Exploration of the Physical Activity Guidelines for People with Multiple Sclerosis

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Exploration of the physical activity guidelines for people with multiple sclerosis

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Candidate Declaration

I hereby declare that:

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

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

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

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

(5) The word count of the thesis is 54,578

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Abstract

Background

Despite the numerous benefits of exercise and the publication of the physical activity guidelines (PAG) in 2013, most people with multiple sclerosis (PWMS) remain physically inactive. Appropriately supported opportunities to engage in physical activity in the community remain scarce, so the extent to which the PAGs inform practice is unclear. The overarching aim of the thesis was to explore what helps PWMS engage in exercise in the community, using the physical activity guidelines as a guide. To achieve this, the thesis explored the exercise experiences, preferences, and support needs of PWMS.

Methods

The research programme included four connected studies using a range of methodologies. Study 1 (Chapter 3) adopted a qualitative approach to explore the thoughts of people with high MS disability. Study 2 (chapter 4) was a mixed-methods feasibility study to explore high-intensity interval training in PWMS. Study 3 (chapter 6) was a qualitative study exploring the opinions of healthcare professionals and PWMS. Study 4 (chapter 8) was a mixed-methods evaluation of a community-based exercise intervention. Additionally, the thesis includes a scoping review (chapter 5) and a systematic intervention development process using the behaviour change wheel (chapter 7). A pragmatic theoretical perspective underpins the research programme as findings were pursued that are applicable in practice and the community.

Key Findings

The PAGs for PWMS lack inclusivity and provide little detail of exercise prescription and application. High-intensity exercise was safe and feasible for PWMS but with limited long-term appeal. For PWMS and some healthcare professionals, there is a need to change their perception of exercise professionals' competence in working with PWMS. Additionally, healthcare professionals state that discussing exercise with their patients is not a priority. Within the community, interventions are primarily aimed at people with mild MS. Also, PAGs and behaviour change theory are used sporadically in community interventions. Encouragingly, a community-based intervention underpinned by BCT and structured using the PAGs was well attended by participants, improved constructs of the COM-B model, and may improve physical activity levels, fatigue, quality of life, self-efficacy, and physical function.

Conclusions

The PAGs exist to help support PWMS to exercise in the community. The deep understanding of the exercise experiences, preferences, and needs of PWMS gleaned through this body of work suggests that the PAGs are currently ineffective, as the infrastructure is not in place for PWMS to enact the behaviour. Theory-informed community-based interventions show promise and need to be used to create an ecosystem where PWMS feel capable, and have the opportunities, and motivation to engage in exercise.

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Finally, a message to my younger self, perhaps you are not as daft as you think you are. When you work hard and apply yourself, you can achieve great things.

You reds!

Publications arising from this work

Publications

- Humphreys, L., Carter, Sharrack, B., & Copeland, R. 2022. High-intensity interval training in people with mild multiple sclerosis: a mixed-methods feasibility study. International Journal of Therapy and Rehabilitation 29:5, 1-14
- Humphreys, L., Carter, Sharrack, B., & Copeland, R. "Not falling in public would be nice": A qualitative study of exercise for people with moderate-to-severe multiple sclerosis disability. (In preparation)
- Humphreys, L., Carter, Sharrack, B., Reece, L, & Copeland, R. Development of a community-based exercise intervention for people with multiple sclerosis. (In preparation).
- Humphreys, L., Carter, Sharrack, B., Reece, L, & Copeland, R. Evaluation of a community-based intervention for people with multiple sclerosis. (In preparation)

Conference and research publications

- Humphreys, L., Carter, Sharrack, B., & Copeland, R. Perspectives of people with MS following participation in a high-intensity trial. MS Frontiers Conference, Bath, 2019
- Humphreys, L., Carter, Sharrack, B., & Copeland, R. Evaluation of a community-based exercise intervention for people with MS. Neurosciences Network Programme Board, 2022

List of Tables

List of Figures

List of Abbreviations

Adapted Patient Determined Disease Steps	APDDS
Affordability, Practicality, Effectiveness/cost-effectiveness, Acceptability, Safety/side-effects, and Equity	APEASE
American College of Sports Medicine	ACSM
Behaviour change techniques	BCT
Behaviour change techniques taxonomy version 1	BCTTv1
Behaviour Change Wheel	BCW
Bodyweight supported treadmill training	BWSTT
Brain-derived neurotrophic factor	BDNF
Capability opportunity motivation behaviour model	COM-B
Centimetre	cm
Central nervous system	CNS
Cerebrospinal fluid	CSF
Confidence interval	CI
Disease-modifying treatments	DMT
Dissemination in space	DIS
Dissemination in time	DIT
Expanded Disability Status Score	EDSS
Experimental autoimmune encephalomyelitis	EAE
Frequency Intensity Time Type	FIIT
Functional Electrical Stimulation	FES
General practitioner	GP
Godin Leisure Time Questionnaire	GLTEQ
Healthcare professional	HCP
Heart rate	HR
Heart rate reserve	HRR
High-intensity interval training	HIIT
Hyperintense lesion on T2	T2 lesion
Interquartile range	IQR
Kilogram	kg
Magnetic Resonance Imaging	MRI
Master's degree	MSc
Maximal heart rate	HRmax
Maximal oxygen uptake	VO2max
Medical Research Council	MRC
Metabolic equivalents	METs
Minimal Clinically Important Difference	MCID
Modified fatigue impact scale	MFIS
Multiple sclerosis	MS
Multiple sclerosis quality of life	MSQoL
Non-exercise physical activity	NEPA
Park Rehabilitation Centre	PCR

Patient Determined Disease Steps	PDDS
People with MS	PWMS
Physical activity	PA
Physical activity guideline	PAG
Physical Activity Support System	PASS
Preferred Reporting Items for Systematic Review and Meta-Analyses	PRISMA
Primary progressive MS	PPMS
Progressive multifocal leukoencephalopathy	PML
Progressive relapsing MS	PRMS
Randomised Controlled Trial	RCT
Rate of perceived exertion	RPE
Recumbent stepper training	RST
Relapsing-remitting MS	RRMS
Repetition maximum	RM
Revolution per minute	RPM
Secondary progressive MS	SPMS
Self-determination theory	SDT
Social cognitive theory	SCT
Standard deviation	SD
Theoretical Domains Framework	TDF
Theory of planned behaviour	TBP
Total Body Resistance Exercise	TRX
Transtheoretical model	TTM
United Kingdom	UK
United States of America	USA
Visual analogue scores	VAS

Defining key terms

Table 1 provides definitions for keywords and terms used throughout the thesis. Physical activity and exercise are used inconsistently within health-related research as the distinction between them is unclear [1]. As the definitions in Table 1 show, the two constructs overlap[1]. More specifically, exercise is a domain of physical activity [2]. Additionally, terms such as physical activity and exercise are perceived differently by people of differing classes, sex, and sociocultural factors[3]. Throughout this thesis, 'exercise' is the primary term used, as the research explores exercise prescription. That being said, 'physical activity' will appear regularly (e.g. physical activity guidelines).

Table 1: Key terms and definitions

Term	**Definition**
Aerobic	Activity in which the body's large muscles move rhythmically for a sustained period. Aerobic activity, also called endurance activity, improves cardiorespiratory fitness. Examples include walking, running, swimming, and bicycling [4].
Disability	From the International Classification of Functioning, Disability and Health, an umbrella term for impairments, activity limitations and participation restrictions, denoting the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors) [4].
Exercise	Exercise is a subcomponent of physical activity. Exercise positively correlates with physical fitness and includes planned, structured, and repetitive bodily movement. The objective of exercise is to maintain or improve physical fitness [2]. Exercise training often includes supervision and a prescription based on its mode (i.e. type of exercise), intensity, frequency, and duration [5].
Light intensity	Light intensity refers to physical activity that is performed between 1.5 and 3 METs. On a scale relative to an individual's personal capacity, light-intensity physical activity is usually an 8-11 on a rating scale of perceived exertion scale of 6-20. Examples include slow walking, housework, or other incidental activities that do not substantially increaseeart rate or breathing rate [4].
Metabolic equivalent (MET)	The metabolic equivalent of task, or simply metabolic equivalent, is a physiological measure expressing the intensity of physical activities. One MET is the energy equivalent an individual expends while seated at rest,

	usually expressed as mLO_2 /kg/min [4].
Moderate intensity	moderate-intensity refers to the physical activity that is performed between 3 and <6 METs. On a scale relative to an individual's capacity, MPA is usually a 12 or 14 on a rating scale of perceived exertion scale of 6-20 [4].
Physical activity	Physical activity is any movement of the body produced by the skeletal muscles resulting in energy expenditure which varies from low to high a positive correlation with physical fitness [2].
Sedentary behaviour	Any waking behaviour is characterised by an energy expenditure of 1.5 METs or lower while sitting, reclining, or lying. Most desk-based office work, driving a car and watching television are examples of sedentary behaviours [4].
High intensity	High intensity refers to activity that is performed at 6.0 or more METs. On a scale relative to an individual's capacity, VPA is usually a 15-20 on a rating scale of perceived exertion scale of 6-20 [4].

Contents

1: Introduction to the thesis

1.1 Chapter summary

The following chapter introduces the thesis, describing the purpose and rationale behind the work. The chapter presents the primary research questions and the underpinning evidence that helped derive them. The aims and objectives of the four studies that comprise this body of work are described along with key terms and the epistemological position of the research that drives the methods employed. The chapter begins with an introduction to multiple sclerosis.

1.2 Background to the thesis

Multiple sclerosis (MS) is a chronic autoimmune, inflammatory neurological disease of the central nervous system (CNS)[6]. An estimated 2.8 million people live with MS worldwide, an increase of 30% from 2013[7]. Living with MS is a physically and psychologically challenging experience[8]. Some of the most common symptoms for people with MS (PWMS) include excessive fatigue, limb weakness, motor abnormalities and sexual dysfunction, with symptoms dependent on the CNS pathology[9]. MS is the most common cause of disability in young to middle-aged adults in the developing world[10]. The condition's relatively high incidence rates and longitudinal nature have a considerable economic impact on the health and care system, PWMS, and their families [11]. Treatments can better manage the condition, but there is still no cure, and the fundamental cause is still unknown. Symptom management and maintenance of function are crucial. Although previously not recommended for PWMS due to fear of aggravating the condition[12], physical activity, including exercise of varying intensity and duration, has been identified as a critical endeavour to help PWMS manage their condition [13]. Evidence indicates that physical exercise is positive for managing symptoms, restoring function, optimising quality of life, and facilitating activities of daily living [14].

In 2015, Motl and Colleagues [15] published an article discussing the top 10 research questions for physical activity in MS. A recommended question was, “how do we translate physical activity research into MS practice?” [15]. This compares with the top 10 MS research priorities developed by the MS Society[16], which asked PWMS what the most important questions are. One of the priorities is, “how can PWMS be best supported to self-manage their condition?”. Regular physical activity is an essential component of the self-management of MS [17]. The challenge for researchers and healthcare professionals (HCP) is to help initiate physical activity with PWMS and provide community support structures to help PWMS independently remain physically active [18].

1.2.1 Purpose and rationale of the thesis

In other conditions, such as cardiovascular disease, exercise is recognised as an integral part of disease care. Within cardiovascular disease rehabilitation, exercise programmes are multifaceted and multi-disciplinary [19]. Over time comprehensive and detailed guidelines on cardiac rehabilitation have been developed. This is also the case for cancer patients[20,21] and stroke survivors [22], as impaired physical fitness presents a risk for recurrent stroke, cardiac disease and fall-related fracture [23]. The strength of the evidence for exercise for PWMS has led to consensus statements specifying exercise as one of the most critical interventions for managing MS [24]. The depth of the literature regarding benefits and safety has resulted in the development of physical activity guidelines (PAGs) for PWMS [25]. The goal of publishing such guidelines is broad dissemination and uptake by PWMS [26]. Unfortunately, PWMS are still much less active than healthy controls [27]. Various factors may account for this, both personal; MS-related impairments, lack of confidence or knowledge regarding exercise and its benefits, and environmental; inadequate provision of support programmes and facilities. The discrepancy between the benefits of exercise and low engagement, despite the PAGs, suggests a translation and implementation issue. Consequently, this thesis aimed to explore the exercise experiences, preferences, and support needs of PWMS using the PAGs as a guide.

1.2.2 Problem statement

The research included in this thesis is focused on the following problem for PWMS:

Despite the reported benefits of exercise, PWMS are less active than the general population

1.2.2.1 Reason for the problem

The problem exists for PWMS because they do not feel capable, have the opportunities, or are motivated to be physically active.

1.2.2.2 The solution to the problem

Physical activity guidelines (PAG) were developed to help increase exercise participation in PWMS. Despite the development of PAGs, activity levels remain low in the MS population.

1.2.3 Research question

The research included in this thesis, therefore, attempts to answer the research question:

Using the physical activity guidelines as a guide, what works to help people with multiple sclerosis engage in exercise in the community?

To answer this question, I undertook four connected studies with the following objectives:

(1) Identify the limitations of the physical activity guidelines for PWMS and the use of the guidelines in community-based interventions.
(2) Explore the perceptions of PWMS after participating in a high-intensity interval training programme.
(3) Explore the needs and preferences for exercise interventions for people with moderate-to-severe MS.
(4) Identify the thoughts of people with mild-to-moderate MS and MS health professionals regarding delivering a community-based exercise intervention.
(5) Develop a community-based exercise programme for MS patients informed by a theoretical behaviour change framework.
(6) Explore the acceptability of a community-based exercise programme for people with MS.

1.3 Research Paradigms

Science (i.e., a way of knowing) is rooted in beliefs and assumptions that embody and support the researcher's hypotheses, methodology, analysis, and conclusions within research [28]. In social research, the term "paradigm" refers to the philosophical assumptions or the fundamental beliefs that guide the actions and define the researcher's worldview[29]. Paradigms have also been called 'philosophical worldviews'[30]. A paradigm is a belief system and theoretical framework with assumptions about 1) ontology, 2) epistemology, 3) methodology and 4) methods [31]. It is how researchers understand and study the world's reality. Ontology refers to the nature of our beliefs about reality[31]. Epistemology refers to the branch of philosophy that studies the nature of knowledge and the process by which knowledge is acquired and validated [31]. The methodology is "an articulated, theoretically informed approach to data production. Methods are specific means of collecting and analysing data, such as questionnaires or open-ended interviews [31].

There are numerous research paradigms widely discussed in the literature. Below, three influential paradigms of positivism/postpositivism, constructivism, and pragmatism, are discussed[30].

1.3.1.1 Positivism/Post-positivism

Positivism emphasises the importance of observation for generating knowledge and considers measuring phenomena as central to developing understanding[32]. The research methodology used in social science for much of the 20th century was primarily quantitative and was concerned with investigating things which could be observed and measured in some way[33].

Such observations and measurements could be made objectively and repeated by other researchers [33]. Positivists believe that reality is unaffected by the researcher or the research process and rejects non-observable (and hence untestable) sources of knowledge as unscientific [32,34]. Positivist research is based on deductive reasoning [35], also known as top-down logic, which is defined as the ability to make inferences about the accuracy of a conclusion based on several, often competing, hypotheses[36]. The deductive process begins with theories and models. It defines variables for study, predicts their relationships by framing hypotheses, and tests those hypotheses. The sample is randomly selected, and primarily quantitative data are collected. From the results, generalisations are made to accept or reject the hypothesis [35].

There have been numerous criticisms of the positivist paradigm, for example, dismissing other sources of understanding such as human experience and interpretation [32]. Positivism also ignores context and individual perspectives, attempting to remove subjectivity, which denies any role for reflexivity (discussed below) among researchers [32]. Due to these criticisms, post-positivism emerged from the positivist view of science[37]. Postpositivism is an approach to knowledge and an assessment of the nature of reality, making it both an epistemological and ontological position [32]. Post-positivism states that hypotheses can never be proven beyond any doubt and that theory should be tested to be falsified and verified [37]. Although we will never achieve absolute truth, post-positivists believe we should strive to get as close as possible [37]. Within post-positivism, validity and reliability are of critical importance. Bias is unavoidable in research as observations are impacted by individual and cultural biases [37]. In post-positivism, reducing or controlling for bias as much as possible in the research design is vital. The researcher must remain neutral, and techniques such as control groups and multiple forms of measurement should be employed [37].

1.3.1.2 Constructivism

Constructivism opposes positivism and assumes that individuals seek an understanding of the world in which they live and work [30]. The belief is that we 'construct' our reality through social interactions, relationships, and experiences [37]. Therefore, research within a constructivist paradigm aims to rely on the participant's view of the situation being studied [30]. Additionally, constructivists recognise that their own experiences influence their interpretation and position themselves in the research to acknowledge how their interpretation emerges from their experiences [30]. The researcher intends to interpret the meanings others have about the world. Rather than starting with a theory (as in postpositivism), constructivists generate or inductively develop a theory or pattern of meaning from data [30].

