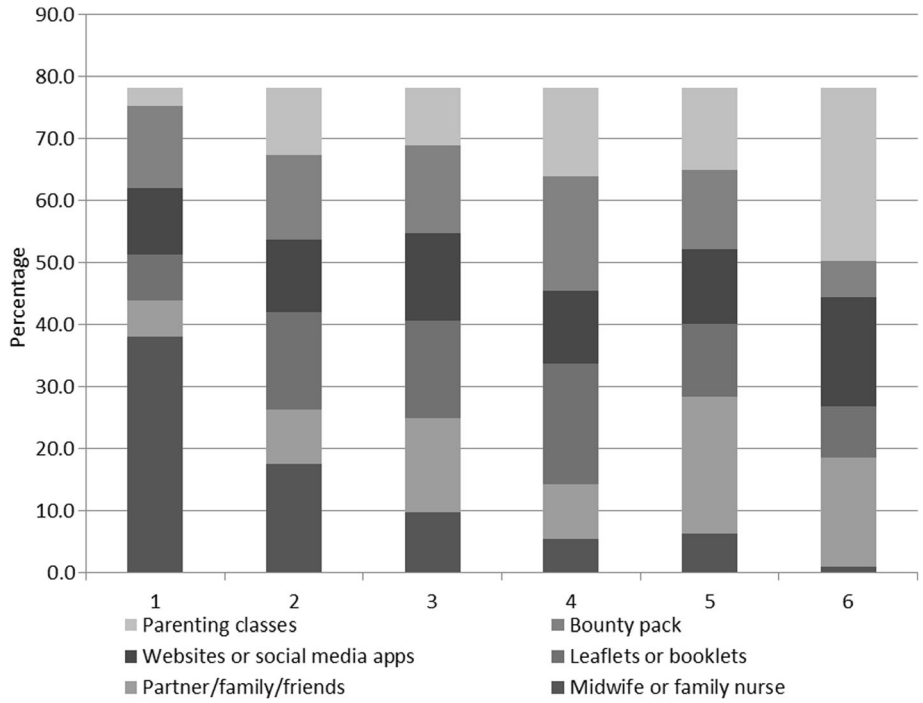

Fig. 4 Where young women would like to receive information during pregnancy* ($N = 205$). *: Participants were asked to put the above 6 options in order of preference, with 1 as the most and 6 the least favourite options

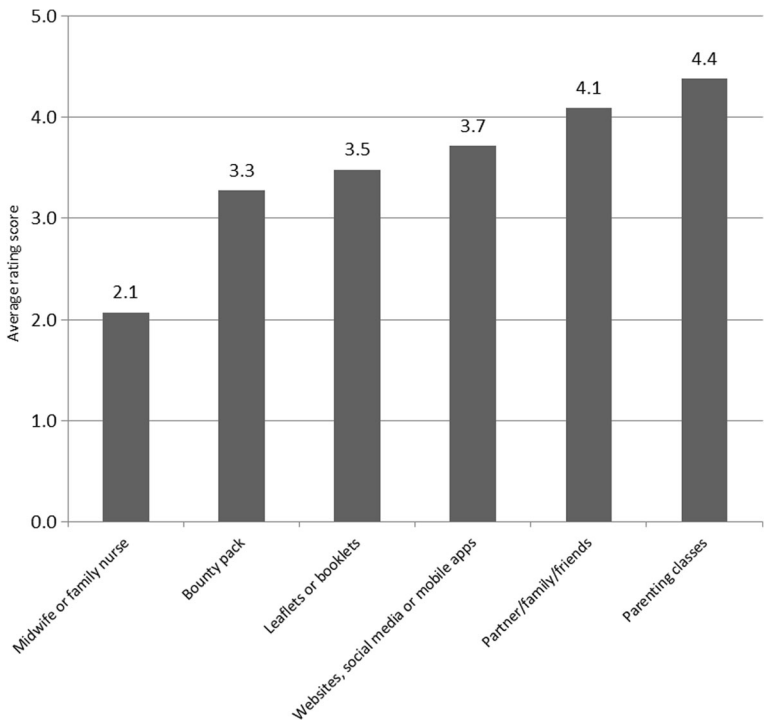

Fig. 5 Average scores based on young women's preferences of information sources during pregnancy* ($N = 205$). *: Participants were asked to put the above 6 options in order of preference, with 1 as the most and 6 the least favourite options

Table 3 Young women's views about sources of information in pregnancy

Sources of information	Advantages	Disadvantages
Health care professionals: Midwife or Family Nurse Partnership	• Trust in Professionals *"My midwife has been doing her job for a long time and I trust her, her knowledge and her judgement"* *"Midwives are qualified and know exactly what they're talking about."* • Accurate and reliable advice *"Midwife know everything what is needed for a healthy pregnancy, she was easy to talk to and very informative"* *"Midwife/Family nurse will have knowledge from training, be more understanding of personal circumstance."* • Face to Face information/questions *"Face to face. Factual and can ask questions and get answers immediately!"* *"The midwife discusses it in more detail."* • Continuous relationship through pregnancy *"My first two pregnancies I had the same midwife, I developed a bond with her in this time and felt I could trust the information that has been given to me."* *"More personal; through experience; they know you better"*	• Not getting sufficient information *"I want information off the midwifes but they haven't given me any"* • Appointment length short *"Pre booked appointment to talk more than seven minutes".*
Self- Study: Leaflet/Booklet/Tommy's Guide	• Easy to read in own time *"I can read through in my own time"* *"Can keep for reference"*	• Lose leaflets *"It's easy to lose bits of paper like booklets and guides"* *"They are easy to misplace and lose"*
Bounty pack	• Good timing and free goodies *"They are given to you at an early stage"* *"Creative and lots of goodies with it"* • Universal *"Everyone gets a bounty pack so everyone gets same info."*	• Too much information/reading *"I would not read a whole book on how to do something"* • Advertising & Commercial (Bounty) *Bounty is a marketing scheme so sometimes sceptical on information as they may be trying to sell things to you*
Websites/Social media/ Apps	• Accessible anytime *"I can gain the information straight away on my phone instead of having to wait to see your midwife to hand you tonnes of stupid pointless leaflets!"* *"Its easy to get hold of the info 24/7"* *"It's easy access, for instance if I'm not sure wether a certain food is safe to eat during pregnancy I try to look online for the answer."* *"As my social media sites are always on so I can easily access it wherever I am"* *"You can access it anytime without feeling you are constantly hassling someone"*	• Unreliable and contradictory information *"Would have liked more information from midwife as you feel it's trusted information coming from a healthcare provider, whereas on the internet you can receive conflicting information"* *"May not be a reliable source"* *"Cannot always trust the Internet as some sites give opposite advice"* *"Some websites can contradict what you have read on other websites"* • Not accessible to all *"Not everybody has access to them"* *"My phone and tablet don't work very well so I was unable to use apps"*
Social support: Partner/Family/Friends	• Available from day 1 *Family cos you change your habits of eating unhealthy the day you find out your pregnant* • Having experience and knowing you *"family told me information because they have loads of experi with preganices and what to do before getting pregnant with vitamins and eating and drinking after your body and baby"*	• Interfering and patronising *"I couldn't have family advising me, I would find it patronizing."* *"Gets frustrating with family interfering"* *"Don't like being told what to do"* • Outdated/inaccurate advice *"What family friends and partners tell you is not always true and is mainly their opinion"* *"They all have different views",* *"A lot of advice you get giving my family, friends etc. are normally 'old wives tales' that are untrue."*

Table 3 Young women's views about sources of information in pregnancy *(Continued)*

Parenting Classes	• Social way to meet other mums *Can all talk about different healthy foods in the classes*	• Content too general *"Never told us about healthy eating focus was on labour and delivery"* • Fear/experience of being judged by other mums and session leaders *"Went once felt inadequate, woman was too patronizing and didn't return"* *"Other mums and leader judging different lifestyles, wouldnt have the confidence to speak in one of those classes"* • Time to attend *"I didn't have time to attend parenting classes when pregnant"* *"Not everyone goes to classes and theres alot to take in"* *"Dislike the parenting class atmosphere."*

parenting classes which some respondents thought were patronising, hard to access or felt judged.

Finally, young women were asked to choose three options from a list of 9 suggestions for developing a new supporting tool to provide information about eating a healthy diet and supplements during pregnancy. These suggestions came from the earlier qualitative study and were included for verification in this study with a larger sample. Table 4, shows that the apps (52.7%) and recipe booklets (51.2%) were the most popular options for future developments.

Health care professionals questionnaire

Respondent characteristics

The 146 respondents were mainly midwives (hospital based, community, specialist teenage pregnancy), FNPs (with health visitor, nursing or midwifery background) or health support workers, qualifying between 1972 and 2012 (Table 5).

Table 4 Responses to the question *"If we could develop something new to provide information about eating a healthy diet and supplements to support young pregnant women, what do you think would be best"* (*N* = 205)

	Young women's choices
App containing healthy eating information	52.7%
Recipe booklet showing healthy meals and snacks to be eaten during pregnancy	51.2%
Education session to be delivered at antenatal/parenting classes	31.2%
Young woman specific booklet	30.2%
Education session to be delivered in secondary schools/colleges	22.4%
Wallet sized fact sheet/reference card	17.6%
Young woman specific online forum	15.1%
Poster summarising key facts	11.2%
YouTube videos about healthy eating during pregnancy	6.8%
Telephone or email helpline	6.8%

FNPs were mainly Band 7/8 and midwives were mainly 6/7. Geographical location was not explicitly asked but qualitative answers suggest one respondent works in the Channel Islands (where Healthy Start is not applicable), one near Castleford and others mentioning schemes in London boroughs.

This paper focuses on midwives and FNPs (90% of respondents) as they provide different models of care to young mothers during the antenatal period, and can be related back to findings from the interviews.

Use of supplements

Nearly all (98.4%) of HCPs provided information about pregnancy supplements for young women, however there were differences in how this information was delivered depending on job role. Midwives were more likely than FNPs to discuss current supplement use and provide a bounty pack whereas FNPs were more likely to provide young women with a copy of the Tommy's 'Young Woman's Guide to a Healthy Pregnancy and other leaflets and booklets and were more likely to help with goal setting or provide worksheets. Differences in how professions provided information on supplements are summarised in Fig. 6.

When asked if they had any comments on young women accessing Healthy Start vouchers and vitamins both midwives and FNPs reported issues, particularly with application, redemption of vouchers, eligibility criteria being too restrictive, lack of supply in local area and access to collect. In some areas they could hand bottles directly to women and this was seen as a good

Table 5 Job role of health care professionals responding to the questionnaire (*N* = 146)

	Number	Percent
Any midwife	46	32
Family Nurse Practitioner (FNP)	84	58
Health visitor	2	1
Other professional	1	1
Any support worker	12	8

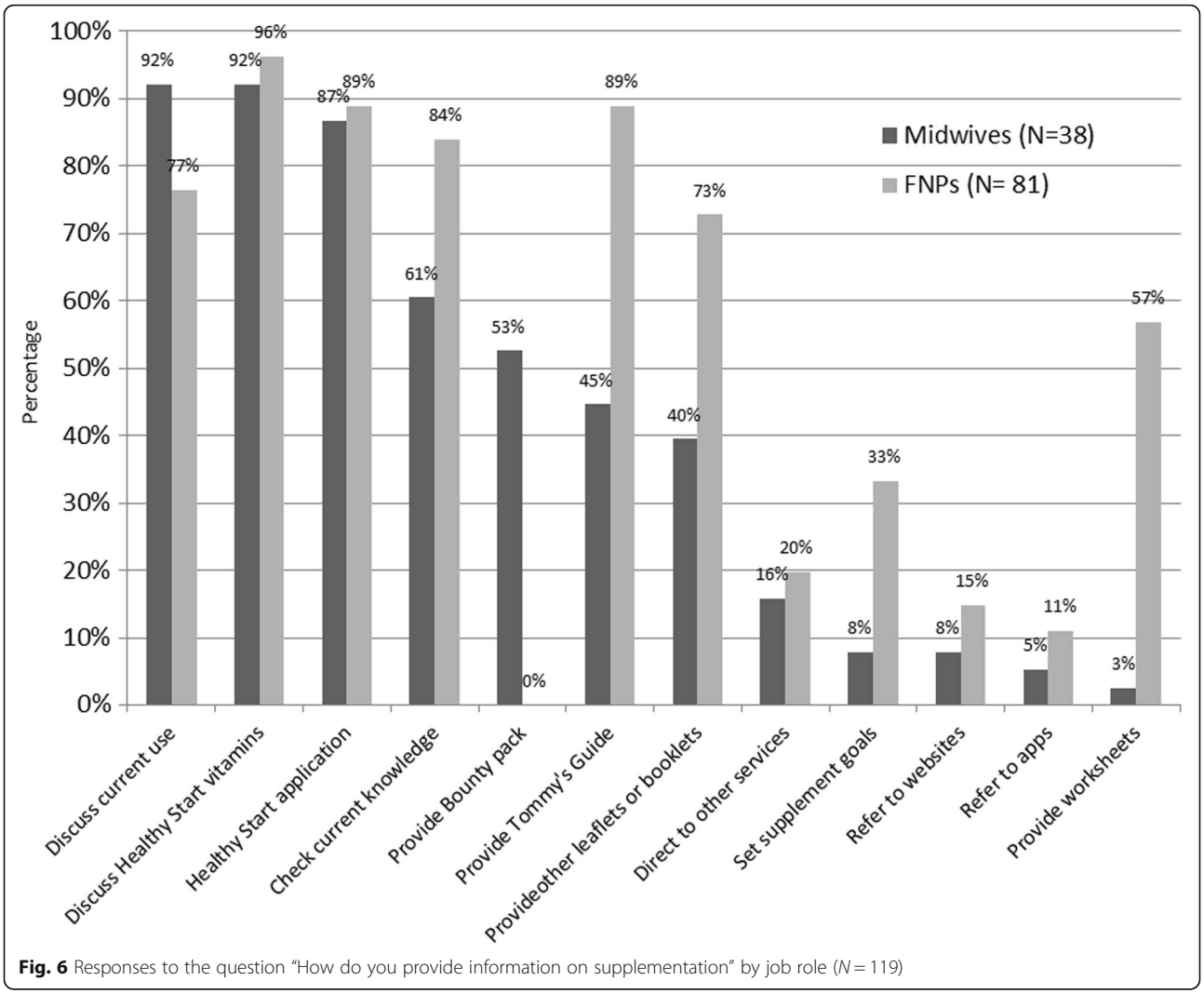

Fig. 6 Responses to the question "How do you provide information on supplementation" by job role ($N = 119$)

system. Others noted that it is those clients who are most motivated that take supplements and so they are likely to buy them from a supermarket to have immediately, rather than apply and wait for their vouchers to come through. Discussions regarding supplements and healthy eating were more likely to be prompted by documentation earlier in the pregnancy with midwives, usually at the booking visit (their longest appointment). Young women are not referred to FNPs until later in the pregnancy (approximately 14 weeks), however prompts to discuss diet and nutrition then occurred at most visits as shown in Fig. 7.