1.3.1.3 Pragmatism

Pragmatism offers an alternative research paradigm compared to positivism and constructivism, which is not committed to any system of philosophy and reality [30]. Pragmatism is concerned with the practical outcomes of human action, the value of science, and the practical evaluation of "truth" [37]. Pragmatism is the practical philosophy in which truth is not absolute but a moveable construct for understanding the nature of reality [38]. Pragmatists are concerned with what works and solutions to problems[30]. Therefore, pragmatism is often associated with putting theory into practice [38]. When designing a research study, a pragmatist will not focus on the methods but instead, emphasise the problem and use all approaches appropriate to solve it [30]. With a pragmatic approach, the research question becomes the stimulus for choosing a particular research design and is not determined by a specific paradigm or methodology, whether quantitative or qualitative[39].

A pragmatic theoretical perspective underpinned the research programme discussed in this thesis. A pragmatic viewpoint is warranted because practicality is a crucial focus of the research. Findings have been pursued that are applicable in practice, in the community, and to the individual to optimise physical activity behaviour in PWMS. Pragmatism is most associated with mixed-methods research. The mixed-use of quantitative and qualitative methods provides an avenue for obtaining data representing various perspectives [40]. However, the pragmatic position does not necessarily mean that mixed methods are preferred to a quantitative or qualitative approach [40]. Rather the choice of methods depends on whether they contribute to solving the problem [40]. This thesis adopted a qualitative-driven mixed methods approach to answer the research question.

1.4 Qualitatively driven mixed methods research

Mixed methods research has increased in popularity over the last 20-30 years [30,38]. It is defined as "research in which the inquirer or investigator collects and analyses data, integrates the findings, and draws inferences using qualitative and quantitative approaches or methods in a single study or a program of study" [38]. The main reason for using mixed methods research is that using both qualitative and quantitative approaches will provide a richer understanding of the research problem than either approach alone[38], which aligns with the philosophical paradigm of the thesis. One major criticism of mixed-method research is that it is primarily driven by quantitative methods [41], with qualitative research being relegated to secondary status [38]. The characteristics of qualitatively driven mixed methods designs are that the qualitative component is the core method and is supplemented by the quantitative component. The core component drives the research findings and forms the basis of the narrative, and the supplementary component adds to the detail [42].

1.5 Application of the research paradigm

There are several reasons why a pragmatic epistemology was applied to this research. Firstly, pragmatism is a valuable framework for conducting real-world research because it emphasises the practical use of knowledge and focuses on real-world problems and solutions [38]. The practical implications for real-world application were imperative in this research programme, which fits a pragmatic epistemology. Secondly, the research question explored in this thesis addresses a practical problem a population (PWMS) faces. Research that addresses real-world issues is more helpful to practitioners and policymakers and positively impacts society [43]. Thirdly, a pragmatic epistemology emphasises the involvement of stakeholders in the research process. By involving stakeholders, researchers can ensure their research is relevant and valuable to those impacted.

Qualitative research is fundamental to developing and answering the research question in this thesis. Qualitative research can be used to explore complex phenomena that cannot be easily measured or quantified, such as emotions, beliefs, and values. Qualitatively driven mixed-methods research, as the name suggests, is an approach where the qualitative component of the study takes the lead in informing the research design, data collection, and analysis. In this approach, the qualitative data is considered more important in shaping the research questions, hypotheses, and sampling strategy, while the quantitative component tests the hypotheses and validates the findings. This approach was chosen because qualitative research can be used to explore a phenomenon in-depth and identify the key themes, issues, and factors that influence it.

Mixed-methods research with a pragmatic epistemology has several advantages, including its ability to produce actionable insights and recommendations that can be applied in practice to improve people's lives [38]. It also allows for a more comprehensive understanding of complex phenomena and can provide insights into the context in which they occur. However, it also has limitations, such as the potential for researcher bias and difficulty integrating qualitative and quantitative data.

1.5.1 Rigour of qualitative research

Rigour is defined as the quality or state of being exact, careful, or with strict precision or the quality of being thorough and accurate [44]. Therefore, a more rigorous research approach will yield more trustworthy results [45]. The trustworthiness or reliability of qualitative research continues to be challenged because of the potential inherent subjectivity in this type of research[44]. There are several elements to classify rigour in qualitative research: transparency, credibility, dependability, and reflexivity [45]. Following is a series of strategies employed during the research process to ensure rigour in designing, carrying out, analysing and presenting the qualitative research [46].

Each qualitative study included a semi-structured topic guide to help shape the discussion. A draft of each topic guide was discussed with the supervisory team, and amendments were made. Amendments were made to ensure the questions would achieve the study aim and enhance the rigour of the data collection. The topic guides for each qualitative study are included as an appendix.

Throughout this thesis, framework analysis is used to analyse the data. Framework analysis is a valid approach for analysing large amounts of data in health-related research[47]. It is a matrix-based analytic method which facilitates rigorous and transparent data management [48]. The name 'framework' comes from the 'thematic framework', which is the central component of the method[48]. Framework analysis is not aligned with a particular epistemological, philosophical, or theoretical approach [49]. Instead, it is a flexible tool that can be used in many qualitative approaches aiming to generate themes [49]. Themes are a common feature of qualitative data analysis and involve the systematic search for patterns capable of elucidating the investigated phenomenon [49].

Framework analysis consists of interconnected but distinct stages, which are discussed below in Table 2. Before completing the framework analysis stages, the data needs to be prepared for analysis. All interviews were recorded using a digital recorder, which produced audio files that could be downloaded to a computer and stored securely. All recordings in this thesis were transcribed verbatim using an external transcription company. It is recommended that researchers complete the transcription process as this allows for immersion in the data [49]. However, the research team deemed it a better use of resources to outsource the task to a professional transcriber. Verbatim transcription is not essential in qualitative research and does not prevent selective interpretations or 'cherry-picking' [46]. However, it did help ensure that the analysis was systematic and thorough.

Table 2: Stages of framework analysis

Stage	Description
1) Familiarisation	Stage 1 involves using the audio recording and the transcripts to become familiar with the data. For each of the qualitative projects in this thesis, the PhD candidate completed the interviews, resulting in some familiarity with the data. It is not necessary to include the entire data set in the familiarisation process[48], but for this thesis, the PhD candidate did use the entire data set to ensure full involvement. Also, in this phase, the transcription was uploaded to QSR-Nvivo (Version 10). Nvivo is software that enables electronic data coding, helping the researcher work methodically, thoroughly, and attentively [50].
2) Identification of a thematic framework	Following the familiarisation stage, the researcher re-reads the transcript and makes notes on the transcriptions and begins forming initial ideas and themes. For each qualitative project in this thesis, the topic guides and the research objectives informed the development of a conceptual framework. In the thematic frameworks, the themes are grouped under higher order categories or 'main themes' with subsequent lower order categories[48]. For this thesis, data analysis began inductively, themes emerged naturally, and no essential aspects of the data were missed. Deductive themes relating to specific research objectives were then identified in the data. The initial frameworks were discussed with the PhD supervisory team. In these discussions, the initial themes were considered to see if the researcher's interpretation was accurate. Themes were also grouped into defined categories, and the framework was adapted until the final framework was agreed.
3) Indexing	In stage 3, the thematic framework is applied to other transcripts from the research. In this stage, the themes were revisited and refined as new ideas developed during the process. Software such as NVivo is beneficial in this stage because it speeds up the process and ensures that data is easily retrievable [49].
4) Charting	Charting is a process of summarising the data whilst retaining its context and the language in which it was expressed and placing it in the thematic framework [48]. NVivo was used to create thematic matrices to facilitate the interpretation of the data. Once charts were created, they were discussed with the supervisory or project team members to ensure accuracy. Charts from the individual qualitative projects are provided as

	appendices.
5) Mapping and interpretation	The final stage in framework analysis is where the researcher combines the key learnings from the earlier steps [51]. The charts and other data are reviewed, recombined, collapsed, or condensed as suggested by the study focus, data, and major patterns [51]. The researcher is ultimately trying to tell a compelling story about how the data are structured and patterned [51]. Each matrix is mapped separately to identify higher-level themes and associated lower-level themes. During this research, discussions were held with the PhD supervisory team during data analysis to ensure agreement on the interpretations of the themes.

1.5.1.1 Reflexivity

Reflexivity can broadly be described as how the researcher has influenced the research project[52]. It involves turning back on oneself so that processes of knowledge production become the subject of investigation[53]. With reflexivity concerning research, the researcher acknowledges that they are not separated from the field of study; they are positioned in it and must therefore reflect upon this position, which includes self-inquiry and examination of the assumptions guiding the research process [54].

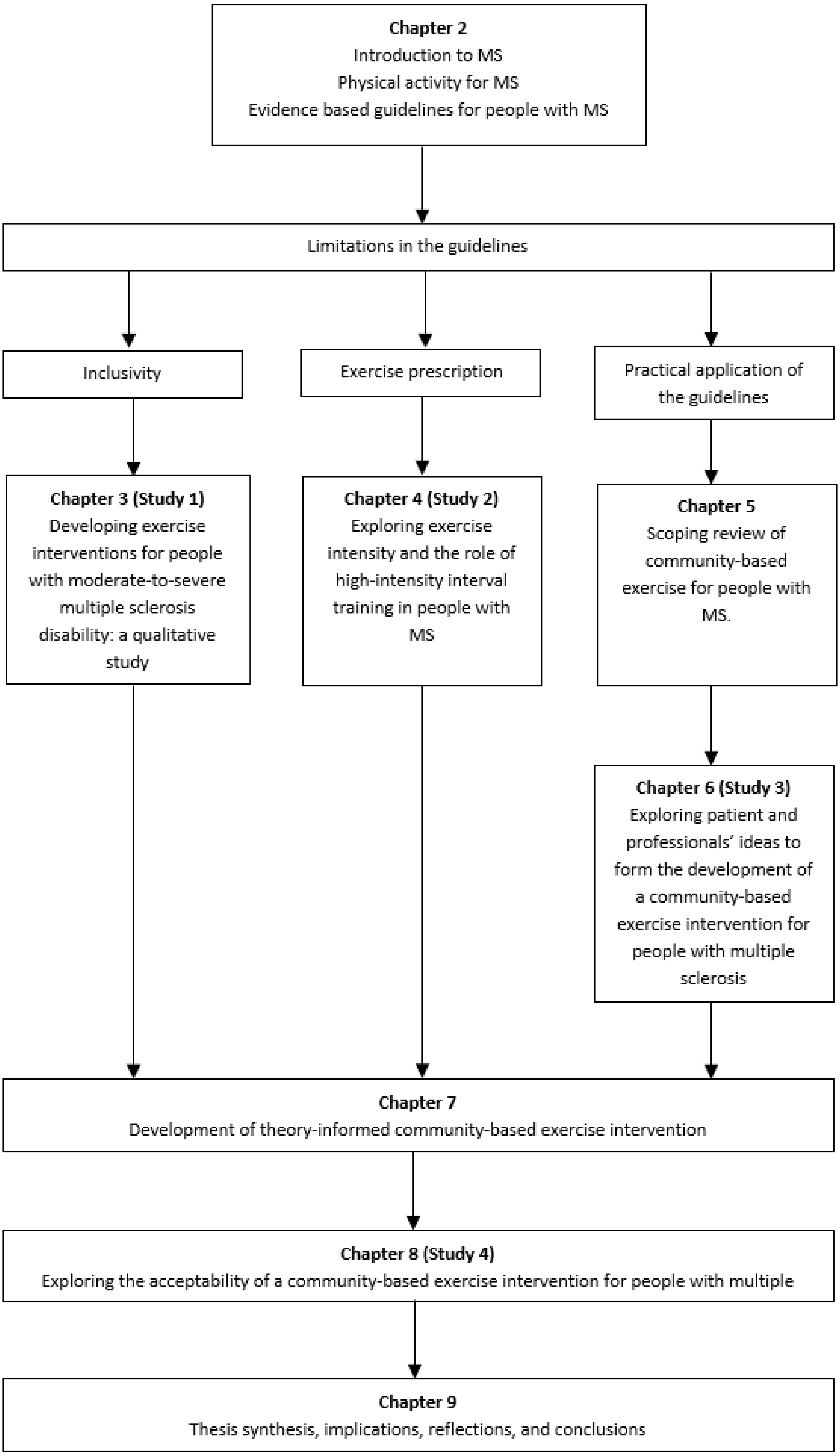
As discussed previously, a central tenet of pragmatic enquiry is the view that research should arise from a desire to produce useful and actionable knowledge [55]. By emphasising the principle of actionable knowledge, researchers can develop research anchored in participant experiences and ensure the research is of practical relevance[55]. As such, pragmatism necessitates a reflexive stance at all stages of data collection [56]. The researcher must develop a relationship of openness to elicit new perspectives rather than direct or prompt respondents [56]. Therefore, a pragmatic researcher must question, “what is the research for?” and “who is the research for?” and “how do the researcher’s values influence the research?” [56].

The researcher's background and worldview will affect how they gather and interpret data, impacting the research findings[57]. The PhD candidate acknowledges that their perceptions have the potential to impact the results of the studies in this thesis. Efforts were made during each study to limit potential biases. These efforts ensured that the researcher was not directing the participants but eliciting new perspectives from them, enhancing the likelihood of producing actionable knowledge. Examples include using a systematic and transparent qualitative analysis method (framework analysis) and discussing qualitative themes with the study team. Throughout the thesis, the PhD candidate has attempted to remain separate and objective from the studies. At the end of the final chapter (chapter 9), a personal reflection section is included that discusses the researcher's background, assumptions, and possible impact on the research.

1.6 Thesis structure

The thesis is comprised of four studies: two qualitative studies (chapters 3 and 6), a mixed-methods feasibility study (chapter 4), and a mixed-methods evaluation (Chapter 8). Additionally, the thesis includes a scoping review (Chapter 5) and a methodological section (Chapter 7) outlining the mapping process to design an intervention. Each study provides a unique contribution to knowledge within the field of exercise for PWMS. Figure 1 illustrates the structure of the thesis and how the chapters amalgamate to answer the research question.

Figure 1: Thesis structure



1.7 Content of this thesis

Below is a summary of each chapter to elaborate on the chapter titles shown in Figure 1.

1.7.1 Chapter 2: Multiple sclerosis

Chapter 2 provides background information for the thesis. It describes MS, the history of the condition, existing options for managing MS, and introduces the evidence for exercise in the management of the condition in PWMS. The chapter also describes the purpose and rationale for developing exercise guidelines. The context is provided by discussing guidelines for the general population and long-term conditions before specifically describing the PAGs for PWMS. The chapter concludes with a discussion of the limitations of the guidelines for PWMS.

1.7.2 Chapter 3: Developing exercise interventions for people with moderate-to-severe multiple sclerosis disability: a qualitative study

Chapter 3 discusses a qualitative study involving people with moderate to high levels of MS-disability. The study investigated the perspectives, needs and desires for an exercise intervention for people with a disability level not accommodated in the PAGs. Following the discussion of the results, crucial components of an exercise intervention for people with high MS-related disabilities are presented.

1.7.3 Chapter 4: Exploring exercise intensity and the role of high-intensity interval training in people with MS

The exercise guidelines recommend low to moderate-intensity exercise for people with mild to moderate MS. Chapter four discusses exercise dose, how it is determined, and why it is essential for prescribing exercise. Chapter 4 presents the patient perspectives of a high-intensity exercise intervention for people with low MS-related disability. Following the presentation of the results, the suitability of high-intensity exercise for PWMS is discussed.

1.7.4 Chapter 5: A scoping review of community-based exercise for people with multiple sclerosis

Chapter 5 presents a systematic scoping review to evaluate the evidence of community-based exercise for PWMS. The scoping review investigates the components, settings, theories, and PAGs integrated into interventions. Included in the review are interventions that are aimed at addressing exercise behaviour in a community-based or non-clinical setting (e.g., fitness/leisure centre, community centre, home). The review also discusses research gaps within the literature, which justify further research to explore the determinants and strategies for developing community-based exercise interventions for PWMS.

1.7.5 Chapter 6: Exploring patient and professionals' ideas to form the development of a community-based exercise intervention for people with multiple sclerosis

Chapter 6 presents a qualitative study exploring the views of PWMS and healthcare professionals (HCP) on the critical success factors necessary for developing a community-based exercise programme for PWMS. This includes discussions of the development, implementation, and delivery of community-based exercise interventions. The chapter also discusses the barriers PWMS cope with and must overcome when exercising in the community and the barriers HCPs face in promoting exercise to their patients. The findings highlight the critical success factors required for successfully delivering a community-based intervention.

1.7.6 Chapter 7: Developing a theory-informed community-based exercise intervention for people with multiple sclerosis

Chapter 7 describes the systematic process of designing and developing a community-based exercise intervention for PWMS. The methods are presented following the phases of the MRC guidance [58] for the design of complex interventions and the behaviour change wheel (BCW) [59]. Chapter 7 provides examples of intervention design frameworks and a rationale for choosing the theoretical framework used. The chapter draws upon existing evidence and the work presented in the preceding chapters. Multiple theoretical components are considered and selected to form the intervention. Following the intervention design process discussion, a prototype of the intervention content is presented. A proof-of-concept study is proposed for intervention evaluation and modelling of processes and outcomes.