Food choices and dietary advice

Information about healthy eating during pregnancy was provided by 98% of midwives and 100% of FNPs, but how this information was provided differed. The FNPs have more time compared to midwives for goal setting (87% vs 14%) and provided more physical resources such as Tommy's Young Woman's Guide to Pregnancy (96% vs 57%) providing other leaflets (94% vs 71%) and worksheets (88% vs 1%) which form a major part of the FNP programme. Bounty packs were handed out by 48% of midwives but no FNPs.

The food topics discussed with young women by health care professionals are shown in Fig. 8. All 13 food topics were covered by at least 70% of FNPs, but only six (healthy eating, regular meals, iron rich foods, food safety, foods to avoid and caffeine) were covered by at least 70% of midwives. Those less often covered by midwives were energy drinks, healthy snacks, 5 A Day, fortified foods, calcium foods, oily fish and weight gain.

Confidence and training

Health professionals claimed they felt confident discussing healthy eating and most supplements, however were less confident discussing omega 3, multi vitamins and

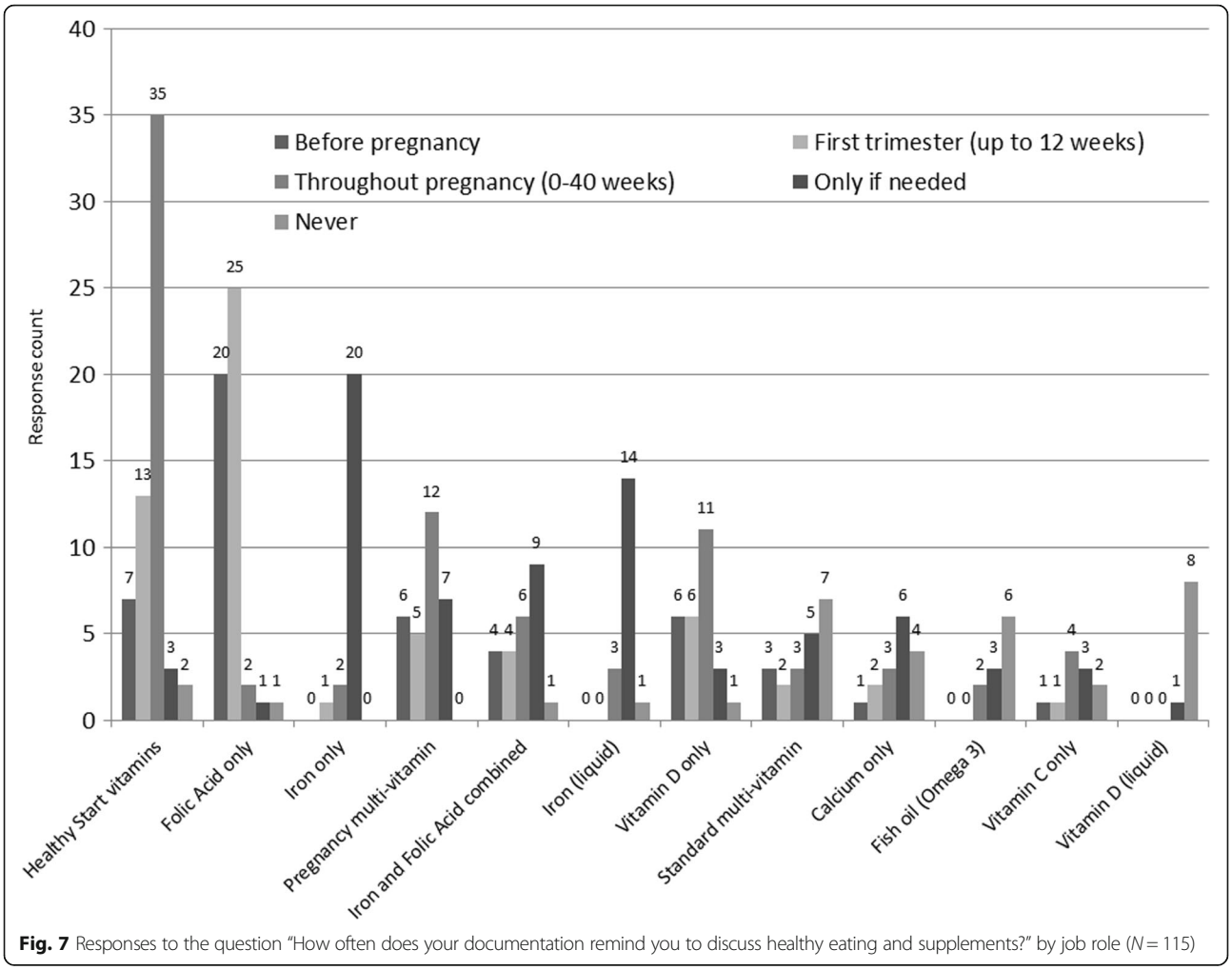

Fig. 7 Responses to the question "How often does your documentation remind you to discuss healthy eating and supplements?" by job role ($N = 115$)

gestational weight gain. This was particularly true for FNPs and is reflected in the topics that they would like further training on. Overall the demand for additional training was relatively low however the topics which professionals in different roles would like training in differed substantially. There was a higher demand for training among FNPs, particularly on Omega-3 fatty acids and gestational weight gain, whereas midwives most commonly requested training on vitamin D as shown in Table 6.

All FNPs and 85% of midwives feel they adequately cover nutrition during pregnancy. The midwives who thought they didn't adequately cover it stated time pressure (4) and lack of clear guidelines as reasons.

When asked where they accessed information on diet and supplements, they reported accessing dietary advice from most sources listed (90–100%) including dieticians, internal and external training, journals, media and slimming clubs; while less sources were used to access supplement information (17–55%). Only 38% of midwives and 55% of FNPs learnt about supplements in prequalification training, however this may be due to some qualifying decades ago when the recommendations were different.

Discussion

This cross-sectional study of young mothers and their health care providers gives an insight into the pattern of dietary changes, supplement intake, current sources of information and preferred information sources in addition to the reasons behind their preferences for information support. Addressing eating behaviour and nutritional requirements of adolescent pregnant women in order to enhance their pregnancy and birth experiences is important as an association between poor nutritional status and adverse pregnancy outcomes is well documented [2–4, 15, 16]. This survey allowed a wider verification of the identified issues in a series of in-depth explorative interviews of young women and health care professionals from Doncaster, Manchester and London, details of which are reported elsewhere [11].