1.7.7 *Chapter 8:* **Exploring the acceptability of a community-based exercise intervention for people with multiple sclerosis**

Chapter 7 described the development of a community-based exercise intervention and presented a prototype ready for initial testing. Chapter 8 details a ten-week proof-of-concept study exploring the acceptability of the proposed intervention with pre-intervention (week zero) and post-intervention (12 weeks) follow-up. The study contained a process evaluation which included discussions with participants and community-based deliverers of the intervention. Following the presentation of the results, recommendations for improving the intervention will be provided.

1.7.8 Chapter 9: Summary and discussion of research findings and implications for research, practice and the community

Chapter 9 summarises the main findings from the studies described in this thesis to address the primary research question, what works to help people with multiple sclerosis engage in exercise in the community?. The chapter outlines the research programme's contribution to knowledge in this field and the implications for future research, practice, community provision, and for PWMS. The chapter concludes with personal reflections from the researcher and plans for follow-on investigations.

2 Multiple sclerosis Overview

This chapter provides the background information for the thesis; it describes MS, the history of the condition, existing options for the management of MS, and an introduction to the evidence for exercise for PWMS. The chapter also describes the purpose and rationale for developing exercise guidelines. The context is provided by discussing guidelines for the general population and long-term conditions before describing the exercise guidelines for PWMS.

2.1 Overview and history of multiple sclerosis

MS is an inflammatory disease of the CNS that results in progressive neurodegeneration and neurological disability[60]. MS is one of the most common neurological causes of long-term disability in young adults, especially women[61]. MS damages myelin, the protective layer surrounding the nerves[62]. The damage results in symptoms such as vision impairment, loss of coordination and balance, extreme fatigue, pain, bladder dysfunction, cognitive impairment, numbness, weakness, and mood changes[62].

At the end of the 19th Century, Jean-Martin Charcot coined the term "multiple sclerosis"[63]. The name described areas of scarring in the CNS of people affected by the condition. To this day, the aetiology of MS is unknown, and the pathogenesis is complicated[64]. There is a multifactorial model to the causes of MS that incorporates interactions between genetic, infectious, nutritional, climatic, or other environmental influences such as sunlight exposure and smoking[65]. Nevertheless, the definite causes of MS are still unknown, and there are no well-established risk factors to assist disease prevention[66]. MS remains a mysterious disease that can follow very different patterns of progression and variable rates of disability accumulation[67].

2.1.1 Pathology, diagnosis, and classification

2.1.1.1 Pathology

MS refers to the demyelinated lesions on the CNS, combined with inflammation, demyelination, axonal injury, and axonal loss[9]. Lesions can appear throughout the CNS but are predominately in the optic nerves, subpial spinal cord, brainstem, cerebellum, and juxtacortical and periventricular white mate regions[68]. The lesions result in blockages to action potentials travelling through the CNS axons[68].

2.1.1.2 Diagnosis

The diagnosis of MS has evolved. Initially, Charcot's clinical observations led to the first diagnostic criteria for MS[69]. The 'Charcot triad' included nystagmus, ataxia, and dysarthria[69]. In 1965 the Schumacher criteria defined MS as "signs and symptoms of neurological dysfunction indicating multiple and separate lesions in the CNS"[70]. The most significant step forward for diagnosing MS was the advancements in magnetic resonance imaging (MRI)[69]. The use of MRI for the diagnosis of MS resulted in the McDonald Criteria for diagnosis[71]. Improvements in MRI technology have resulted in revisions in the McDonald criteria in 2005, 2010 and 2017[70]. See Table 3 for the 2017 McDonald diagnostic criteria.

The diagnosis of MS is challenging, and rates of misdiagnosis may be as high as 10%[72]. Diagnosis requires dissemination in space (DIS) and dissemination in time (DIT) of lesions in the CNS with the condition that there is no alternative diagnosis that better explains the symptoms[73]. Due to the complex process of diagnosing MS, misdiagnosis remains a problem in clinical practice[70].

Table 3: Summary of the 2017 McDonald Criteria for the diagnosis of multiple sclerosis

Clinical presentation	**Additional data needed for a diagnosis of multiple sclerosis**
…in patients with an attack at the onset	
• ≥Two attacks and clinical evidence of ≥Two lesions; OR • ≥Two attacks and clinical evidence of one lesion with clear historical evidence of prior attack involving a lesion in a different location	None. DIS and DIT have been met.
• ≥Two attacks • clinical evidence of one lesion	DIS is shown by one of these criteria: - additional clinical attack implicating different CNS site - ≥One MS-typical T2 lesions in ≥two areas of CNS: periventricular, cortical, juxtacortical, infratentorial or spinal cord
• One attack • Clinical evidence of ≥two lesions	DIT is shown by one of these criteria: • Additional clinical attack • The simultaneous presence of both enhancing and non-enhancing MS-typical MRI lesions, or new T2 or enhancing MRI lesion compared to baseline scan (without regard to timing of baseline scan) • CSF oligoclonal bands
• One attack • Clinical evidence of one lesion	DIS is shown by one of these criteria: • Additional attacks implicating different CNS site • ≥One or more MS-typical T2 lesions in ≥two areas of CNS: periventricular, cortical, juxtacortical, infratentorial or spinal cord AND DIT is shown by one of these criteria: • Additional clinical attack • The simultaneous presence of both enhancing and non-enhancing MS-typical MRI lesions, or new T2 or enhancing MRI lesion compared to baseline scan (without regard to timing of baseline scan) • CSF oligoclonal bands
…in patients with a disease course characterised by progression from onset (primary progressive multiple sclerosis)	
One year of disease progression (retrospectively or prospectively determined) independent of clinical relapse	DIS is shown by at least two of these criteria: • ≥One or more MS-typical T2-hyperintense lesions in ≥one of the following brain regions: periventricular, cortical, juxtacortical or infratentorial • ≥Two T2-hyperintense lesions in the spinal cord • Presence of CSF-specific oligoclonal bands

DIT = Dissemination in time CNS = central nervous system CSF = cerebrospinal fluid DIS = Dissemination in space T2 lesion = hyperintense lesion on T2-weighted MRIAdapted from The Lancet, Vol. 17, Thompson et al., Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria [74].

2.1.1.3 Classification

MS has four main types: relapsing-remitting, secondary progressive, primary progressive, and progressive-relapsing. Less common subtypes include benign, malignant, and clinically isolated forms of the disease. An International Panel on Diagnosis of MS defined a relapse or an attack as 'patient-reported symptoms or objectively observed signs typical of an acute inflammatory demyelinating event in the CNS, current or historical, with the duration of at least 24 hours, in the absence of fever or infection'[75]. The MS types are discussed briefly below.

2.1.1.3.1 Relapsing-remitting MS

Relapsing-remitting MS (RRMS) is the most common type of MS, occurring in 85-90 % of people at the onset of disease[76]. RRMS involves alternating series of relapses of symptoms which they can recover from, with periods of clinical stability in between[77].

2.1.1.3.2 Secondary progressive MS

Secondary progressive MS (SPMS) begins with an initial RRMS disease course followed by progression with or without relapses, minor remissions, and plateaus[75]. Most patients with RRMS will enter a secondary progressive disease course. The time to onset of SPMS is approximately 20 years [78].

2.1.1.3.3 Primary-Progressive MS

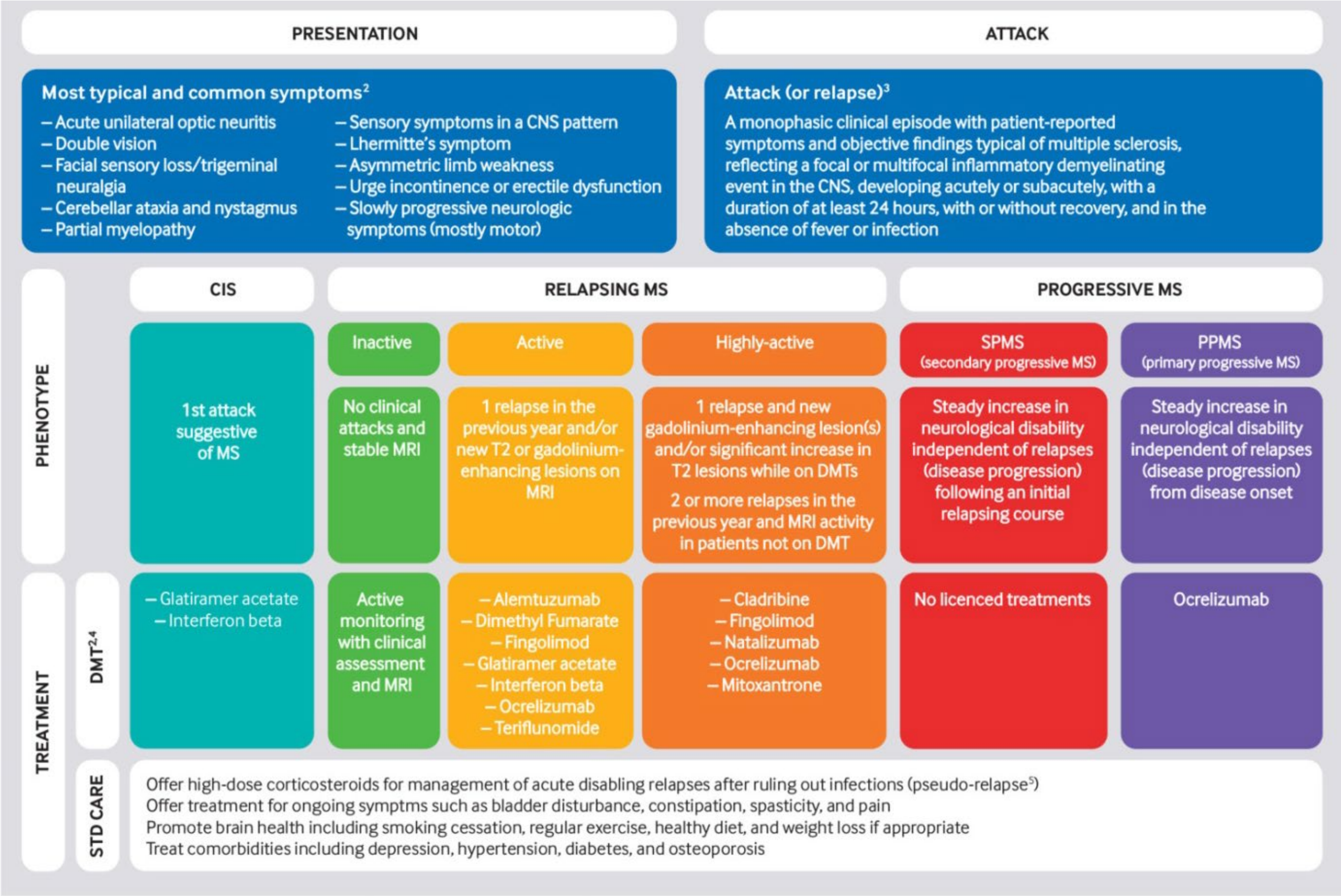
Primary progressive MS (PPMS) involves the progression of the disease from the outset with occasional plateaus and temporary minor improvements[75]. The age of symptom onset for PPMS is estimated to be 40 years [78]. PPMS makes up approximately 10-15% of people diagnosed at onset [79].

2.1.1.3.4 Progressive-relapsing MS

Primary progressive MS (PPMS) and progressive relapsing MS (PRMS) are the subtypes of progressive onset MS. PPMS patients have progressive disease without relapses [80]. PRMS is diagnosed when a patient with at least one year of progressive onset MS experiences one or more relapses [80]. Approximately 28% of progressive onset MS patients are reported as having relapses as PRMS [80].

Figure 2 provides an overview of multiple sclerosis with an approach to treatment according to the European Medicines Agency.

Figure 2: Overview of MS



PRESENTATION	ATTACK
Most typical and common symptoms[2] – Acute unilateral optic neuritis – Double vision – Facial sensory loss/trigeminal neuralgia – Cerebellar ataxia and nystagmus – Partial myelopathy – Sensory symptoms in a CNS pattern – Lhermitte's symptom – Asymmetric limb weakness – Urge incontinence or erectile dysfunction – Slowly progressive neurologic symptoms (mostly motor)	**Attack (or relapse)**[3] A monophasic clinical episode with patient-reported symptoms and objective findings typical of multiple sclerosis, reflecting a focal or multifocal inflammatory demyelinating event in the CNS, developing acutely or subacutely, with a duration of at least 24 hours, with or without recovery, and in the absence of fever or infection

		CIS	RELAPSING MS			PROGRESSIVE MS	
			Inactive	Active	Highly-active	SPMS (secondary progressive MS)	PPMS (primary progressive MS)
PHENOTYPE		1st attack suggestive of MS	No clinical attacks and stable MRI	1 relapse in the previous year and/or new T2 or gadolinium-enhancing lesions on MRI	1 relapse and new gadolinium-enhancing lesion(s) and/or significant increase in T2 lesions while on DMTs 2 or more relapses in the previous year and MRI activity in patients not on DMT	Steady increase in neurological disability independent of relapses (disease progression) following an initial relapsing course	Steady increase in neurological disability independent of relapses (disease progression) from disease onset
TREATMENT	DMT[2,4]	– Glatiramer acetate – Interferon beta	Active monitoring with clinical assessment and MRI	– Alemtuzumab – Dimethyl Fumarate – Fingolimod – Glatiramer acetate – Interferon beta – Ocrelizumab – Teriflunomide	– Cladribine – Fingolimod – Natalizumab – Ocrelizumab – Mitoxantrone	No licenced treatments	Ocrelizumab
	STD CARE	Offer high-dose corticosteroids for management of acute disabling relapses after ruling out infections (pseudo-relapse[5]) Offer treatment for ongoing symptms such as bladder disturbance, constipation, spasticity, and pain Promote brain health including smoking cessation, regular exercise, healthy diet, and weight loss if appropriate Treat comorbidities including depression, hypertension, diabetes, and osteoporosis					

CNS=central nervous system; CIS= clinically isolated syndrome; MS= multiple sclerosis; SPMS= secondary progressive multiple sclerosis; PPMS=primary progressive multiple sclerosis; DMT= disease-modifying therapy; MRI=magnetic resonance imaging; Std=Standard

The figure is taken from De Angelis et al 2018[77]

2.1.2 *Prevalence and epidemiology*

2.1.2.1 *Prevalence*

MS is the most common inflammatory demyelination disorder of the CNS. In most cases, MS diagnosis occurs between 15 and 45 years of age and is the most common cause of permanent disability in this segment of the population [81]. MS in childhood and adolescence is diagnosed more frequently due to increased awareness and improved diagnostic imaging [82]. Approximately 3-to-10% of patients with MS experience the onset of their disease before age 18 years[83]. Globally, approximately 2.5 million people suffer from this disease. In the UK, approximately 126,669 people were living with MS in 2010, a prevalence of 203.4 per 100,000 population[84]. Additionally, there were 6003 new cases diagnosed that year (9.64 per 100,000/year)[84].

2.1.2.2 Epidemiology

Epidemiological and genetic evidence suggests that an interplay of multiple genetic and environmental factors causes MS[64]. Epidemiological data show a high disease prevalence in distinct ancestral groups (particularly the northern European region) compared with others (e.g., African and Asian)[65]. One hypothesis for the susceptibility to develop MS is that it emerged in Southern Denmark and spread with the Vikings[85]. The risk of familial recurrence is 15-20% of MS patients, with the highest being in first-degree relatives[60] (age-adjusted risk 2-3%). Monozygotic or identical twins exhibit a higher risk (35%) than dizygotic or fraternal twins[60].

Several environmental factors have been linked to the risk of contracting MS[66]. Environmental factors include latitude, smoking, and Epstein-Barr virus infection[66]. MS is a prevalent neurological disease in the northern hemisphere, with prevalence rates of 0.5-1.5 per 1000 inhabitants[86]. The incidence varies with latitude; the lowest risk for MS is in people living near the equator[64]. In Europe, the disease has a north-south prevalence gradient (higher in the North, lower in the South)[87]. High prevalence areas of Europe include Scandinavian countries and the UK[87]. Low prevalence areas include Italy, Greece, and Spain[87]. Other environmental factors that promote autoimmune diseases, like MS, include stress, occupation, and diet[88]. The consumption of 'Westernized food', including high salt, fat, protein, and sugar intake, has also been associated with an increasing prevalence of the disease[88].