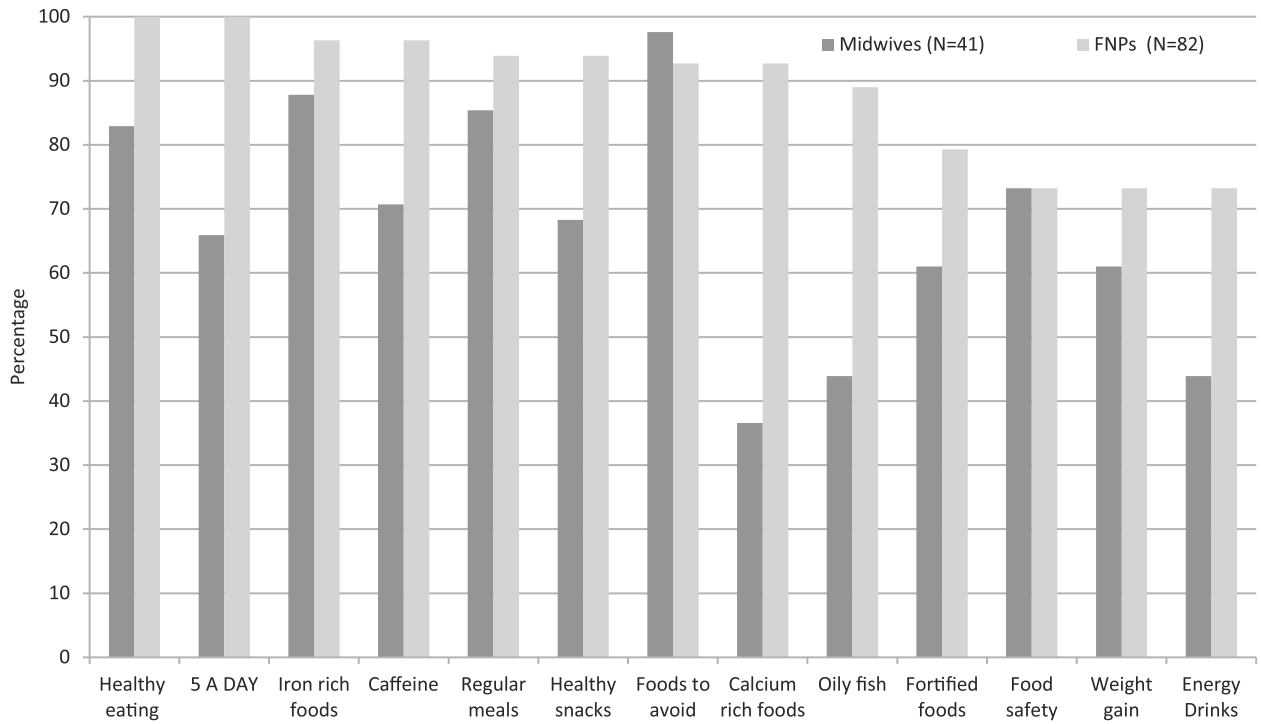

Fig. 8 Food topics discussed with young women by health care professionals ($N = 123$)

These surveys which included responses from all regions in England as well as Scotland, Wales and Northern Ireland showed that young mothers are motivated and keen in adopting healthy dietary changes as indicated in their responses for making positive changes during pregnancy. However it was important that a considerable proportion of responding women were not consuming red meat, eggs, oily fish and soft cheese (such as cream cheese or spreadable cheese). It was encouraging to see a high level of interest and enthusiasm for making positive changes however such a high proportion of adolescents indicating avoiding foods which are potentially valuable sources of vitamins and minerals, such as B vitamins and iron (red meat and eggs) or vitamin D and calcium (oily fish and soft cheese) [17] are of concern. Attention to adequate nutrition in supplying sufficient amount of nutrients are increasingly realised due to its impact on healthy pregnancy and birth outcomes [18].

The poor dietary habit identified in this study is in line with other investigators' findings showing a poor nutritional intake in young mothers [1, 8]. The low intake of foods such as soft cheese and eggs may suggest inadequate communication with young women and a state of confusion regarding prohibiting raw/runny eggs or unpasteurised mould ripened soft cheeses rather than avoiding all types of eggs or pasteurised soft cheeses. It is likely that food avoidance be due to personal taste or cultural restrictions in which case health professionals' role in guiding for alternative sources becomes essential for all particularly this group of women.

It is therefore of prime importance to provide sufficient support and appropriate education for health professionals who have direct contact with young pregnant mothers to enhance their knowledge and dietary behaviour with the overall aim of optimising pregnancy and birth outcomes. This is particularly noteworthy, considering the level of awareness and appreciation of the role, and the trust these young women place in their health professionals, especially in midwives, to obtain nutritional information. This ultimately affirms the need for equipping health professionals with appropriate support, skills and knowledge for effective communication of nutritional messages during pregnancy and postpartum.

The majority of midwives and family nurse practitioners felt that they were providing nutritional support to young women during pregnancy as part of their role but acknowledged there were some areas where they lacked confidence and would like further training. The role of midwives in promoting dietary changes has been explored in previous studies and it has been shown to be central in supporting women to make positive changes [19, 20]. The qualitative interviews with young women and health professionals undertaken as part of the earlier stages of this study however found that while most health care professionals provided some nutritional

Table 6 Responses to the question "How confident do you feel discussing the following topics with young women?" ($N = 108$)

	Midwives			FNPs		
	Confident	Not confident	Would like training	Confident	Not confident	Would like training
Folic Acid supplements	97%	3%	0%	88%	3%	7%
Good dietary sources of Folic Acid/Folates	89%	9%	3%	87%	8%	4%
Vitamin D supplements	86%	6%	9%	89%	8%	5%
Other sources of Vitamin D	71%	21%	9%	91%	7%	4%
Iron supplements	97%	0%	3%	92%	7%	3%
Good dietary sources of Iron	97%	0%	3%	99%	0%	1%
Healthy Start	94%	6%	0%	97%	0%	3%
Pregnancy multi-vitamins	83%	14%	3%	75%	18%	8%
Omega 3 (fish oils)	56%	35%	9%	62%	25%	15%
General healthy eating guidelines for pregnancy	100%	0%	0%	97%	3%	1%
Foods to avoid during pregnancy	100%	0%	0%	93%	7%	4%
Caffeine	100%	0%	0%	96%	4%	3%
Alcohol	100%	3%	0%	99%	4%	1%
Gestational weight gain	88%	12%	3%	72%	17%	11%

support and information, the extent to which this was tailored to young women's individual needs varied considerably [11]. There are significant barriers to providing individualised nutritional support particularly in terms of time pressures and a lack of appropriate resources [21]. It is therefore important that the need for post-registration training, both relating to the specific nutritional issues identified in this study and wider skills regarding how behaviour change techniques can be applied in this context [22].

There were differences in the resources provided by midwives and FNPs to young women and also in the resources used for their own information. These differences however largely reflect the different models of support and care offered by the different professions. This is further supported by open answer comments from young women, although indicating a high satisfaction and trust in midwifery care, expressing a sense of time limitation or insufficient resources to provide adequate and appropriate support during pregnancy. Young women were aware of risks and biases associated with accessing information via websites or commercial sources due to a lack of consistency and trustworthiness. The findings however were indicative of their desire to receive specific, robust, trustworthy and standardised information from authoritative sources; the potential for alternative digital formats is also indicated via mobile technology (e.g. apps) or interactive websites (e.g. easy to follow recipes, healthy eating guidance). Although they acknowledged mobile technology and digital sources should not replace face to face contacts, they appreciated additional support to allow continuous access, facilitate healthy dietary change and maximise benefits in between appointments. A lack of using online technologies either as tools to facilitate discussion or for helping young women to access further support was evident in the data collected from health care professionals. Young women have been found to routinely access online information [23] and support [24] during pregnancy; however research has suggested that health care professionals lack confidence in using these technologies effectively [25]. This suggests that further investigation to develop and evaluate dietary and lifestyle interventions delivered through mobile technology and interactive websites as an adjunct to care provided by health care professionals may be advantageous.

Limitations and strengths

The majority of young women respondents were aged over 20 years at the time of the survey; however young women were invited to participate if they aged between 16 and 20 during their pregnancies.

Young women were asked their current age and number of pregnancies, but were not asked to specify their age when they had their first child, so those '20 or over' at the time of the survey, may have had their first child as an adolescent.

Although we asked participants to respond if they were pregnant or recently have been pregnant, the time since the pregnancy may also have varied between participants meaning that some young women may be less likely to remember details about their diet or supplement use accurately. However, the overall dietary habit rather than details of dietary intake was explored which

may have less of an impact on the availability of the information. Any pregnancy complications experienced may also have affected the young women's ability to recall information accurately however pregnancy complications were not recorded. With the exception that none of our participants were from Chinese origin, the participants' ethnic backgrounds were mainly in line with the national data as a great majority have identified themselves as white and a much smaller proportions were from black, mixed and Asian ethnic minorities (national data includes 2.0, 84.4, 2.7, 2.0, 2.1% respectively) [26].

Our study included a self-selected group of young pregnant mothers or those who recently gave birth and this limits the representativeness of our findings; this may have been a more motivated and interested group of young women to respond to such a survey. However, the variation in the included ethnicities in line with the national data regarding ethnicities and postcode data indicating inclusivity of all geographical regions within the UK is encouraging. This as well as the nature of provided information in identifying the poor quality of nutritional behaviour of a considerable proportion of young mothers and their desire for making healthy changes confirms the need for developing appropriate supportive interventions delivered through health care professionals.

Similarly with respect to the health care professionals' survey it was not possible to calculate a response rate or record the number or characteristics of non-responders to determine if they differed in any way from respondents. This may also have had an impact in that those professionals least comfortable with using online resources may have been less likely to complete the questionnaire. However using online networks allows a remote access with a possibility of open and honest answers without interference or the pressures sometimes felt in the face to face or research situations with close contacts [27].

Conclusions

A stated positive change in dietary intake by majority of young women in this survey indicates willingness to adapt a healthy lifestyle. This in addition to their trust in health professionals provides an opportunity for health interventions to improve birth outcomes. Avoiding or reducing foods such as red meat, eggs, oily fish or soft cheeses as major sources of required vitamins and minerals is of concern. Improving confidence among health professionals in using a range of resources, including online technologies, to support young women would be advantageous.

Implications for practice

Providing support for communicating appropriate knowledge and information regarding diet and supplement use to improve nutritional health of this vulnerable group of women is essential. Independent and trustworthy resources for women and professionals, available in a range of formats, providing up to date information which is accessible in between appointments would also be beneficial.

Abbreviations

FNP: Family nurse practitioner; NDNS: National diet and nutrition survey; NHS: National health service; SD: Standard deviation; UK: United Kingdom; YMCA: The young women at the local young men Christian association

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Availability of data and materials

Data will be available through Sheffield Hallam University website.

Authors' contributions

HS was the project lead and managed the overall study progression and research governance approval. The questionnaire was designed initially by RR & AD and confirmed by HS, and data was collected by AD and RR. Qualitative data was predominantly analysed by RR and quantitative data predominantly analysed by AD and HS and all cross-validated by HS. All authors contributed to the paper writing, HS and KMD completed the paper draft, it was commented by AD and confirmed by RR too. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

The data will be reported and publications will be in line with Data Protection Act, respecting full anonymity and confidentiality of information.

Ethics approval and consent to participate

This project was approved by Sheffield Hallam University Ethics Committee.

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Appendix 11

Exploring the views of young women and their healthcare professionals on dietary habits and supplementation practices in adolescent pregnancy: a qualitative study.

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Exploring the views of young women and their healthcare professionals on dietary habits and supplementation practices in adolescent pregnancy: a qualitative study

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Abstract

Background: Nutrition is a modifiable factor affecting foetal growth and pregnancy outcomes. Inadequate nutrition is of particular concern in adolescent pregnancies with poor quality diet and competing demands for nutrients. The aim of this study was to explore knowledge and understanding of nutrition advice during adolescent pregnancy, and identify barriers and facilitators to dietary change and supplementation use in this vulnerable population.

Methods: Semi-structured interviews were conducted with young women and key antenatal healthcare providers: midwives, family nurses and obstetricians. Doncaster, Manchester and London were chosen as sites offering different models of midwifery care alongside referral to the Family Nurse Partnership programme.

Results: A total of 34 young women (adolescents aged 16–19 years) and 20 health professionals were interviewed. Young women made small changes to their dietary intake despite limited knowledge and social constraints. Supplementation use varied; the tablet format was identified by few participants as a barrier but forgetting to take them was the main reason for poor adherence. Health professionals provided nutrition information but often lack the time and resources to tailor this appropriately. Young women's prime motivator was a desire to have a healthy baby; they wanted to understand the benefits of supplementation and dietary change in those terms.

Conclusion: Pregnancy is a window of opportunity for improving nutrition but often constrained by social circumstances. Health professionals should be supported in their role to access education, training and resources which build their self-efficacy to facilitate change in this vulnerable population group beyond the routine care they provide.

Keywords: Adolescent pregnancy, Dietary habits, Nutrition supplementation, Behaviour change

Background

The increased risk of poor birth outcomes and adverse health consequences for mother and child are well documented for adolescent pregnancy [1–4]. Nutrition is a potentially modifiable risk factor but one that is challenging to address [5, 6] given the poor dietary patterns associated with adolescent young women, particularly those from socially disadvantaged groups, which experience higher rates of adolescent conception [7, 8]. Young women with habitually poor dietary intake are at increased risk of nutritional deficiencies when entering pregnancy. Without dietary modification or supplemental nutrition interventions during pregnancy this may decrease the likelihood of their baby achieving an adequate birth weight [1].

Addressing diet and nutrition is central to improving birth outcomes and maintaining well-being throughout pregnancy. In the UK routine antenatal care for adolescent pregnancy prompts discussion of diet and nutrition at key points within the care pathway [9–11]; this covers nutrition supplementation, food-acquired infection (foods to avoid) and the provision of "*information on the benefits of a healthy diet and practical advice on how to eat healthily*

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throughout pregnancy... tailored to the woman's circumstances" [12]. In the face of complex, competing social and emotional issues associated with adolescent pregnancy [8] the time available and approaches taken to addressing these factors effectively are less well known. Therefore, whilst the majority of young women will receive some nutrition guidance during their pregnancy it is unclear how much they understand, whether they make any changes to their diet as a result and the extent to which they adhere to recommendations for nutrition supplementation. For such a nutritionally vulnerable population it is important to understand how existing practices impact on their choices and the additional support required, for both young women and their ante-natal care teams.

Therefore the objectives for this study were; (i) to explore young women's knowledge and understanding of diet and nutrition advice during pregnancy; (ii) to identify whether they make any changes to their dietary intake and what prompts these changes; (iii) to understand young women's use of nutrition supplements before and during pregnancy; and (iv) to explore sources of information and support regarding diet and nutrition.

Methods

Study design

In this multicentre explorative study, the views of key antenatal care providers and a diverse population of pregnant adolescents were sought. In the UK midwives provide the majority of antenatal care with the youngest and most vulnerable being referred for obstetric support. In some areas the Family Nurse Partnership [13], provides additional care and support to young women assigning them to a family nurse practitioner for intensive intervention until their child is 2 years of age. Therefore, views of obstetricians, midwives, and family nurse practitioners were sought alongside young women. The data collection strategy and interview guide were developed in consultation with a research user group (comprising five young women (antenatal and postnatal) one midwife and one family nurse). The user group made valuable suggestions in terms of terminology (preferring terms such as *"food you choose to eat"* rather than *"your diet"*, *"healthy eating"* rather than *"nutrition"* and *"young women"* or *"young mums"* rather than *"teens"* or *"teenagers"*) interview structure and incentives which informed recruitment and data collection.

Settings

Doncaster, Manchester and the London boroughs of Lambeth and Southwark were chosen as research sites offering different models of service provision for pregnant young women. During the study period, Doncaster and Manchester offered community midwifery led services with one specialist midwife in young women's pregnancies for the service, locally referred to as the "teen pregnancy midwife" by other health professionals; this is noteworthy given the user group's preference in terminology for *"young mums"*. London offered a specialist case-loading midwifery led continuity care model where young women were assigned to one key specialist midwife for their pregnancy with support from other members of the midwifery team. At the time of study the family nurse partnership followed the national model at all three research sites [13]. Obstetricians across the three sites provided specialist support for high risk pregnancies in young women.