Belbasis and colleagues[66] completed a comprehensive review of the environmental risk factors associated with MS. They found that 44 risk factors have been studied for an association with the disease. These included infections, vaccinations, comorbid diseases, surgeries, traumatic events and accidents, exposure to toxic environmental agents, and biochemical biomarkers. They found that the Epstein-Barr virus was the only viral agent with consistent evidence for an association with multiple sclerosis[66]. Infectious mononucleosis and anti-EBNA IgG seropositivity had significantly positive associations with MS with no signs of bias. Smoking was the only other risk factor that showed a consistent association with MS without the presence of bias[66]. The review also found that the association between MS and many risk factors is null or has a minimal effect[66]. These include vaccinations (tetanus, diphtheria, influenza, BCG, mumps, measles and rubella, poliomyelitis, hepatitis B virus, and typhoid fever), biochemical factors, presence of dental amalgam, past surgeries and traumatic events[66]. Sun exposure and vitamin D has been linked as a risk factor for MS due to the geographical trends of MS incidence[89]. Higher vitamin D levels are associated with a reduced risk of developing MS[89]. However, Belbasis and colleagues[66] found that the effect of vitamin D on MS might be absent.

2.1.3 Effects of multiple sclerosis: Symptoms and treatment

2.1.3.1 Symptoms

Due to lesions distributed throughout the CNS, MS symptoms can be neurological and systemic[90]. Consequently, PWMS can develop various symptoms such as fatigue, reduced mobility, weakness, reduced balance, stiffness, spasms, cognitive issues, bladder and bowel problems, pain, anxiety, depression, visual disturbance, and dizziness [91].

2.1.3.2 Treatment

There is no cure for MS, but there are numerous disease-modifying treatments (DMT) that can reduce disease activity and progression in patients with relapsing-remitting MS[6]. Since 2011, there has been an exponential increase in DMTs for relapsing-remitting MS[92]. DMTs aim to shorten the duration of relapses, decrease their frequency, and provide symptom relief[6]. Currently, 15 DMTs are available for RRMS. The most prescribed DMTs are interferon beta and glatiramer acetate[77]. The first treatment for PPMS, ocrelizumab, was licensed in 2017[77]. There is moderate to high-quality evidence from randomised controlled trials and systematic reviews for the use of DMTS[77]. Based on their impact on relapses compared with placebo (or interferon beta), the DMTs can be categorised as moderately effective (interferon beta, glatiramer acetate, teriflunomide, dimethyl fumarate, fingolimod) or highly effective drugs (natalizumab, ocrelizumab, alemtuzumab, cladribine, and mitoxantrone)[77]. However, highly effective DMTs come with the risk of serious safety concerns and require increased safety monitoring[77,92]. Serious adverse reactions include progressive multifocal leukoencephalopathy (PML), cardiac arrhythmias, hepatotoxicity, secondary autoimmunity, and malignancy[77]. Interferon-beta and glatiramer acetate are not associated with long-term harm but are still subject to side effects. For example, flu-like symptoms and injection site reactions. Relapse reduction and adverse effects of licensed DMTs are outlined in Table 4.

PWMS have an ongoing challenge to balance the benefits of drug therapy with the adverse effects that can potentially worsen other aspects of the disease[93]. As a result, PWMS need a holistic treatment plan which includes symptom management and maintenance of function[93]. Exercise is now recommended as a therapeutic option to manage symptoms (e.g. fatigue, pain, cognitive and physical function) and promote a satisfactory quality of life[6].

Table 4: Licensed disease-modifying drugs used for the treatment of people with MS

DMT	**Relapse rate reduction**	**Adverse reactions**
Injectable (subcutaneous or intramuscular injection)		
Glatiramer acetate	30% v placebo	Injection site reactions, immediate post-injection reaction
Interferon beta preparations	34% v placebo	Flu-like illness, injection site reactions, deranged LFTs, lymphopenia
Oral		
Cladribine	58% v placebo	Herpes zoster infections, lymphopenia, rash, alopecia
Dimethyl fumarate	48.5% v placebo	Flushing, gastrointestinal upset, lymphopenia, PML (rare)
Fingolimod	51.5% v placebo	First-dose bradycardia, macular oedema, Herpes Zoster, deranged LFTs, hypertension, basal cell carcinoma, PML (rare)
Teriflunomide	33.5% v placebo	Nausea, diarrhoea, hair thinning, hypertension, deranged LFTs, teratogenicity
Alemtuzumab	52% v interferon beta	Infusion reactions, infections (herpes, varicella, listeria, superficial fungal), autoimmunity (ITP), nephropathy, thyroid disorders, leucopoenia, lymphopenia
Mitoxantrone	66% v placebo	Cardiotoxicity, infection, myelosuppression, gastrointestinal disturbance, alopecia, leukaemia, and other malignancies
Natalizumab	68% v placebo	Infusion reaction, PML, gastrointestinal disturbance, acute retinal necrosis (rare)
Ocrelizumab	46-47% v interferon beta	Infusion reactions, herpes virus-associated infections, and other infections
ITP=idiopathic thrombocytopenic purpura; LFTs=liver function tests; PML=progressive multifocal leukoencephalopathy. * This refers to the relative risk reduction of relapses. Relative measures are preferred over absolute measures to compare MS treatments because they tend to be more stable across populations of patients with different relapse rates and MRI measures of disease activity.		

TABLE ADAPTED FROM DE ANGELIS ET AL. 2018 [77] DMT= DISEASE-MODIFYING THERAPY

2.2 Exercise for multiple sclerosis

Throughout this PhD, physical activity and exercise will be defined in the following ways (see Page ix for further definitions of key terms):

- Physical activity is any bodily movement produced by skeletal muscles that result in energy expenditure over resting levels[2].
- Exercise is a subset of physical activity and is planned, structured or repetitive bodily movement done to improve or maintain one or more components of physical fitness[2].

The attitudes towards the effects of exercise on MS have changed over time. Over the last 25 years, there has been a substantial growth in the number of randomised controlled trials documenting the beneficial effects of exercise and physical activity in PWMS [26]. This has resulted in a paradigm shift from fear of triggering and aggravating the disease toward exercise being an integral part of disease management.

2.2.1 History of exercise for multiple sclerosis

In the late 19th Century Dr Wilhelm Uhthoff reported blurred vision during physical exertion in MS patients[94]. In a survey of 100 PWMS, Dr Uhthoff discovered four individuals affected by the exertion[95]. The appearance of new or amplified symptoms with increased body temperature is still referred to as the Uhthoff Phenomenon[94]. The factors that cause the Uhthoff phenomenon include fever, infection, exercise, hot bath or shower, exposure to high ambient temperatures, perimenstrual temperature, and stress. Uhthoff did not record the patient's body temperature in the study; therefore, concluding that the physical exertion caused the blurred vision, not an increase in body temperature. Over 60 years later, it was suggested that one-third of MS patients could have symptoms induced or worsened by exercise[95]. It is now understood that the exacerbation of symptoms following exercise is temporary[96]. This information was not previously available, and thus physical exertion became the catalyst for the disease[94]. Consequently, health professionals advised PWMS not to engage in exercise. The idea that PWMS should avoid exercise has resulted in fear and insecurity that is still present today[94].

The first evidence for the benefits of exercise on MS symptoms emerged in the 1960s[94]. In 1963 Geisler and Jousse[97] evaluated 28 patients referred for rehabilitation. The rehabilitation included active and passive individual exercises such as group callisthenics and mobilisation of spastic limbs. The evaluation results found that patients with progressive disease fared the poorest from rehabilitation. In total, 57% of the group benefited from the treatment[97]. Early research focused on rehabilitation-based physiotherapy treatments[98] and water-based exercise[99]; these studies generally had small sample sizes and lacked a robust randomised-control trial (RCT) design. The first RCT to explore exercise and its effects on PWMS was by Petajan and colleagues [100] in 1996. The study found that 15 weeks of aerobic exercise training improved fitness (V_{O2}Max, upper and lower limb strength) and positively impacted quality of life factors (decreased fatigue and depression).

2.2.2 Exercise for people with multiple sclerosis today

The first Cochrane review on 'exercise therapy for Multiple Sclerosis' was published in 2006[101]. The study concluded that exercise benefits PWMS after identifying nine high-quality randomised controlled trials. Further research has followed supporting the beneficial effects of exercise on fatigue[102], fitness, walking mobility [103] and general quality of life[104] for people with mild-to-moderate disability. The NICE guidance recommends supervised exercise programmes to improve symptoms such as mobility problems and fatigue [105]. Further reviews supported these findings and concluded that supervised exercise (aerobic and/or strength) training benefits people with mild-to-moderate MS [25,106-109].

Consensus statements now specify exercise as one of the most critical interventions for managing MS[110]. A recent Cochrane review investigating the efficacy and safety of various rehabilitation approaches for PWMS found two reviews evaluating the effectiveness of different exercise programmes[111]. The authors concluded that there is moderate-quality evidence that exercise can improve functional outcomes (mobility, strength), patient-reported fatigue, improve psychological symptoms (such as mood) and quality of life[111]. Additionally, there is low-quality evidence that exercise can improve balance and symptoms[111].

Platta and colleagues[112] published a meta-analysis examining the effect of exercise on muscular and cardiorespiratory fitness in PWMS. The meta-analysis concluded that exercise is associated with minor improvements in muscular fitness (10%; Cohen's $d = 0.27$) and moderate increases in cardiorespiratory fitness (18%; Cohen's $d = 0.47$).

2.2.3 The potential disease-modifying effects of exercise for MS

Several studies have suggested that exercise may have disease-modifying effects by reducing inflammation, promoting neuroplasticity, and enhancing the function of the immune system [113-115]. One mechanism by which exercise may have disease-modifying effects for MS is by reducing inflammation [116]. Chronic inflammation is a hallmark of MS and is believed to contribute to the ongoing damage to the CNS [117]. Cytokines are proteins secreted from different tissues and influence the reproduction, differentiation, proliferation and function of immune cells [118]. Exercise has been shown to reduce the production of pro-inflammatory cytokines while increasing the production of anti-inflammatory cytokines [116]. This may help to reduce inflammation in the CNS, which in turn could slow down the progression of the disease [118]. However, a systematic review [118] found limited and contradictory results on the effects of exercise on cytokines. They concluded that current research does not support a substantial impact of exercise training on cytokines in PWMS [118].

Another potential mechanism by which exercise may have disease-modifying effects for MS is by promoting neuroplasticity [119]. Neuroplasticity refers to the brain's ability to modify, change, and adapt both structure and function throughout life and in response to experience [120]. In PWMS, damage to the CNS can disrupt normal neural pathways, leading to a range of symptoms. Exercise has been shown to promote neuroplasticity by increasing the production of neurotrophic factors, which are proteins that support the growth and survival of neurons [121]. This may help to restore normal neural function, which in turn could slow down the progression of the disease. However, systematic reviews suggest the current evidence base is not robust, as there are insufficient data to draw such conclusions [119,122].

There is an ongoing debate within MS research on the potential of exercise as a disease-modifying therapy. This is highlighted by recent commentaries in the Multiple Sclerosis Journal, with researchers claiming yes exercise has a disease-modifying effect [123]. Other researchers claimed that no exercise does not have a disease-modifying effect [124]. However, supporters [123] acknowledged that currently, the evidence is circumstantial. However, they do not suggest that clinicians should replace pharmacological agents with exercise for managing the disease but rather embrace exercise as a complementary disease-modifying behaviour [123].

2.3 Physical activity guidelines

Physical activity and exercise offer a range of health benefits and reduce all-cause mortality [125]. Although, global estimates show that one in four (27.5%) adults do not meet the recommendations for physical activity[4]. This discourse between the benefits and the engagement in physical activity has led national governments to produce recommendations for physical activity levels for their populations[125]. Guidelines contain summary statements or recommendations, based on the latest evidence, that communicates the necessary amounts of physical activity required for specific and general health gains [126].

Global and national guidelines on physical activity are a central component of comprehensive governance and policy framework for public health action [4]. In the United Kingdom (UK), there are published guidelines for those under 5's, young people, adults, older adults, those with a disability, pregnant women, and women after childbirth, covering aerobic physical and strength-based activity recommendations and advice on sedentary time[126]. The World Health Organisation has created global recommendations on physical activity for health[127]. The typical recommendation is that 150-300 minutes of moderate-intensity or 75-150 minutes of vigorous physical activity per week provides substantial health benefits for adults. The recommendations also conclude that activity of any duration, without a minimum threshold, is associated with improved health outcomes, including all-cause mortality [128].

Physical activity recommendations represent the culmination of the process of knowledge translation[128]. Translating knowledge into practice is the most challenging step for science[129]. Although countries have developed national physical activity recommendations, there appears to be an implementation gap[130]. Countries are having difficulties in translating their policy intent into practice[131].

2.3.1 Scope of physical activity guidelines

Physical activity guidelines are designed to provide individuals with evidence-based recommendations on the amount, frequency, and intensity of physical activity needed to promote health and reduce the risk of chronic diseases [127]. Public health organisations develop these guidelines based on a comprehensive review of the scientific literature on physical activity and health [4]. PAGs provide population-level guidance rather than personal prescriptions. These guidelines are tools that offer evidence-based recommendations to individuals, communities, and policymakers, aiming to improve public health outcomes on a broad scale[132]. They consider the diverse needs, capabilities, and circumstances of various population groups, considering age, gender, socioeconomic background, and health conditions. However, these groups must adapt the messages and recommendations in this report to suit the specific needs and interests of those they are working with and the context they are working in[132].

It is crucial to recognise that every person is unique, and their physical activity needs may vary based on age, health status, and personal goals [4]. Simply providing PAGs wherein the message is “get this much physical activity” or “exercise more” is insufficient to produce behaviour change[133]. PAGs provide a foundation for individuals to build their personalised activity plans. By understanding the population-level recommendations, individuals can assess their abilities, preferences, and limitations and adjust accordingly while seeking guidance from healthcare professionals when necessary [132].

PAGs aim to promote physical activity to improve health and quality of life. The scope of guidelines often includes recommendations for all age groups, from children to older adults [4]. The guidelines provide specific recommendations for different age groups and populations, considering differences in physical abilities, health status, and lifestyle factors. PAGs typically include recommendations for aerobic activity, muscle-strengthening activity, and flexibility exercises. The PAGs provide specific recommendations for the amount and intensity of each type of activity needed to promote health.

In addition to promoting physical activity, the guidelines aim to reduce sedentary behaviour [127]. Sedentary behaviour refers to any activity that involves sitting or lying down and expending very little energy [134]. Excessive sedentary behaviour has been linked to an increased risk of chronic diseases and premature death [135]. Therefore, PAGs may include recommendations to reduce sedentary behaviour, such as limiting screen time or taking frequent breaks from sitting [127].

Certain topics fall outside the scope of physical activity guidelines. For example, PAGs do not typically address the specific types of physical activity that an individual should engage in. While guidelines may recommend aerobic, muscle-strengthening, and flexibility exercises, they do not provide specific recommendations on which specific activities an individual should engage in, such as running, swimming, or weightlifting. Additionally, PAGs do not address individual preferences or constraints that may affect an individual's ability to engage in physical activity.

While PAGs provide evidence-based recommendations on physical activity and sedentary behaviour, they do not address all physical activity and health aspects. Individual preferences, constraints, and underlying causes of physical inactivity require additional considerations beyond the scope of PAGs.

2.3.2 Exercise prescription guidelines for clinical populations

The global PAGs[127] are for the general population but are not optimal for addressing the diverse needs of people living with chronic medical conditions[129]. As a result, clinical exercise prescription guidelines are available for many conditions, including cancer, Parkinson's disease, cardiovascular disease, diabetes, and stroke[136]. Pedersen and Saltin[136] published a review on prescribing exercise for 26 different conditions.

'Miracle cure' is a label often given to exercise[137]. The idea that exercise is medicine or should be part of medicine is not new[138]. Hippocrates noted that "eating alone will not keep a man well; he must also take exercise"[138]. Prescribing exercise to a patient like a drug prescription will help implement exercise guidelines in clinical practice[139]. Exercise prescription guidelines intend to identify the 'dose' of exercise required to *(a)* produce fitness gains and health benefits and *(b)* minimise the risk to individuals as much as possible[128]. However, prescribing exercise as medicine is a medical convention instead of behavioural science[140]. Exercise guidelines and physical activity recommendations lack any guidelines on the behavioural change aspect of becoming more active[128]. An exercise prescription may be safe and effective on paper but will have no value if the individual does not engage with the programme[128]. Factors at various levels influence the adoption of exercise, for example, individual, inter-individual organisational, municipality, and public policy[141].

2.3.3 Exercise guidelines for people with multiple sclerosis

Several guidelines exist for exercise prescription for MS [25,107,142-145]. Table 5 provides an overview of the recommendations for exercise prescription for PWMS. The NICE guidelines [146] provide recommendations to exercise but not information on intensity, duration or frequency [147], so they have not been included. Each resource is suitable for individuals with mild to moderate MS-related impairment. There are several similarities between the recommendations. For aerobic exercise, the recommendations generally start at two days per week and then progress to three days. The suggested duration of a session ranges from 10 minutes to 40 minutes. The recommended intensity is consistent at mild to moderate-intensity exercise. For resistance training, the frequency of sessions ranges from 2 to 3 per week. The training programme should focus on large muscle groups. The exercise bouts should range from 1 to 3 sets with an intensity of 8 to 15 repetitions. Rest between sets ranged from 1 to 4 minutes.