Participants and recruitment

A purposive sampling strategy was employed for data collection. Selection criteria for young women were based on age and pregnancy status; 16–19 years whilst pregnant, currently pregnant or had given birth less than 6 months previous. Young women were provided with an information sheet and referred to the study by their midwife or family nurse practitioner based on our selection criteria; these details were confirmed whilst written consent was obtained. All young women were offered a £20 high street voucher in appreciation of their time. Health professionals were also purposefully sampled to include obstetricians and family nurse practitioners with the majority being midwives (specialists in young women, community and hospital). Interviews were conducted in quiet spaces within the ante-natal setting, in community venues or in young women's homes.

Data collection

Semi-structured interviews were designed to explore diet, supplementation use and sources of information and support during pregnancy. Interviews were conducted independently by two researchers and lasted between 10 and 42 min (mean time 25 min). The researchers were experienced in the collection of interview data and had prior experience working with young women from more socially disadvantaged backgrounds, both having previously worked in the National Health Service in community outreach programmes. A visual interview guide was used to keep conversations on topic and act as a focal point e.g. to limit distraction from mobile phones (see Additional file 1 Young Women's Interview Guide). The guide included photos of routinely used information sources, different types of nutrition supplements and tablet formats to demonstrate variations in tablet size; the same guide with minor changes to wording was used with the health professionals. During the interviews with young women the researchers sought to put them at ease and establish a rapport, reassuring them that their individual experiences were important and that there were no "right or wrong" answers. The majority

of young women talked freely but some of the shorter interviews (<15mins duration) were a result of young women giving very brief responses. Young women that were pregnant at the time of interview were asked to focus on their experiences up to that point and postnatal young women were asked to think back to their pregnancy. Health professionals were asked to focus on their experiences and perceptions working with adolescent young women in their current role; this was particularly relevant for family nurse practitioners that had previously worked as midwives or health visitors. Interviews were audio recorded and professionally transcribed verbatim. The initial audio recordings and transcriptions were reviewed by both researchers for consistency and completeness.

Data analysis

The data was analysed thematically using the approach advocated by Braun and Clarke [14]. Through careful reading, data coding, categorisation of codes and constant comparative analysis, similarities and differences were explored in order to develop the overarching themes and subthemes. The main data analysis was managed by two researchers independently and verified by a third researcher (not one of the interviewers) to reduce the potential for bias and "sense check" during theme/sub-theme development thus reducing ambiguity of meaning. It was not the purpose of the analysis to compare different models of service provision at each research site rather highlight the aspects of care that were barriers to or facilitated young women to make healthier food choices and take their supplements.

Results

Fifty four in-depth interviews were conducted across the three study sites; young women ($n = 34$) and health professionals ($n = 20$). The characteristics for young women are presented in Table 1. All health professionals were involved in some aspect of antenatal care. Midwives made up the greatest proportion of the sample ($n = 12$) followed by family nurse practitioners ($n = 5$) and obstetricians ($n = 3$); of the midwife interviewed five had specialist adolescent pregnancy roles, two as *"teen pregnancy"* specialist for their locality (Doncaster and Manchester) and three with adolescent pregnancy caseloads (London).

Table 1 Participant characteristics for young women (aged 16–19 years) recruited across the three interview sites (Doncaster, Manchester and London)

Variable	n (%)	mean
Age (years)		17.62 years
16	4 (12)	
17	13 (38)	
18	9 (26)	
19	8 (24)	
First pregnancy	33	
Second pregnancy	1	
Stage of pregnancy at interview		
Pregnant	24 (70)	
Gestational age (weeks)		28 weeks
Postnatal	10 (30)	
Weeks		14 weeks
Living situation		
Alone, own home (rented)	3 (8.5)	
With partner, own home (rented)	10 (30)	
With family, at home	12 (17)	
With partner and family, at home	6 (17)	
Shared house, hostel accommodation	3 (8.5)	

Theme 1: A time for dietary change amidst confusion

(See Additional file 2: Table S2 of results for "Diet" theme and sub-themes).

Pregnancy was acknowledged by the majority of interviewees as a time for dietary change yet the opportunity to make healthier dietary choices was often hampered by misconceptions and entrenched food preferences. A "*typical teenage diet*" was how many health professionals referred to young women's food choices with lack of understanding regarding the impact of dietary intake affecting their motivation to change. Midwives and family nurse practitioners often spoke about developing young women's *"connection with their baby"* as a means of initiating dietary change. Where young women made this connection, "*All the way through, like, I just eat healthier because then your baby will come out healthier*", more regular eating patterns and healthier food choices were reported. Conversely misaligned beliefs about what they ate and their baby's development were a barrier to positive change. Young women reported restricting food intake, motivated by a desire for a *"smaller baby"* in the belief that it would ease labour; health professionals highlighted the importance of dispelling these misconceptions.

Food safety advice often prompted dietary changes but young women could recall few specifics when asked; they admitted to feeling confused which led them to exclude certain foods such as tinned tuna, eggs, nuts and cheese, in particular processed soft cheeses,. Midwives expressed concern that some of these foods (e.g. cheese, eggs and tuna) could provide potentially cheap and useful sources of nutrients (e.g. calcium and protein). Yet despite their confusion young women's motivation was primarily to protect their baby; they believed consuming these foods may be harmful, even though they did not understand why, and they erred on the side of caution by excluding them completely from their diet.

Health professionals often described young women's dietary choices as being of poor nutritional quality, expressing concern about missed meals and long periods of time between eating. Where young women reported making healthier choices these were not in the absence of junk food, crisps and confectionary but small positive changes to an overall poor diet; for example, one portion of fruit per day where none had been consumed prior to pregnancy, swapping carbonated sugary drinks for fruit juice, milk or water or eating breakfast.

Young women's living arrangements, access to cooking facilities and financial constraints all influenced food choice. Cooking was not a regular feature of their day and they relied on others cooking for them (mother, grandmother or partner's family). Some health professionals felt that living with family meant young women had a more balanced and nutritious diet but others felt this was not the case where the habitual family diet was reliant on take-away and convenience foods. Young women living alone or in temporary accommodation were least likely to cook for themselves. A few young women, particularly those with a supportive partner, spoke about taking more interest in cooking and trying new foods during pregnancy.

Young women's use of the Healthy Start voucher scheme [15] which provides monetary assistance for purchasing fruit, vegetables and milk during pregnancy was also explored during the interviews. They reported using the vouchers for fruit and milk or as contribution towards the household food shopping. The application process for the vouchers was a barrier and decreased motivation for some young women. One family nurse highlighted misuse of the vouchers as an issue in her locality although this was attributed to small local retailers. Whilst this was corroborated by some young women they were not concerned when they were able to exchange the vouchers for ineligible foods such as bread. Health professionals also felt that supporting development of shopping and cooking skills alongside use of Healthy Start vouchers could improve confidence to make small dietary changes in young women that in many cases are fending for themselves for the first time.

Theme 2: Erratic adherence to supplementation despite uncertainty

(See Additional file 3: Table S3 of results for "Supplementation" theme and sub-themes).

Use of nutritional supplements during pregnancy varied amongst the young women and was often challenging to explore when they were confused about what they were taking and why. Some young women denied taking any pregnancy supplements, associating them with *"medicine"* which they had been told to avoid. Often as interviews progressed they would talk about *"starter vits"* or *"folic something"* and by sensitive exploration the interviewer was able to elicit what supplements they were taking (if any), when and why.

Whilst the majority of young women reported taking a nutritional supplement at some stage of their pregnancy they often took them erratically and started later, towards the end of their first trimester. Later presentation of pregnancies was commonly reported by midwives and they were concerned the delayed initiation of folic acid supplementation resulted in the critical first trimester being missed. They felt being able to provide folic acid or Healthy Start vitamins directly to young women at first contact (8–10 weeks), rather than a prescription or application for Healthy Start, would provide an opportunity to reinforce the importance of taking supplements. One obstetrician expressed a desire to be more proactive in their approach to identifying those at risk of nutritional deficiencies earlier in pregnancy.