Each resource is evidence-based (includes a literature review), but only one involved a standardised consensus development process [25]. As a result, these guidelines are accepted as the official guidelines in the MS literature [26,27,148] and will be viewed as such throughout this thesis. Latimer-Cheung and colleagues [25] followed a rigorous guideline development process. The AGREEII instrument guided the process[149] and was consistent with the recommended steps for physical activity guideline development[150]. The review included 54 studies that examined the effects of exercise on aerobic capacity, muscular strength, mobility, fatigue, and health-related quality of life [25]. All studies included in the guideline eliminated people with severe gait issues. The overall objective of the guidelines is to recommend the minimum dose of physical activity necessary to improve fitness, mobility, fatigue, and quality of life among adults with MS [151]. The guidelines are meant for all contexts, including gyms, clinics, and home settings [151]. However, because the evidence base comprises primarily structured exercise trials, the guidelines are especially relevant to supervised gym settings [151]. The target population for the guidelines is adults (aged 18-64 years) with mild-to-moderate MS (EDSS 0-7) resulting from relapsing-remitting and progressive (secondary and primary progressive) forms of MS [151]. The intended users of the guidelines are [151]:

- People living with MS and their families
- Healthcare professionals (HCP), including certified exercise physiologists, kinesiologists, trainers, physiotherapists, occupational therapists, physicians, and attendant care provider

Table 5: Overview of exercise prescription guidelines for people with MS

Author (year)	**Country**	**PA recommendations**
White and Dressendorfer (2004) [142]	USA	- Alternate between aerobic and resistance training days with 24-48 hours rest between sessions. Aerobic - Frequency of 2-3 sessions per week. - An intensity of 65-75% of HRpeak, 50-70% of VO_2 peak, or Rate of perceived exertion (RPE) of 11-14. - Duration of 20-30 minutes or 2 x 10-15 minutes. Resistance - A training frequency of 2-3 sessions. - Whole-body programme consisting of 4-8 exercises. - Intensity in range the of 8-15 reps. - Sets in the range of 1-3 with rest periods.
Dalgas et al (2008) [107]	Denmark	- Recommendations for MS patients with an EDSS score of less than 7. Aerobic - A training frequency of 2-3 sessions. - An intensity of 50-70% of VO_2 max, corresponding to 60-80% of maximum heart rate. - Duration of 10-40 minutes. - Progress exercise by increasing the duration or adding an extra training day. Resistance - Supervised by an expert. - Training machines preferred over free weights - Home-based training can be done using elastic bands and/or bodyweight. - A training frequency of 2-3 sessions. - Whole-body programme consisting of 4-8 exercises. - Intensity in range the of 8-15 reps. - Sets in the range of 1-3 with rest periods of 2-4 minutes. - Progress to 3-4 sets.
Ronai et al (2011)[143]	USA	- Preferable to not train aerobic and resistance on the same day. Aerobic - Frequency of 3-5 sessions per week. - An intensity of 40-70 of VO_2 peak or 40-60% of VO_2 reserve. - RPE of 11-13. - Duration of 30 minutes per session (can be accumulated in 10-minute bouts). Resistance - Major muscle groups consisting of 8-10 exercises. - An intensity of 8-15 repetitions with 60-80% of 1 rep maximum (RM). - Minimum of one-minute rest between sets.
Sandoval (2013) [144]	USA	Aerobic - Frequency of 2-3 times per week.

		• Duration of 10-40 minutes. • An intensity of 50-70% of VO_2 max corresponding to 60-80% of maximum heart rate or RPE of 11-14. Resistance • Weight machines are preferred to free weights. • Frequency of 2-3 days. • Intensity in the range of 8-15 reps with 60-80% of 1 RM. • Sets in the range of 1-3 with rest periods of 2-4 minutes. • Whole-body programme consisting of 4-8 exercises.
Latimer-Cheung et al (2013) [25]	Canada	• Adults aged 18-64 years. • Mild to moderate MS. • Aerobic and strength can be done on the same day. • Rest at least one day between strength sessions. Aerobic • Frequency of 2 days per week. • Gradually increase up to 30 minutes. • Perform at a moderate intensity. 5 or 6 on a scale of 10 (Person can talk but not sing). Resistance • Frequency of 2 days per week. • Intensity in the range of 10-15 repetitions. • Sets in the range of 1-2.
Halabchi et al (2017) [145]	Iran	• For people with mild to moderate MS. • Do not train aerobic and resistance on the same day. Aerobic • Frequency 2-5 sessions. • Low to moderate intensity. • An intensity of 40-70% of VO_2max or 60-80% of maximal heart rate. • An RPE of 11-13. • Training duration of 10-40 minutes. This can be accumulated from shorter bouts. • Progression should be attained by increasing the duration or frequency of exercise session. Resistance • Supervised by experienced staff. • Weight machines are preferred to free weights. • Home-based training can be done using elastic bands and/or bodyweight. • A training frequency of 2-3 sessions. • Whole-body programme consisting of 4-10 exercises. • Intensity in the range of 8-15 reps with 60-80% of 1 RM. • Sets in the range of 1-3 with rest periods of 2-4 minutes. • Progress to 3-4 sets.

2.4 Limitations in the physical activity guidelines for people with MS

Guidelines are developed to decrease the gap between research and current practice and are valuable tools in situations where multiple therapies are available or there is uncertainty in treatment options[152]. The development and implementation of guidelines are intended to organise and provide the best evidence to support decision-making [152]. Despite the growing number of guidelines, their use in practice is reportedly unpredictable, slow, and complex [152]. It takes, on average, 17 years for research evidence to reach practice [153]. The conventional thinking was "if you build it [the guidelines], they [the stakeholders; clinicians, practitioners, the general public, patients] will come" [153]. However, as discussed previously, physical activity levels are not improving despite developing guidelines [4].

Previous research has shown a disparity between positive attitudes toward guidelines and their actual use by physiotherapists [154]. In the study, 96% of responders considered guidelines important, but fewer than half reported using them frequently[154]. The most important determinants of frequent guideline use were considering guidelines essential and knowing how to adapt the guidelines to patient's preferences [154]. HCPs who might be required to provide exercise advice to PWMS need detailed evidence-based to ensure optimal and safe application.

Despite evidence for the benefits of exercise and the development of exercise guidelines, PWMS are less active than the general population[155]. Inactivity leaves PWMS susceptible to secondary conditions such as obesity, diabetes, and heart disease. In 2005, Motl and colleagues published a meta-analysis of 13 studies that included 2,360 patients[156]. The evidence concluded that PWMS are physically inactive[156]. Physical activity measured using accelerometers showed that PWMS are 13 minutes less active per day (1.5 hours less per week) than healthy controls[157]. In 2017 the authors of the original meta-analysis published an update to see if the increased awareness of physical activity for MS impacted activity levels[158]. The updated review included 21 studies involving 5303 patients with MS. The evidence again suggested that PWMS are less active than non-diseased populations. The meta-analysis also found that physical activity levels of the MS population closely mirror those of other chronic disease populations[158]. A further review conducted to quantify objectively measured physical activity levels in PWMS also found people with MS to be less active than the general population[159].

The PAGs for PWMS [25] are underpinned by robust, standardised consensus development processes [160], but there remain several limitations in the guidelines [160-162]. These limitations can be categorised into three themes: 1) the inclusivity of PWMS, 2) the exercise prescription, and 3) the application of the guidelines.

2.4.1 The inclusivity of PWMS

The PAG is designed for adults aged 18-64 with mild to moderate MS [25]. Firstly, the guidelines provide an age limit to adults under 65, implying that older adults with MS do not need to be active or should not be active [161]. There is an increasing number of PWMS who are entering older adulthood [163]. This offers the problem for PWMS whereby they combine the effects of normal ageing and those of MS itself [164]. Exercise specifically for older PWMS is an under-researched area [165]. Physical activity behaviour declines with increasing age in adults with MS [164]. Research shows that older adults with MS engage in less physical activity than young and middle-aged adults with MS [166]. Over time, the deterioration of functional and cognitive capacity can make the initiation and maintenance of exercise challenging for older individuals [165]. The interest in research exploring health behaviours (e.g., physical activity and diet) in older adults with MS has increased recently[164] but is currently not included in the PAG for PWMS.

The PAG guidelines also exclude individuals with higher disability levels. Most evidence regarding exercise for PWMS has been conducted with people with mild-to-moderate disabilities [160]. Currently, there is limited but promising evidence for the benefits of exercise training in PWMS [167]. Further research is required to determine the most efficacious and effective exercise approaches for PWMS with severe disabilities [167].

In the development of the guidelines, there was no inclusion of PWMS. Guidelines should focus more on patient-relevant outcomes and patient involvement in the development process [152]. Given the individual nature of MS, there is important information to be gained from discussions of patient experiences [165]. For example, discussions around exercise preferences, social support, and barriers will be valuable in learning the factors that impact participation in exercise [165]. The PAGs do not provide any information on facilitators and barriers to the application of the guidelines or present criteria for monitoring or auditing [160]

2.4.2 The exercise prescription details

The intended users of the PAG are PWMS, their families, and HCPs [25]. HCPs who recommend or prescribe exercise need detailed, evidence-based recommendations for optimal and safe application [160]. Exercise recommendations must include information on the appropriate dose to achieve health benefits [160]. At the basic conceptual level, exercise dose is determined by frequency, intensity, and duration [168]. The PAG include details on these three variables; for example, aerobic exercise is recommended twice (frequency), for at least 30 minutes (duration), and at moderate intensity (intensity) [25]. Although the PAG only provide general recommendations on increasing the dose of exercise toward the recommended amount

[161]. The basis of exercise prescription in clinical populations should adhere to the ‘principles of training’ [169,170]. The essential principles of training comprise specificity, individualisation, progressive overload, and recovery [170]. A brief overview of each of these principles is provided in Table 6. It is vital to provide PWMS with instructions on starting and maintaining their exercise programme, whether they are inactive or regularly active people with no exercise experience.

2.4.3 The application of the guidelines

Given the evidence for the benefits of exercise for PWMS, there is a need to promote exercise for this population and provide opportunities for them to exercise safely. Streber et al.[171] conducted a systematic review of correlates and determinants of physical activity in PWMS. A correlation is a statistical association between a measured variable and physical activity[172]. Determinants are causal factors, and variations in these factors are followed systematically by changes in physical activity behaviour[172]. The review found associations between physical activity and disability level, physical activity-related self-efficacy, self-regulation constructs, employment status, and level of education. The environment is correlated with physical activity in this population. The presence of shops within walking distance, availability of public transport, and accessibility of free or low-cost facilities are related to physical activity levels in PWMS [173]. The PAG for PWMS does not provide information on the most appropriate locations to be physically active. Although the guidelines claim to be applicable to all contexts, the evidence base used in the guidelines is from gym and clinical settings [25,160]. Common personal barriers to physical activity for PWMS include fatigue, fear and apprehension[173]. This suggests that expecting PWMS to initiate activity independently is unrealistic. However, PWMS have reported exercise as a high priority[174]. Receiving information on lifestyle factors (exercise and diet) is a higher priority than pharmaceutical information[174]. Currently, the PAG for PWMS appears to be informative rather than instructional, which is more appropriate for physically inactive people attempting to start [161].

Table 6: The principles of training

Principle	**Description**
Specificity	Training adaptations are specific to the organ system or muscles trained with exercise. For example, aerobic exercise such as brisk walking is more appropriate for an intervention aimed at increasing cardiovascular fitness than strength training [169]
Individualisation	The concept of individualisation is defined as the customised application of training toward the physiological status of the individual [170].
Progressive overload	Over time, the body adapts to exercise. For continued improvement, the volume or intensity of the training must be increased [169].
Recovery	The inclusion of recovery is often a neglected area of exercise prescription [169]. The aim is to ensure the individual has adequate rest to ensure physiological adaptations can take place [170]. Conversely, an extended period without adequate stress will result in a loss of adaptation. This is the principle of reversibility [169].

2.5 Conclusion and statement of purpose

Physical activity and exercise offer a range of benefits for PWMS, such as improved fatigue, walking ability, and quality of life. The strength of the evidence has resulted in the development of robust PAGs for PWMS. Despite this, exercise levels in this population are low, which leaves them at greater risk of secondary conditions. This suggests that the PAGs are not meeting the needs of PWMS. The limitations of the PAG include 1) the inclusivity of the recommendations, 2) the application of the guidelines in the community, and 3) the details of exercise prescription.

This thesis aimed to explore the PAG for PWMS. This was completed through a series of studies focusing on previously discussed limitations. Despite the knowledge that exercise benefits PWMS, commitment and adherence to exercise in the community is challenging. The PAGs have the potential to influence HCPs and enhance exercise opportunities in the community for PWMS. This thesis aims to advance understanding of what works to help PWMS engage in exercise in the community with the PAG as a guide.

3 Developing exercise interventions for people with moderate-to-severe multiple sclerosis disability: a qualitative study

3.1 Overview

MS is a progressive disease, meaning most PWMS will likely have a severe disability in the future. The exercise guidelines for PWMS recommend low-to-moderate intensity exercise for mild-to-moderate MS [25]. Due to the limited research on the effects of exercise on people with moderate-to-severe MS [145] (EDSS >6.0), researchers cannot develop guidance or recommendations. However, just because people are impaired does not mean they should be 'disqualified'. Although the recommendations do not apply to people with higher levels of disability, it does not mean they do not want to exercise or should not.

This chapter describes a qualitative project involving people with moderate-to-severe levels of MS-related disability. The lack of guidance for exercise for people with moderate to severe MS exposes a gap in the existing literature. This study adopted a qualitative method to explore the needs and lived experiences of people with moderate to severe MS to understand their views on exercise and what type of intervention they would find feasible.

The research team for this study included HCPs (MS nurses, neurologists, and neuro physiotherapists) and researchers. The study served as the foundation for understanding the current state of knowledge, identifying gaps in provision, and informing the development of an exercise intervention. The study involved discussions and consultations with individuals with moderate-to-severe MS to learn their specific needs, preferences, and challenges related to exercise participation for PWMS. Through interviews, participants shared their experiences, perspectives, and expectations regarding exercise, allowing the research team to begin the creation of a meaningful and relevant intervention for the target population.

This research project builds upon the existing body of knowledge in the field of exercise for MS. It acknowledges the limitations of previous studies, which often focus on individuals with a mild-to-moderate disability and seeks to fill the gap by addressing the specific needs of individuals with moderate-to-severe MS disability.

3.2 Introduction and rationale

3.2.1 Moderate-to-severe MS-related disability

The accumulation of neurological disability independent of relapses characterises the progressive forms of multiple sclerosis (MS)[175]. People with the condition will become increasingly disabled as the disease progresses[176]. Progression is a steady deterioration in neurologic function, which occurs over at least six months or 12 months [177]. The patterns of early relapses and slow progression during MS lead to the idea that there are two distinct phases of the condition[177]. Firstly, there is relapsing-remitting MS (RRMS), which includes periods of relapses alternating with dormancy [177]. The second is the progressive phase, characterised by steady deterioration[177]. Chapter 2 describes the different disease phases.

From the onset of MS to the beginning of the progressive phase is estimated to be about 9-11 years [177]. However, approximately 15% of all individuals with MS become severely disabled in a short time [178]. Also, for 20% of patients, the disease is progressive from the onset, termed primary progressive MS [178]. The accumulated damage in the CNS can manifest as physical disability, particularly mobility disability [179]. Mobility disability is one of the most widespread and impactful consequences of MS. It is defined as an impairment in ambulation, including a reduction in walking speed, decreased walking endurance, and reduced postural stability during walking or standing [179].

Moderate-to-severe MS-related disability is defined as a Patient Determined Disease Steps (PDDS) [180] score of 3-7 or an Expanded Disability Status Scale (EDSS) of ≥ 6.0 (e.g., Significant walking limitations that require support for gait) [176]. Individuals with an EDSS score of ≥ 6.0 or PDDS of 3-7 have considerable impairments in muscular strength, aerobic fitness, mobility, and balance compared to individuals with lower disability scores[181]. Additionally, fatigue, depression, spasticity, and cognitive impairment become more severe with increasing disability [181]. Approximately 30% of PWMS need assistance from family members to carry out activities of daily living [176]. The resulting demand for assistance can also negatively affect the caregiver's health [176]. The consequences of mobility disability support the need to identify approaches to improve or slow mobility issues in this population [179]. One of the rehabilitation strategies to manage some of the impacts of MS is physical activity and exercise.

3.2.2 *Physical activity behaviour of people with moderate-to-severe MS-related disability*

The worsening of MS symptoms over five years is associated with lower self-reported physical activity levels independent of depression, neurological disability, and MS disease course [182]. Furthermore, objective data show that people with high MS disability are less active than less disabled PWMS [166,183]. PWMS who have mobility disability are sedentary for 65-76% of the day and engage in moderate-intensity activity for 1% of the day [176,183]. Compared to PWMS without mobility disability, who were sedentary 60% of the day and engaged in moderate-intensity activity 3% of the day [183].

3.2.3 Exercise interventions for people with moderate-to-severe MS-related disability

3.2.3.1 Traditional exercise

Although there is evidence of the benefits of exercise for people with mild-to-moderate MS, little is known of the benefits in higher levels of disability [145]. This population's most prescribed forms of exercise include aerobic training and progressive resistance training [184]. Aerobic training includes treadmill walking, cycle ergometer, arm ergometer, and aquatic exercises. Resistance training includes weight machines, free weights, bodyweight exercises, cable pulleys or elastic bands [184].

Edwards and Pilutti [181] conducted a systematic review of the literature involving exercise in people with severe MS. The review identified 19 studies, five of which were conventional exercise modes. Three studies involved aerobic exercise training, and two explored resistance training [181]. No statistically significant outcomes were found from aerobic exercise, although non-significant improvements were reported in $VO_{2peak,}$ physical function tasks (balance, gait, agility, walking extremity), depression and quality of life [181]. Resistance training significantly improved muscular strength in both studies reviewed [181].

There are several advantages to traditional exercise training. Exercise training is cost-effective and can be made available in community settings [184]. Additionally, a combined aerobic training and resistance programme can benefit health and fitness, such as improved bone density, body composition, and comorbid disease profile [184]. To date, accessibility issues have been found to limit the feasibility of conventional exercise training for people with higher MS disability [185].

3.2.3.2 Adapted Exercise

Several adapted forms of activity aim to overcome the issues of inaccessibility. The typical examples of adapted exercises are discussed below.

3.2.3.2.1 Functional Electrical Stimulation

Functional Electrical Stimulation (FES) is a technique that delivers brief electrical pulses to generate contractions in paralysed muscles [186]. FES is an established management strategy for people with foot drop in PWMS [187]. A six-month retrospective study found that FES training can improve walking speed (15% improvement) and quality of life[187]. The review from Edwards and Pilutti[181] identified 13 studies examining adapted exercise training. Five studies used FES to assist stationary cycling. None of the studies reported significant improvements in physical function, and there was mixed evidence for the effects of FES on spasticity and walking speed [181]. All five studies were of low quality [181].

3.2.3.2.2 Bodyweight-supported treadmill training

Bodyweight-supported treadmill training (BWSTT) consists of a motorised treadmill with a supportive harness [184]. The harness suspends the patient over the treadmill with a certain amount of body weight off-loaded by a counter-balancing system[184]. BWSTT allows individuals with a mobility disability to practice walking in an upright position without the risk of falling [184]. A systematic review found that BWSTT significantly affected comfortable walking velocity, and treadmill training without support did not have a significant impact [188]. The review by Edwards and Pilutti [181] included eight studies involving BWSTT, four of which were level-one evidence-randomised controlled trials. The review reported mixed results from the included studies [181]. Some studies reported significant improvements in physical function, including walking endurance (n=3), walking speed (n=3), gait kinematics (n=2), balance (n=1), and agility (n=1). However, other studies reported non-significant improvements and no change in the same outcomes [181].

Despite the potential benefits of BWSTT, it is expensive, requires specialised personnel, and is often only available in specialised settings [181]. BWSTT is rarely available in community settings, and when it is, this is usually at a high cost to the user [184].

3.2.3.2.3 Recumbent Stepper Training

Recumbent stepper training (RST) allows patients to step against a graded resistive force from a supported seated position [184]. RST allows people with mobility disability to participate in full-body exercise in a safe and accessible manner [185]. Despite the potential benefit of RST, few studies have assessed its efficacy. The review by Edwards and Pilutti [181] found one study [185]. The study by Pilutti and colleagues aimed to determine the safety and participant-reported experience of RST in people with progressive MS with severe mobility impairment [185]. Overall, the study found RST to be safe and well-tolerated [185].

Compared with the FES and BWSTT, RST is cost-effective and straightforward to operate. RST could easily be implemented in the community or home setting [184]. The main disadvantage is that the stepping motion is less specific to ambulation than the FES and BWSTT [184].

3.2.3.3 Experiences of exercise for people with moderate-to-severe MS-related disability

A disability can negatively impact physical, psychological, and social health [189]. Physically individuals can experience secondary health issues, such as cardiovascular disease [189]. Psychologically, having a disability can cause mental health issues such as depression, anxiety, and feelings of isolation [189]. For PWMS specifically, they have the additional concern of the progression of disability over time, which may result in the future use of a wheelchair [190]. Previous studies have explored the perceptions of exercise for PWMS [191-193]. Barriers have included disease-specific obstacles (e.g., weakness, fatigue), lack of accessibility to facilities, lack of appropriate support, and low confidence in their capabilities.

To date, only a few qualitative studies have explored experiences, perceptions and preferences of exercise in those with more advanced MS. Learmonth et al. [194], and Silveira et al. [190] have both published qualitative studies exploring perceptions of physical activity in wheelchair users with MS. Both studies found that PWMS who use wheelchairs are interested in exercise programmes, but felt they lacked the opportunity and resources to engage. These highlight the lack of opportunity for people with high MS disability to be physically active.

3.3 Study aim

This study explored the topic of exercise with people with moderate-to-severe MS. By discussing participants' attitudes, preferences, and barriers to exercise and their experiences and needs, it is possible to develop interventions to allow this population to be physically active.

3.3.1 Aims

(1) To explore the views of people with moderate-to-severe MS-related disability (EDSS 6.0-8.0) regarding exercise.

(2) To discuss what type of exercise intervention may be feasible for people with higher levels of MS disability.

3.3.2 Objectives

(1) To explore the attitudes, barriers, and motivators regarding exercise using semi-structured interviews.

(2) Using semi-structured interviews, determine exercise preferences (type, frequency, duration, intensity, location).

3.4 Methodology

3.4.1 Study design

The study adopted a qualitative design involving semi-structured one-to-one telephone interviews to explore the design of a physical activity intervention for people with higher levels of MS disability. Ethical approval was granted by the NRES Committee South East Coast, Brighton and Sussex (Reference: 14/LO/1591).

Recruitment was conducted via neurological clinics at Sheffield Teaching Hospital NHS Foundation Trust. The neurological consultants and research nurses identified individuals who met the inclusion and exclusion criteria.

3.4.1.1 Inclusion criteria

(1) Males and females aged over 18 years of age

(2) Moderate to severe MS (determined by 6.0-7.0 on the EDSS)

3.4.1.2 Exclusion criteria

(1) Failure to meet the inclusion criteria

Participants were then provided a patient information sheet (Appendix A) and completed the permission to contact form. The PhD candidate conducted a brief telephone call to confirm eligibility, answer questions regarding the study, and schedule a date and time for the interview.

3.4.1.3 Participants

A total of 15 participants with moderate to severe MS were recruited to participate in the telephone interviews (9 female, 6 male). Two individuals had RRMS, and the remaining participants (n=13) had progressive forms of MS. Table 7 provides the participant demographics.

Table 7: Participant Demographics

ID	Gender	Age	Type of MS	EDSS	Years since diagnosis
01	Male	50	SPMS	6.0	15
02	Female	52	SPMS	7.5	16
03	Female	44	SPMS	6.5	10
04	Female	42	RRMS	6.0	9
05	Female	48	RRMS	6.5	13
06	Male	36	PPMS	6.5	2
07	Male	63	SPMS	6.5	28
08	Female	47	SPMS	6.5	13
09	Female	43	SPMS	6.0	10
10	Female	55	SPMS	7.0	20
11	Male	37	PPMS	6.5	2
12	Male	53	SPMS	7.0	13
13	Male	40	PPMS	7.5	4
14	Female	38	PPMS	6.5	2
15	Female	37	SPMS	6.5	3
		44(median)		6.5 (median)	10 (median)

EDSS= EXPANDED DISABILITY STATUS SCORE; SPMS= SECONDARY PROGRESSIVE MULTIPLE SCLEROSIS; RRMS= RELAPSING REMITTING MULTIPLE SCLEROSIS; PPMS= PRIMARY PROGRESSIVE MULTIPLE SCLEROSIS

3.4.1.4 Interviews

A guide was used during the telephone interviews (Appendix B) to ensure consistency across the interviews, but the semi-structured nature allowed each participant to raise important issues. The PhD candidate developed the guide with support from the research team. The guide focused on open-ended questions about living with MS, the experience of exercise, challenges/barriers, suitable activities, and expectations. The interview length ranged from 13 to 55 minutes. Interviews were conducted via telephone to make participation easy for people with higher MS disability. All conversations were digitally recorded and transcribed verbatim.

3.4.2 Data analysis

Data were analysed thematically using framework analysis (discussed in Chapter 1) [195]. This approach consists of five interconnected but distinct stages for analysis: familiarisation, identifying a thematic framework, indexing, charting, and mapping and interpretation [49]. The unique aspect of this methodology is the latter stage, where associations between themes are made and related to the research objectives. All interviews were coded using the NVivo qualitative data-indexing package (NVIVO 10), with the lead researcher (PhD candidate) identifying the initial thematic structure. A second researcher then independently reviewed the thematic framework to improve the reliability of the interpretation of the data. After 15 interviews, there was a consensus agreement between the study team that no new data emerged, and therefore data saturation was achieved.

Transcripts were coded primarily on a priori concepts guided by central questions. Concepts explored in the framework included a) understanding and experiences of exercise, b) challenges to exercising, and c) exercise options and preferences. Codes were then organised into themes that best described the perspective being explored. An example of the coding framework is presented in Appendix C.

3.5 Results

Results are displayed according to key themes and sub-themes derived via framework analysis[49]. I identified three main themes for PWMS. Specifically, 1) barriers to participating in exercise, 2) finding reasons to exercise, and 3) critical components required for exercise interventions in this population. These themes and their subthemes are described in Table 8. The themes presented illustrate the important overriding features of developing an exercise intervention in this population. Quotes are included to demonstrate the key themes. Figure 3 provides an overview of the findings from the qualitative data and provides the foundation for designing an exercise intervention for people with moderate to severe MS.

Table 8: Higher and lower order themes

Higher-order theme	**Lower-order theme**
Barriers to exercise	• Effects of MS on their ability to exercise • Fear of adverse effects of exercise • Limited accessibility to exercise opportunities
Finding reasons to exercise	• Maintain or improve functional ability • Improve quality of life
Critical components of an intervention	• Trained practitioners are essential • Exercise programmes need to be tailored to the individual • The pacing of the exercise programme is important • The frequency and duration of sessions must be realistic

3.5.1 Theme 1. Barriers to exercise

This theme characterised the current exercise behaviour of the participants. Participants identified several barriers to being physically active even though all participants understood that physical activity might be positive for their health.

3.5.1.1 Effects of MS limit their ability to exercise

Symptoms of MS were an internal barrier to being physically active. Participants had been active in the past but could not be active presently. Participants discussed their lack of ability to be physically active and not knowing what they would be able to do. The main effects of their condition were a high level of fatigue and mobility problems, which considerably impact an individual to be active safely and effectively.

"But I have quite a lot of fatigue now anyway, so, you know, I just have a sleep!"(P2)

"Probably the pain and the fatigue which is preventing me from doing things."(P4)

"In my head, I want to do all sorts of things, but realistically my body doesn't let me, you know do, do things."(P5)

3.5.1.2 Fear of adverse effects of exercise

Among the participants, 11 identified fear as a barrier. Participants commented on fear of worsening their condition and fear of doing too much.

"I just want to do something that I know wouldn't adversely knacker me up too much."(P8)

I think things like would I feel safe because I've had falls, and that's what always worries me, it worries me with, with walking that I'm going to fall over."(P12)

"Because there's always the worry that you're going to hurt, hurt yourself more."(P3)

3.5.1.3 Limited accessibility to exercise opportunities

Due to difficulties in travel for this patient group, an accessible location is essential. Although some participants liked the idea of getting out of the house, the most preferred location (n=10) to exercise was within their own homes. The home was preferred as it removed the stress and risk of travelling to and from a community location.

"The difficulty is getting there."(P2)

"Doing things in the comfort of your own home is a lot nicer than going to another hospital or anything like that because you go to that many."(P3)

"I've not bothered to go out because that always takes time and adds a risky journey."(P6)

"Most exercise stuff I'm thinking of I can do in the house, and I'd rather do that than have the added barrier of can I be bothered to get there?"(P11)

3.5.2 Theme 2. Reasons to exercise

The second higher-order theme identified what persons with moderate-severe MS hoped to achieve from participating in an exercise intervention. Participants discussed how they hoped to achieve physical and psychological improvements.

3.5.2.1 Maintain or improve functional ability

Participants anticipated that exercise would positively impact their daily lives. Ten interviewees stated a need to regain function and independence. Specific activities participants would like to improve included walking, balance and getting up from a chair.

"I just wish I could, I'd just love to be able to walk without my crutches and just walk normal."(P9)

"But to be able to keep going is the most important thing for me."(P15)

"To be able to function yeah, normally be able to walk down the street, stand up at the cooker for a long period of time, have enough strength to put bedding on the bed."(P14)

"I need to lose weight, if I have less weight, I'll have less balance problems."(P4)

"You want to get back to being as mobile and independent as you were."(P13)

"Not falling in public would be nice!"(P4)

3.5.2.2 Improve quality of life

Eight participants discussed how exercise could help them improve their quality of life through increased independence, improved outlook on life, and increased confidence.

"I'd hope to gain a bit more independence really, rather than having to have my husband do everything for me, which can get degrading at times."(P3)

"I would hope that I would start to feel - this will sound stupid - start to feel human again because I have the ability to use my body in a way that I've kind of opted out of."(P5)

"It's like you're independence and everything."(P14)

"Just more mobility and more outlook." (P15)

"You would gain more confidence in yourself."(P10

3.5.3 Theme 3. Design of the intervention

The following theme describes the critical factors required for an ideal exercise intervention for people with moderate-to-severe MS. The theme describes the detail of an intervention that participants feel is suitable, specifically who should deliver an intervention, how frequent the exercise sessions should be, the intensity of the sessions and how the intervention should be progressed.

3.5.3.1 Trained practitioners are essential

There was much discussion about who designs and delivers the exercise programmes. Thirteen participants stressed the need for practitioners to be experienced and knowledgeable in working with PWMS. It was perceived that trained practitioners could provide confidence that the patient's well-being was safeguarded. Six participants suggested physiotherapists as the ideal person to deliver the exercise intervention.

"I think physiotherapy really, a physiotherapist because they understand all the muscles and everything, how they work and everything, don't they?"(P1)

"A physio because they know what they're talking about and they know what kind of movements are possible with MS and which ones aren't, which ones are safe and which ones are dangerous and they're, they're medically trained."(P2)

"I probably wouldn't say an exercise specialist because they've not got the medical background, background of the MS. I think someone with a medical background."(P3)

"Yeah, just someone who knows what they're on about sort of thing."(P9)

"I would think appropriate experience and knowledge, somebody with knowledge of MS particularly."(P12)

"I think obviously you'd want somebody who was trained in exercise and stuff for people with MS because then they could give advice, I suppose, on things, you could do when they're not there."(P13)

3.5.3.2 Exercise programmes need to be tailored to the individual

Participants stressed the need for the intervention to be tailored to the individual, allowing for exercise tolerance to be built gradually and responsive to the variations in the condition. Participants felt that any intervention would need to be broad enough to encompass the variability of individual experiences.

"Well, it's the fact that we all were suffering from MS however it shows itself and everybody's got different problems."(P5)

"You don't want to get to the point where you knacker yourself so much that the next day your body is physically unable to then do the training again… the exercise or the physio, or whatever it is."(P6)

"Something I could go slowly at and find something that I am able to do"(P8)

3.5.3.3 The pacing of the exercise programme is important

The most discussed fear of exercising was the fear of doing too much and worsening their condition. Therefore, a slowly progressed physical activity programme was identified as the most desirable. Ten participants discussed how they would want to take exercise slowly or gave examples of when they had done too much and had a negative experience.

"Sometimes, I push myself too hard."(P12)

"You know, you push yourself, but don't push yourself so far that your body takes two days to recover!"(P6)

"It's just a case of not going too mad with yourself."(P1)

3.5.3.4 The frequency and duration of the sessions must be realistic

Participants varied in their views regarding the best frequency of exercise sessions, with suggestions ranging from one to three sessions per week. Most participants (n= 8) felt that two sessions per week would be realistic. A further three people suggested 1-2 sessions per week, and three suggested once per week. One participant suggested three sessions per week because that was what they had achieved prior to their MS.