Young women were most knowledgeable of the recommendation for folic acid; prior to their initial contact with a midwife or GP, a supportive partner, family or friend was more likely to prompt taking folic acid than other types of supplement. Some young women did not realise the Healthy Start vitamins contained folic acid and were safe to use throughout pregnancy. They considered them *"not safe after 12 weeks"* and were concerned about *"overdosing"* or *"harming my baby"* if they continued. Young women described iron as being important for *"blood or brain"* but had poorer knowledge of vitamin D. Midwives described the routine haemoglobin test at 20 weeks as an opportunity for discussing dietary modification and supplementation where necessary. The use of multi-vitamins and fish oil supplements was less common but these were sometimes purchased by a well-meaning partner or relative. Young women considered them expensive but the premium packaging and marketing alongside these products made them wonder whether they were better than folic acid or Healthy Start vitamins alone. Some midwives also reported recommending multi-vitamin supplements in circumstances where they were particularly concerned about poor habitual dietary intake.

Health professionals frequently reported to young women's reluctance to take supplements in the tablet format but the most common reason for young women not taking them was simply forgetting. Some young women reported feeling nauseous when the tablet size was too large, (more commonly with folic acid/iron combinations and vitamin D) or when taking them on an empty stomach or with sugary carbonated beverages. Young women that were motivated to take their supplements set their own prompts such as putting the tablets in a memorable place (e.g. by their toothbrush, kettle or in their purse), setting an alarm on their mobile phone

or enrolling a willing partner or mother to remind them. Midwives used results from routine blood tests to prompt young women to take their supplements and tried to incentivise them by promoting baby's healthy development and fewer pregnancy complications.

Alternative supplement formats were only made by two young women; these were for fortified products such as "*healthy chocolate*" or fruit smoothies. Few health professionals suggested alternatives, usually a fortified biscuit, but they acknowledged that it would be challenging to find an acceptable alternative with young women's varied food preferences. It was also noted that where healthcare trusts experienced difficulties with the supply and distribution of Healthy Start vitamins this would not be eased by a more costly and bulkier product to provide the necessary supplementation. In addition, it would be counter-intuitive to promote "*healthy chocolate*" or "*healthy biscuits*" when these are the foods young women try to reduce or substitute in an attempt to make small positive dietary changes.

Theme 3: Seeking relevant and reliable information and support

(See Additional file 4: Table S4 of results for "Information & Support" theme and sub-themes).

Midwives and family nurses felt that providing information and support on diet and nutrition was part of their role. Obstetricians described supporting the most vulnerable young women but assumed discussions about diet and supplementation would be provided by the midwifery teams. Partner, family and friends were highlighted as influential sources but the accuracy and consistency of their advice was questioned by both young women and health professionals. Midwives and family nurses recognised the trust that develops between themselves and the young women they care for. Yet the challenge of tailoring information to meet young women's needs, given the pressured environment in which they work was acknowledged by all health professionals. The majority of midwives were confident providing routine information but admitted that time constraints and other priorities meant conversations were brief and not always relevant to young women's situation. Midwives were frustrated they could not do more, particularly specialist *"teen pregnancy"* midwives that were the only person in that role for a particular locality. Health professionals identified a lack of confidence and practical skills as key barriers for young women putting dietary advice into practice. Family nurses acknowledged their unique position in having more time to spend with young women, which enabled them to tailor information and provide practical and emotional support. Family nurses spoke about their training and specially developed programme resources designed to help young women make the connection with their baby and offer a more holistic view of diet, supplementation and pregnancy.

Leaflets and booklets were routinely provided during antenatal appointments but there was mixed response to these. Some young women valued a resource they could keep and refer to after the appointment whilst others expressed apathy unless they had been developed specifically for adolescent pregnancy (e.g. Tommy's Young Women's Guide to Pregnancy). Midwives acknowledged their limitations and some reported to using them sparingly. However, young women's experience of receiving leaflets with little opportunity for discussion often left them feeling overwhelmed and confused. Alternative sources of information were explored with websites, apps for mobile devices, You Tube (video) clips and online discussion forums being the most accessible. Social media was frequently used by young women for seeking information and sharing their experiences. They valued the experiences of other young women, particularly when it came to practical tips and ideas for making changes, which were seen as more relevant to their needs. Health professionals acknowledged young women's prolific use of such social media platforms but were wary of user-generated content. Young women expressed concern about the reliability and accuracy of some online information. Midwives used online resources as part of their routine care but whilst most were familiar with branded sites such as NHS Choices [16] they were less familiar with other sources. Some midwives reported using You Tube videos, to deliver key messages in a more engaging manner.

Young women's understanding and interpretation of the information received during pregnancy had the potential to influence the changes they made. Making the connection with their baby appeared to influence young women's motivation to change; for some this was a natural result of being pregnant but others struggled to make the connection due to lack of physical changes, heightened concern with their own bodies changing (weight gain) or other competing priorities. Some health professionals felt that over and above providing information about healthy eating and supplements their responsibility lay in helping young women foster their connection with baby by developing an awareness of the impact their choices on their baby's health.

Discussion

This multi-centre qualitative study provides an in depth insight into young women's dietary behaviours and supplementation use during pregnancy. The findings from our study illustrate that pregnancy is a window of opportunity when young women are willing to change albeit constrained by social circumstance and lack of intrinsic motivation. Evidence of what works to improve the nutritional status for this vulnerable population group is

limited but through our analysis we have attempted to identify existing good practice, highlight the challenges and propose mechanisms for facilitating change; both behaviour change for young women and changes in practice for healthcare teams and the support they provide.

Making the connection with baby and enabling dietary change

Studies have shown that pregnancy is a time when women are motivated to make small changes to health behaviours, but that changes to dietary patterns are limited and the extent to which they impact on nutritional status unknown [17, 18]. A recent survey of dietary beliefs and behaviours of pregnant adolescents [19] found that whilst participants recognised the importance of dietary intake this knowledge did not always translate into behaviour. Yet our study recorded accounts of dietary change, albeit small, that were made despite lack of understanding, social support and financial constraints. Our young women expressed a desire to do the best for their baby, attempted and appeared more willing to change than health professionals gave them credit for. The extent to which our young women's dietary changes impacted on their nutritional status is unknown but reinforcing small steps in the right direction and increasing young women's self-efficacy to change would be a valuable approach for health professionals.

Studies have acknowledged midwives central role in the provision of nutrition education and counselling during pregnancy [20] and their role in motivating and effecting dietary change [21]. However, we found that whilst the majority of health professionals provided nutrition information the extent to which this was tailored to young women's needs and enabled change varied considerably. The barriers to providing adequate, timely and tailored nutrition support are acknowledged by ours and other studies; a directive, risk-reduction approach to providing dietary information [22] plus lack of time and appropriate resources [23] impact on women's experiences and motivation. Information overload without opportunity for discussion can result in young women feeling confused and overwhelmed. Health professional's nutrition knowledge and self-efficacy in tailoring information and support were also identified as important in our study. The need for improved post registration nutrition training and skills development for midwives [20, 24] plus a better understanding of how this can impact on practice and pregnancy outcomes [25, 26] has been identified. Understanding of specific techniques and approaches with regards to dietary behaviour change, particularly within disadvantaged and vulnerable population groups is still limited. Supporting health professionals to effectively direct the nutrition education and support they provide is essential to enable sustained dietary changes. Therefore, drawing on wider understanding of how different behaviour change techniques can be employed to effect dietary change [27, 28] alongside improved nutrition education would be worthy of exploration.