"Just basically set a target of like three times a week, er, because that's what I used to do before, go three times a week" (P1)

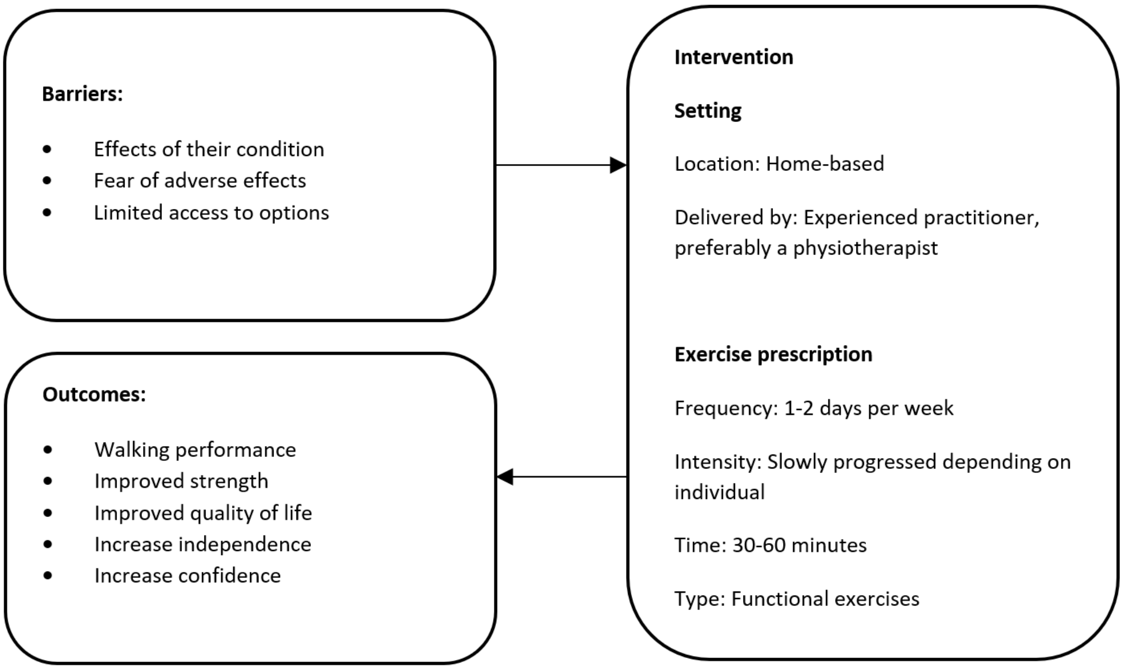
Participants suggested a range of times for the duration of the sessions. Five participants suggested one-hour person, which would allow for plenty of rest.

"But I would say, an hour, with gaps I should imagine, yeah, but building up to that." (P4)

Two participants suggested 30-minute sessions, and 15-20 minutes was suggested by two participants. Three participants discussed how the sessions would need to be flexible due to the variable nature of the condition.

"I think you'd, you'd do it, the say your first time and then you'll know your own self. I couldn't say to you now, because I don't know how I would feel that day or sort of thing, or how tired I felt, you know. Other days I might feel like I can do a little bit longer, but not the same the following day." (P9)

Figure 3: Foundations of an exercise intervention



3.6 Discussion

This study explored the views of people with moderate-to-severe MS-related disability regarding exercise and provided new insights into the preferences for an attainable exercise intervention for this population. Participants recognised the potential benefits of exercise for maintaining and improving function and increasing self-confidence and independence. Barriers to exercise included high fatigue levels, mobility problems, fear of worsening their condition, and accessibility to exercise options. This population's preferred exercise intervention characteristics were one to two 30-60 minute home-based exercise sessions per week, tailored to the individual, slowly paced, and led by an appropriately trained practitioner, preferably a physiotherapist. People with moderate to severe MS identified barriers to participating in exercise that included effects of the condition (fatigue, pain, functional limitations), fear associated with participation in exercise (safety, making their condition worse), and accessibility issues (transport, safety, lack of confidence). These results concur with previous research on barriers to exercise in PWMS [192,196]. The top three barriers for PWMS are (i) too tired, (ii) level of impairment and (iii) lack of time [197].

Participants in the study discussed the main reasons they would like to exercise. These reasons included physical motivators (e.g. improved functional ability, walking, improved strength and balance, reduced fatigue, and weight management) and psychosocial motivators (e.g. improved confidence and increased independence). These results highlight how complex the decision to take part in exercise is for this population. The decision to engage in exercise is not a one-off event; but rather a fluid process where the individual continually reassesses the decision considering new information and personal exercise experiences [198]. The key factor in bridging the intention-behaviour gap is applying behaviour change theory[199]. Behavioural science and applying behaviour change theories could provide the missing link in promoting exercise and physical activity participation in MS [200]. The existing research in this area has focused mainly on examining the application of the social cognitive theory [201] (SCT) for understanding exercise and physical activity in MS [200]. Other popular theories include the transtheoretical model (TTM) [202], the theory of planned behaviour (TPB)[203], and the self-determination theory (SDT) [204]. Another possible theory is the health action process approach [205], which includes constructs from SCT, TPB, and TTM to predict engagement in a health behaviour [206]. Behaviour change theories will be discussed in more detail in Chapter 5.

In addition to behaviour change theory, several essential components must be included for an exercise intervention to be successful. The participants discussed location as a barrier to exercise and suggested that exercising in their homes would be preferable. Home-based exercise interventions could minimise multiple sclerosis-related barriers to exercise [207]. Leisure facilities such as gyms and swimming pools often lack proper equipment for disabled people [208]. A home-based exercise intervention offers a cost-effective alternative to facility-based supervised exercise and reduces barriers to participation for people with moderate-to-severe MS[207]. Research suggests that unsupervised home-based exercise interventions with PWMS may be less effective than supervised home-based training [209], indicating that appropriate supervision is critical.

In the current study, improving or maintaining functional ability was cited as a positive reason to exercise, which supports previous research finding that PWMS are motivated by a desire to stay mobile [210]. Interventions that target a reduction of sedentary behaviour and increase light-to-moderate intensity exercise levels in the person's home may be appropriate [183] and feasible [166] in this population.

The results confirmed that despite an awareness of the potential benefits of exercise, participants do not know what exercise they should do, with fear of making their condition worse a barrier to engaging [198]. Participants in this study discussed the importance of a knowledgeable practitioner delivering the intervention. Previous qualitative research supports the importance of quality instructors [211]. Participants in the present study felt that a physiotherapist should lead an intervention. Physiotherapy is an accepted part of the multi-disciplinary approach to assisting PWMS [212]. Physiotherapists are well-positioned to play a central role in promoting exercise to PWMS[213]. Additionally, due to the level of impairment for individuals with EDSS ≥ 6.5, their goals will be to prevent functional decline [110], which is well suited to the skills of physiotherapists.

Participants discussed the need for programmes that are tailored and paced to their needs. Individualised programmes of exercise that account for physical limitations and the person's goals will minimise their perceived barriers [110]. Fatigue is one of the most common and devastating MS symptoms[214], and learning to pace themselves to avoid fatigue is a valued strategy for PWMS [192]. Exercise pacing aims to prevent over-exertion and avoid the detriment associated with fatigue-induced inactivity [215]. Additionally, participants suggested that the frequency of exercise sessions ranged from one to three sessions per week, with the majority saying that two sessions were the most realistic. In the review by Edwards and Pilutti [181], the frequency of sessions ranged from two to five, with the majority recommending between two and three sessions. The recommended frequency for people with mild-to-moderate MS-related disability is at least twice per week, dependent on the person's toleration [25].

3.6.1 Implications for the physical activity guidelines

Determining if the PAGs can aid people with severe MS to increase fitness and general health is critical. Unfortunately, the evidence for the benefits of exercise for people with severe disability is limited [145,160,181]. The potential benefits of exercise are essential, but there are considerable barriers to people with severe MS engaging in exercise. For example, the opportunities for people with more severe MS to be in the community are low. Future studies should explore the effectiveness of exercise in this population with interventions delivered in the community and underpinned by behaviour change theory. Additionally, people with more severe MS may require specific recommendations due to this population's different needs and preferences, as highlighted in this study. Future studies could explore a weekly cumulation of exercise rather than more prolonged bouts of activity.

3.6.2 Strengths and limitations of the study

Strengths of this study include the recruitment of both male and female participants and the range of years since the participant's diagnosis of MS. This allowed for the collection of experiences from a broad range of perspectives, for example, recently diagnosed and 20 years post-diagnosis. Future research should explore if there are differences in perspectives of exercise as time progresses from diagnosis.

Some limitations need to be taken into consideration when interpreting the results. The sampling strategy may have attracted individuals who have positive views on physical activity and exercise. Additionally, all participants were recruited from a single city; therefore, results may not represent PWMS from other areas. One interview was brief (13 minutes) and therefore questions the quality of the data from that individual. Additionally, all interviews were conducted on the telephone, which has been deemed an inferior qualitative data collection method[216]. Previous research has suggested that face-to-face interviews allow the interviewer to build rapport with interviewees [216]. Telephone interviews were chosen for this study due to cost-effectiveness and wanting the study to be accessible to the participants.

3.7 Conclusions

Overall, people with moderate-to-severe MS disability in this study supported the idea of exercise for managing their condition, with the most desired outcome being maintaining or improving functional capacity. The study findings support the need for embedding behaviour change theory in designing exercise interventions to help people with high MS-related disabilities overcome the barriers to exercise. Participants felt that an exercise intervention that can be carried out twice weekly, at home, with face-to-face support from a physiotherapist, would be safe and achievable. Nevertheless, an exercise intervention must reflect individual needs and variations in their ability and should be appropriately tailored, paced, and allow flexibility.

4 Exploring exercise intensity and the role of high-intensity interval training in people with MS

4.1 Overview

The exercise guidelines recommend low to moderate-intensity exercise for people with mild to moderate MS. The PAG for PWMS lacks depth and technical information on the actual exercise delivery and FITT principles. Chapter 4 will briefly overview the standardised exercise intensity terminology before discussing high-intensity interval training (HIIT) and its potential impact on PWMS, including symptom management. This chapter outlines the protocol for a non-randomised feasibility trial of HIIT for PWMS. The study results are presented and discussed in terms of the criteria for feasibility, alongside study limitations and recommendations for future research.

The research team comprised professionals from various disciplines, including exercise scientists, neurologists, and physiotherapists. Their collective expertise ensured a comprehensive approach to addressing the complex interactions between exercise intensity, MS pathophysiology, and the potential benefits of HIIT.

Previous studies have demonstrated the positive impact of exercise on various outcomes, such as physical functioning, fatigue, depression, and overall well-being. However, a knowledge gap remains regarding the optimal exercise intensity for individuals with MS, particularly concerning HIIT. Previous research has predominantly focused on moderate-intensity continuous training in MS populations. However, HIIT has gained attention in recent years due to its time efficiency and potential for greater physiological adaptations. However, its feasibility, safety, and effectiveness in individuals with MS are yet to be fully explored.

By conducting this feasibility study, I aimed to bridge this knowledge gap and provide insights into HIIT's potential benefits and safety considerations in people with MS. The findings from this study will contribute to a better understanding of exercise prescription for individuals with MS, with implications for exercise guidelines, rehabilitation programs, and future research endeavours.

The results of the high-intensity interval study have been published in the International Journal of Therapy and Rehabilitation. Parts of the results and data are repeated in this chapter, with additional context provided.

4.2 Introduction and rationale

The PAGs for MS have been developed for adults (aged 18-64 years) with mild to moderate MS-related disability and recommend moderate-intensity aerobic exercise and strength training [25,217]. More information is required on the precise exercise dose to achieve optimal improvements in function and management of the disease and, alternatively, if a dose is too high and may cause harm[218]. As discussed in Chapter 2, exercise dose is determined by three variables: duration, frequency, and intensity [168]. High-Intensity interval training (HIIT) is a mode of exercise that has grown in its application, including use with clinical populations[219]. HIIT is characterised by short bursts of vigorous effort followed by rest periods or low-intensity exercise[220]. HIIT is a highly variable exercise mode with sessions altered by intensity, duration, number of intervals, and duration of activity chosen during the rest period. HIIT is an effective alternative to traditional endurance training[221], producing similar results to moderate-intensity continuous exercise despite a substantially lower time commitment[220]. In healthy populations, HIIT has been shown to improve maximal oxygen uptake to a greater extent than continuous exercise[222] and is reported as more enjoyable[223].

4.2.1 Definitions of exercise intensity

Standard definitions of exercise intensity are essential for monitoring exercise, measuring health outcomes, and planning and guiding safe and effective exercise prescription[224]. Exercise intensity is commonly prescribed using objective and subjective measures. A task's metabolic equivalent (MET) is a physiological measure expressing the intensity of physical activities. One MET is the energy equivalent an individual expends while seated at rest, usually expressed as mLO_2 /kg/min [4]. All physical activities result in energy expenditure ranging from sedentary activities (e.g. sitting), which is referred to as 1 MET, to high-intensity exercise (over 9 METs) [224]. Generally, the higher the exercise intensity, the higher the physiologic or metabolic stress is placed on the body [224]. Definitions of exercise intensity are essential for professionals in various roles. For example, researchers can track developments over time and measure health outcomes, and practitioners can plan safe and effective exercise sessions and programmes. Table 9 shows the standardised exercise intensity terminology.

Table 9: Categories of exercise intensity, adapted from Norton et al. [224]

Intensity category	Objective measures	Subjective measures	Descriptive measures	Examples
Sedentary	< 1.6 METs < 40% HR_{max} < 20% HRR < 20% VO_{2max}	RPE < 8	• Activities that usually involve sitting or lying and that have little additional movement and low energy requirement	Sleeping, sitting, watching TV, riding in a car, standing in line
Light	1.6 < 3 METs 40 < 55% HR_{max} 20 < 40% HRR 20 < 40% VO_{2max}	RPE 8-10	• An aerobic activity that does not cause a noticeable change in breathing rate • An intensity that can be sustained for at least 60 minutes	Washing dishes, hanging washing, playing darts
Moderate	3 < 6 METs 55 < 70% HR_{max} 40 < 60% HRR 40 < 60% VO_{2max}	RPE 11-13	• An aerobic activity that can be conducted whilst maintaining a conversation uninterrupted. • An intensity that may last between 30 and 60 minutes.	Mopping/vacuuming, mowing the lawn, walking, gentle swimming, social tennis, golf
Vigorous	6 < 9 METS 70 < 90% HR_{max} 60 < 85% HRR 60 < 85% VO_{2max}	RPE 14-16	• An Aerobic activity in which a conversation generally cannot be maintained uninterrupted. • An intensity that may last up to 30 minutes.	Jogging, cycling, aerobics, competitive tennis
High	≥ 9 METs ≥ 90% HR_{max} ≥85% HRR ≥ 85% VO_{2max}	RPE ≥ 17	• An intensity that generally cannot be sustained for longer than about 10 minutes.	Stationary cycling at 200W, stationary cycling at 200W

Relative intensity measures = % HRmax (maximum heart rate); % HRR (heart rate reserve = HRmax - resting HR) and % VO2max (maximal oxygen uptake) [224]; Subjective intensity measures = Borg's RPE scale range 6 - 20 [224]

4.2.2 HIIT for people with MS

HIIT has the potential as a training mode for PWMS, but the research evidence is developing in this area[225]. It is, therefore, not included in the exercise prescription recommendations for PWMS. Initially, studies were conducted in animal models [225]. Experimental autoimmune encephalomyelitis (EAE) is an animal model useful for studying disease pathogenesis and potential therapeutic interventions [226]. EAE exhibits the characteristics associated with MS, including CNS inflammatory infiltrates, demyelination, and axonal damage [227]. Research has shown that high-intensity running exercise can reduce muscle fibre atrophy in EAE rats, compared to no impact on muscle atrophy in different exercise intensities[225].

Additionally, research has been conducted to investigate the effects of exercise on brain health [228]. Brain-derived neurotrophic factor (BDNF) is a mechanism by which exercise may help brain health [228]. BDNF is a neurotrophin that regulates CNS functions such as neurogenesis, neuroprotection, neuro-regulation, and cell survival [228]. Acute exercise training results in increased expression of BDNF in the hippocampus of rodents [226,228].

High exercise intensity can determine the impact of training on the course of EAE [225]. This impact has led to further research investigating this hypothesis in MS, with promising results. A systematic review recommends HIIT as a possible effective intervention for PWMS [229], concluding that HIIT is safe and effective at improving fitness [229]. While these data are encouraging, the evidence of the benefits of HIIT for PWMS is in its infancy, and further research is needed to confirm whether PWMS enjoy HIIT and feel it is tolerable. Given the nature of MS, it is crucial to consider factors such as fatigue, increased temperature, and exacerbation of symptoms. Understanding participants' experiences and perspectives of engaging with programs will inform future interventions and healthcare strategies [192].

4.3 Study aim

This study aimed to evaluate the feasibility of delivering HIIT to people with low MS-related disability.

4.3.1 Objectives

(1) To investigate the feasibility of carrying out HIIT twice per week for six weeks

(2) The aspects of feasibility measured were acceptability (participant experiences, attendance at exercise sessions, compliance with the HIIT protocol, and drop-out and safety (number of adverse events).

(3) To discuss the experiences of people with low MS disability following a HIIT intervention.

(4) To test the impact of HIIT on the fitness levels of people with low MS disability.