Pregnancy resources as an adjunct to care and in an accessible format

It was acknowledged in our study that there already exists a wealth of resources to support healthy choices in pregnancy but these are not always tailored to young women's needs or available in accessible formats. Information that is representative of young women's experiences and acts to complement health professionals in their role is needed. We found that leaflets were routinely used to provide information on diet and supplementation with mixed response from young women; whilst some young women welcomed a resource they could take home and read at a later time, often, especially where these were provided without opportunity for discussion, young women were left feeling overwhelmed and confused, which mirrors findings from other studies [21, 23, 29]. Studies have shown that where time constraints and other pressures result in leaflets being provided without opportunity for discussion this reinforces hierarchical relationships [30] which could limit young women's motivation and self-efficacy to change. Supporting health professionals in their role by utilising new communication networks, such as web-based and mobile technology, could be a means of easing time constraints by increasing accessibility of tailored information beyond routine antenatal contact.

The use of the internet, particularly by young women, is widely accepted as a means of seeking information during pregnancy [31, 32] and has been shown to be effective as a means of providing emotional support for isolated young mothers [33]. Similar to the health professionals in our study other research has found that health professionals are more likely to express reservations and lack of skills in using technologies effectively [32]. Drawing on existing evidence of how adolescents use social media to access health information [34] and how health literacy skills can impact on accessibility and use of online information [35] are all worthy of further exploration within pregnant adolescents. The potential for digital and social media opportunities to support dietary behaviour change have been acknowledged [36] although specific approaches and methodologies are still developing.

Supplementation – Understanding benefits, barriers and access to pregnancy vitamins

Poor adherence to recommendations for pregnancy supplementation is not unique to adolescents and studies have highlighted women's negative attitudes and ambivalence

[37–39]. Yet our findings show that where women understand supplementation recommendations in terms of their baby's health and development, and identify practical strategies to prompt use, these barriers may be overcome. Our findings also echo those found in a study exploring the uptake of Healthy Start vitamins and vouchers in England [40] where health professionals experienced difficulties with the supply and access to vitamins which reduced uptake of vitamins in those eligible for the scheme. Universal provision of Healthy Start vitamins to all pregnant women has been proposed [40] but this was not considered cost effective in a recent review by NICE [41]. Other studies have found that direct provision of folic acid to women, in addition to counselling and reminder phone call, increased weekly intake of folic acid [37]. More research is needed to establish whether the mode of accessing vitamins (direct provision from health professionals rather than the existing application and assessment process) plus behavioural counselling can increase uptake and use, particularly in nutritionally vulnerable populations.

Strengthening the evidence base for effective dietary intervention

Whilst there is evidence that intervention to improve nutrition through foods, fortified foods and nutrition counselling may have benefits in terms of birth outcome, particularly for low income and nutritionally vulnerable populations [42, 43], there is a dearth of evidence for effective interventions in pregnant young women and adolescents in particular. A recent systematic review of nutritional interventions and birth outcomes with this population group identified only five studies eligible for inclusion and only two of the five reported significant effect on birth outcome [44]; one study using zinc supplementation reducing the likelihood of low birth weight and the other increasing average birth weight with four servings of dairy each day. The challenge of implementing interventions to change dietary behaviour in a particular group has been acknowledged and recognises the need to also change the behaviour of those delivering the intervention [45]. More research is needed which combines improving knowledge, skills and self-efficacy in health professionals to facilitate behaviour change with targeted dietary outcomes based on the available evidence.

Strengths and limitations of the study

The strength of this research is the combined exploration of young women's and health professional's experiences of dietary change and supplementation use in adolescent pregnancy; we have also considered their different perspectives in terms of access to information and support and their relevance to young women's needs. We have considered how the synergies and differences between young women's and health professional's views can provide insights into changes in practice and where additional research is needed. In qualitative studies such as this expectations of the researchers prior to the data collection should always be acknowledged. In this instance, based on literature reviews and anecdotal evidence from health professionals, young women were assumed to have limited interest in nutrition and resistance to dietary change during pregnancy. However, the researchers approached the interviews with an open mind and a willingness to explore young women's experiences and they found their initial pre-conceptions challenged. Adolescent pregnancies, as represented by the young women interviewed, should not be viewed as a homogenous group whose nutritional needs can be met by a simple one-size fits all intervention. The diversity of opinion and willingness to change within the young women interviewed reinforced the researcher's belief that their experiences should be heard and better ways of supporting them, during pregnancy and beyond, should be explored.

Limitations of the research primarily concern the age and representativeness of the young women in the interview sample; the youngest (< 16 years) and potentially most vulnerable (those not accessing routine antenatal care) may be under-represented. However, the method of recruitment enabled midwives and family nurse practitioners to refer some of their most vulnerable young women to the research team and the use of high street vouchers as an incentive may have provided encouragement to participate irrespective of individual's prior knowledge or interest in nutrition.

To ensure reliability of the methods for data collection the researchers (interviewers) worked closely together checking the questioning style and topic coverage within the interview guide. However, there will be inevitable differences in style and rapport of the interviewer with the study participants and it is acknowledged that this may have had an impact of the reliability of data collected. Reliability of the data analysis and interpretation of codes into themes and sub-themes was aided by the oversight of the third researcher to ensure the decisions made were clear and transparent. Throughout the analysis process discussions were had to ensure that the personal viewpoints and experiences of the researchers were recognised but did not unduly impact on the impartial interpretation of the findings. We have sought to represent the experiences and viewpoints of all participants in this research as truthfully as possible to ensure the validity of our findings; whilst they may not be generalisable across all adolescent pregnancies and approaches to healthcare in the ante-natal setting we believe they offer valuable insights.

Conclusion

Supporting young women to improve dietary quality and adhere to recommendations for pregnancy supplementation

is complex. The habitual diet of young women and their families, combined with a lack of knowledge, confidence, skills and encouragement contribute to entrenched behaviours that are difficult to change. Diet may be low on the list of priorities for young women and their health professionals, particularly when faced with more immediate health and social concerns. Yet, as so many of the young women in our study reported, pregnancy is a time when they are prepared, willing and motivated to change, however small those changes may be. Whilst acknowledging that young women face numerous challenges, their prime motivator is a desire to have a healthy baby; they need to understand the benefits of supplementation and how healthier dietary choices can enhance nutrition and outcomes for their baby in those terms. Health professionals should be supported in their role to access education, training and resources which build their knowledge, skills and confidence to facilitate change in this vulnerable population group beyond the routine care they provide. This is an opportunity not to be missed as the potential benefit for mother and baby are lifelong, including improved pregnancy outcome and healthier habits into childhood and beyond.

Additional files

Additional file 1: Young Women's Interview Guide. (PDF 1208 kb)

Additional file 2: Table S2. Diet theme, sub-themes and coding with illustrative quotes from young women and health professionals. (DOCX 22 kb)

Additional file 3: Table S3. Supplementation theme, sub-themes and coding with illustrative quotes from young women and health professionals. (DOCX 20 kb)

Additional file 4: Table S4. Information and support theme, sub-themes and coding with illustrative quotes from young women and health professionals. (DOCX 20 kb)

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Availability of data and materials
The anonymised datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions
RR, HS and AD developed the study design. All interviews were conducted by RR & AD; also reviewed transcripts. Data was analysed by RR and AD; themes, sub-themes and meaning were verified by HS. The manuscript was written and prepared by RR with contributions and revisions of successive drafts by HS. All authors read and approved the final manuscript.

Ethics approval and consent to participate
Ethical approval to conduct the interviews was sought and granted by the NRES Committee East Midlands-Derby (13/EM/0082), in addition to full compliance with local R&D frameworks at each research site. Written informed consent was obtained from all participants.

Consent for publication
Consent to use anonymised data in publication of this research was obtained alongside consent for participation.

Competing interests
The authors declare that they have no competing interests.

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