4.4 Methodology

4.4.1 Study design

Methods are adapted from Humphreys et al. [217]

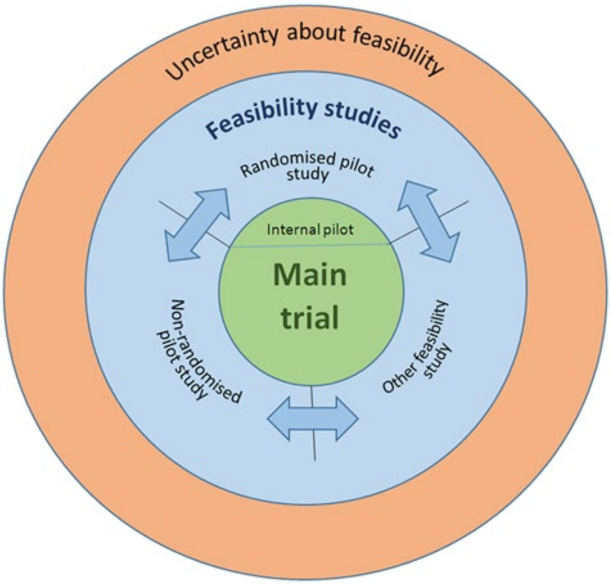
4.4.1.1 Design and ethical approval

This study was a 6-week single group, non-randomised, feasibility study. A mixed-methods approach was used to determine feasibility and acceptability, whereby quantitative and qualitative data were collected and analysed. The research team conducted the study at Sheffield Hallam University, UK. NHS Ethical approval was obtained from the National Research Ethics Service Committee Yorkshire and the Humber (REF 15/YH/0441).

4.4.1.2 Pilot and Feasibility studies

Pilot and feasibility studies play an essential role in health research[230] by providing evidence of whether research protocols are appropriate and warnings about whether a large trial could fail[231]. The value of preliminary work is recognised in the extant literature [232,233], and researchers are encouraged to publish pilot work before a main trial [234]. One issue, however, in the growing number of studies described as 'pilot' or 'feasibility' studies is that authors label a study a ‘pilot’ or ‘feasibility’ to excuse a small sample but still conduct a study with treatment efficacy as the primary objective[234]. There have been several attempts to provide definitions for the terms pilot and feasibility to address this[232-235]. In 2016, Eldridge and colleagues [233] developed a conceptual framework for defining a pilot and feasibility study (Figure 4). They decided that feasibility is the overarching concept for studies assessing whether a future trial is worthwhile [233]. Three distinct trial types fit under the umbrella of feasibility study: a randomised pilot study, a non-randomised pilot study, and feasibility studies that are not pilot studies (other feasibility studies). Therefore, a feasibility study can be used to determine whether a future study can be done. A pilot is a subset of feasibility that resembles the main trial but aims to measure the feasibility rather than the effectiveness of a trial [233,236].

Figure 4: Pilot and feasibility conceptual framework



There are four reasons for conducting a feasibility study[232]:

1. To inform process (e.g., the feasibility of recruitment, retention, intervention adherence)
2. To understand resource requirements (e.g., time and budget issues)
3. To inform management (e.g., personal challenges, data collection, or organisation)
4. To advance scientific enquiry (e.g., intervention safety, appropriate dose, potential treatment effect)

Before starting a feasibility or pilot study, it is vital that a criterion for feasibility is agreed upon and that the results do not focus on intervention efficacy outcomes [232]. The study discussed in this chapter investigated reasons one (to inform process) and four (to advance scientific enquiry).

4.4.1.3 Participants and Recruitment

Recruitment was conducted via neurological clinics at Sheffield Teaching Hospital NHS Foundation Trust. The neurological consultants and research nurses identified individuals who met the inclusion and exclusion criteria.

4.4.1.4 Inclusion criteria

1. Males and females aged between 18 and 65 years of age
2. Mild MS (measured using the PDDS)
3. Clinical diagnosis of MS for more than three months
4. Have not had more than one relapse in the previous year

4.4.1.5 Exclusion criteria

1. Failure to meet the inclusion criteria
2. Have comorbid condition(s) or injury that impairs their ability to exercise

To determine the disability level of the participants, the Patient Determined Disease Steps (PDDS) [180] measure was used (Appendix D). The PDDS is a short, simple questionnaire that strongly correlates with the EDSS [237], a clinician-reported measure of disability[238]. The criterion for mild multiple sclerosis was 0–1 (mild disability).

The PhD candidate aimed to recruit 10 PWMS. This was due to limited funding. However, the research team felt it would be a sufficient sample to gather qualitative experiences of the intervention. Participants were then provided with a patient information sheet and completed the permission to contact form (Appendix E). The PhD candidate conducted a brief telephone call to confirm eligibility, answer questions regarding the study, and schedule an initial meeting. Participants were introduced to the study laboratory at the initial meeting and taken through the study protocol. Informed consent was taken at the end of this meeting. Recruitment closed once ten eligible PWMS had consented to participate in the study. One person dropped out of the study. Therefore, the research team recruited one extra participant.

People with mild MS-related disability were sampled, as HIIT is not part of the recommended exercise prescription guidelines for PWMS [25,217]. We, therefore, felt it was essential to determine the acceptability of HIIT initially in people with mild disability. Additionally, early exercise initiation in the disease course has been identified as a focus area in research for PWMS [239]. Riemenschneider and colleagues state that exercise is often initiated at a late disease stage, and initiating exercise earlier may have neuroprotective and disease-modifying effects [217,239].

4.4.1.6 Baseline Assessment

To establish cardio-respiratory fitness, participants performed a VO_{2peak} test on a cycle ergometer under the supervision of the PhD candidate. VO_{2peak} was used because symptoms of MS can affect a person's ability to achieve a true VO_{2max} [240]. The lead researcher (PhD candidate) measured the participant's height and weight before the fitness test. The gas exchange measurement was conducted breath-by-breath using telemetric spirometry (Ultima, MedGraphics, St Paul, MA, USA); heart rate was measured by Polar system. The exercise test began with pedalling at 60-65 revolutions per minute (rpm) with the power output set to 30 watts. After the first four minutes, the power output increased by 15 watts every 2 minutes. The test was conducted to volitional exhaustion. Heart rate and rate of perceived exertion (RPE) were collected at the end of each minute and the highest VO_2 (ml/kg/min) observed before reaching volitional exhaustion determined VO_{2peak}. This test protocol has been used previously in people with mild MS [241].

Three questionnaires were administered to the participants to determine the impact of the exercise interventions on physical activity level (Godin Leisure Time Questionnaire [242]), fatigue (modified fatigue impact scale [243]), and health perception (MSQoL [244]). The Godin Leisure Time Questionnaire (GLTEQ)[242] is a self-administered two-item measure of usual physical activity with no specified time component [245]. There is evidence that the GLTEQ is a valid measure for the physical activity levels of PWMS [246]. The modified fatigue impact scale (MFIS) is a shortened version of the original 40-item Fatigue Impact Scale [243]. The MFIS has good psychometric properties for PWMS and correlates well with other fatigue measures, such as the Fatigue Severity Scale [247]. The MSQOL-54 includes both generic and MS-specific quality of life question [248]. It has been shown to have high test-retest reliability and construct validity [249].

4.4.1.7 Intervention protocol

Participants attended two sessions per week for the 6-week intervention. The rationale for using a six-week high-intensity intervention for people with MS is based on resources (e.g., funding) and previous research [229]. Campbell and colleagues [229], stated that HIIT interventions ranged from 3-to-12 weeks. The PhD candidate, therefore, decided that a six-week program provides enough time for participants to experience the HIIT intervention but would be short enough to be manageable and less intimidating for those who may be new to exercise or have concerns about their ability to participate in an intensive program.

Traditional HIIT training involves repeated 'all-out' maximal effort (the Wingate test). This type of training is highly demanding and thus may not be safe or practical for some individuals [250]. The study followed a protocol adapted from previous research[251]. Hood and colleagues (2011) reported that all-out intervals (repeated Wingate tests) were not safe, practical, or well-tolerated and instead suggested intervals be longer in duration (60 seconds) with active rest [251]. The protocol has been used in clinical populations such as type 2 diabetes[251] and stroke rehabilitation[252].

Each session consisted of 6-to-10 sets of 60 seconds high-intensity intervals interspersed with 120 seconds of recovery. The number of repetitions increased each week, starting at six until the participants could complete ten repetitions per session. The workload during each interval was set at 80-90% of peak power achieved during the VO_{2peak} test. This was predicted to elicit 85-95% of the participant's maximum heart rate. After each interval, the PhD candidate collected the participant's heart rate and RPE. After each session, the PhD candidate completed a session feedback form (Appendix F). At the start of the next session, the feedback form was again used to record any issues following the previous session. Events included any exacerbation of multiple sclerosis symptoms, such as fatigue, or serious adverse events, such as hospitalisation.

4.4.2 Feasibility criteria

The attrition rate and semi-structured interviews assessed feasibility in terms of acceptability. The attrition rate was defined as any discontinuation of the intervention or loss to follow-up. Attendance at the exercise sessions and compliance with the prescribed intensity was also measured. Compliance with the protocol was defined as; the average heart rate of the high-intensity intervals being between 85-95% of heart rate maximum.

4.4.2.1 Acceptability

Semi-structured qualitative interviews were used to explore the acceptability of intervention through participant's perceptions and experiences. At the end of the intervention, each participant was interviewed. Interviews were conducted by the lead researcher (PhD candidate), who is experienced in qualitative research. A semi-structured interview schedule was used to ensure consistency across interviews. The interview topics and example questions are provided in Table 10. Interviews were conducted over the telephone and recorded using a digital device. The interview length ranged from 14 to 34 minutes, and the mean interview duration was 22.5 minutes.

Table 10: Interview topics and example questions

Topic	Example question
Previous experiences of exercise	What are your previous experiences of exercise?
Expectations of HIIT	What made you sign up for the study? How did you expect your body to react?
Delivery of the HIIT sessions	How did you find the exercise sessions? How did you feel after each session? How did you feel during the session?
Impact of the HIIT sessions	How did the HIIT sessions impact you? Would you consider this type of exercise in the future?

4.4.2.2 Safety

Participant safety was assessed by the number of events occurring during the exercise sessions. An adverse event can be serious or non-serious [253]. A serious adverse event is defined as an event that leads to a serious risk of deterioration in health, hospitalisation, or death. Other reported adverse events such as pain, fatigue and a fall were defined as non-serious [253]. As previously discussed, the PhD candidate monitored participants throughout the exercise sessions and completed a session feedback form. To determine whether the intervention was safe any adverse events were discussed with the study clinical neurologist to understand if the event was due to the exercise protocol.

4.4.2.3 Estimation of intervention effect (Secondary outcome measures)

Changes to cardio-respiratory fitness were measured using the VO_{2peak} cycle ergometer test. Fatigue and general quality of life questions were used to measure changes to the impact of MS on the patient. Outcomes were assessed at two-time points: at baseline (week 1) and the follow-up assessment (week 8) after completion of the 6-week intervention (weeks 2-7).

4.5 Approach to data analysis

4.5.1 Qualitative analysis

Each of the ten interviews was transcribed verbatim. The data were analysed using framework analysis [254], previously discussed in Chapter 1. Framework analysis involves several interrelated but distinct stages [49]. This methodology is increasingly used in health research, is considered straightforward, and enables the researcher to transparently link results and conclusions back to the original data [255]. The transcripts were read before coding, indexing, and charting to create an initial thematic framework with subthemes. The themes from the transcripts were clustered around the participant's experiences before and after the intervention. An example of the coding framework is provided in Appendix G.

4.5.2 Quantitative Analysis

Statistical analysis was performed using SPSS (version 24). Based on the study's feasibility design with a small sample size and no comparison arm, statistical comparisons of effectiveness would not be appropriate. As a result, inferential statistics were not performed. Only descriptive statistics are presented (means, standard deviations, and mean change with the corresponding 95% confidence intervals (95% CI)). Data for the participant who withdrew were removed from the analysis.

4.6 Results

Results are adapted from Humphreys et al. [217]

4.6.1 Participants

In total, eleven participants consented to the study and completed baseline measures. The descriptive characteristics of the 11 participants (10 female and 1 male) are summarised in Table 11.

Table 11: Descriptive characteristics at baseline

ID	Gender	Age	MS Duration (years)	PDDS	Height (cm)	Body weight (kg)	V02peak (ml/kg/min)
01	Female	28	2	1	166	61	26.2
02	Female	27	1	1	170	107	20.6
03	Female	50	5	1	159	54	25.1
04	Female	37	3	1	169	60	29.1
05	Female	45	4	1	172	63	14.7
06	Male	36	2	1	181	117	20.3
07	Female	34	2	1	157	74	15.2
08	Female	31	1	1	158	94	8.3
09	Female	37	3	1	156	78	13.6
10	Female	43	6	1	164	60	31.4
11	Female	45	2	1	164	75	16.7
Mean		38 (± 7.1)	3 years (±1.6)	1	165 (±7.6)	77 (±20.9)	20.1 (±7.2)

PDDS= PATIENT DETERMINED DISEASE STEPS; MS= MULTIPLE SCLEROSIS; CM= CENTIMETRES; KG= KILOGRAM; VO2PEAK (PEAK OXYGEN UPTAKE)

4.6.2 Acceptability

4.6.2.1 Participant perspectives

The qualitative findings are presented according to higher-order themes and lower-order themes, in line with the framework analysis technique[254]. The main themes centred on the participants' experiences before, during and after the intervention. These themes contextualise the experiences and perspectives of the participants in the study (Table 12). Direct quotes, with reference to participant number, illustrate the themes.

Table 12: Higher and lower order themes

Higher-order theme	Lower-order theme
Feelings before the trial	Participants' concerns about high-intensity exercise Comments from friends and family Their motivation for taking part
Positive impact of the HIIT intervention	Increased energy levels Psychological improvements
Negative impact of the HIIT intervention	Negative impact on symptoms The dose of exercise The mode of exercise

4.6.2.2 High order theme 1: Feelings before the trial

Before commencing the study, participants had some doubts about taking part. These doubts came from their low confidence in their ability to complete high-intensity exercise and from the opinions of their family and friends.

4.6.2.2.1 The participant's concerns about high-intensity exercise

Participants discussed having concerns about how their bodies would react with the high-intensity sessions.

> *"I fully expected to feel awful and tired, and achy and that I would hate it, and to be totally honest I didn't think I'd be able to do it. So, I kept having this earwig going you're not going to be able to do it, you're going to hurt yourself, this is a bad idea." (P2)*
>
> *"I was thinking, you know, kind of maybe I'm not up to this." (P3)*
>
> *"When I started this study, I did not feel as though I had the energy levels required for strenuous or even moderate levels of exercise." (P6)*

4.6.2.2.2 Comments from friends and family

Some participants discussed that friends and family also have concerns about them completing the exercise sessions.

> *"My mum and dad are very protective. So, they kept saying oh don't overdo it, you'll end up hurting yourself." (P2)*
>
> *"My friends were concerned. My parents were uneasy about it and thought I should be taking it easy and weren't convinced it was a good idea." (P4)*
>
> *"My friends were worried I was doing too much." (P11)*

Others reported having positive encouragement from friends and family, usually from a physically active person.

> *"A couple of friends have bikes and they say you should come with us, trying to get me to go out." (P1)*
>
> *"My husband was supportive and keen for me to do it and thought I would enjoy it." (P4)*

4.6.2.2.3 Participant motivation for taking part

Despite the concerns, participants signed up for the study and reported several of different reasons for doing so. These included; the opportunity to improve health, finding an alternative to pharmacological treatment and because the consultant recommended it.

> *"It's not like you are pumping yourself full of drugs. It's not drugs, it's something completely natural." (P1)*
>
> *"I just wanted to get fit again, to be honest." (P3)*
>
> *"I just wanted to feel fitter. So it was an opportunity to actually do something in a controlled environment." (P11)*
>
> *"The consultant recommended it so I said yes." (P9)*
>
> *"Well it's just somebody telling you to do exercise that's got a background in MS." (P5)*
>
> *"I think you always put your trust in the people who are supposed to know more than you. So if he [the neurological consultant] recommended it regardless of my personal view on something I think I'd probably give it a crack." (P2)*

4.6.2.3 Higher order theme 2: The positive impact of the high-intensity interval training intervention

Participants reported positive and negative impacts from engaging in the study, including increased energy levels and psychological improvements.

4.6.2.3.1 Increased energy levels

Participants discussed how the HIIT intervention improved their energy and perceived levels of fatigue:

> *"I'm like I'm awake, I'm not tired, you know. So, it's totally overthrown my fatigue and it feels awesome." (P2)*
>
> *"I have found that as my time on this study has progressed that my energy levels have increased and that I have been more alert and lively in the workplace and particularly at evenings and weekends whereby I can now go on walks with the family." (P6)*

4.6.2.3.2 Psychological improvements

Some participants discussed how taking part in the HIIT sessions improved their ability to cope and accomplish something they did not believe they could do and provided a sense of achievement.

"I feel much better and able to cope with everything." (P11)

"It was enlightening. I didn't think I'd be able to do that." (P1)

"Really good, really positive. I come out afterwards and go oh guess what I did. I'm like a child." (P2)

"It gave me confidence to do things like go jogging with one of the mums from school. I previously thought I'm not fit enough etc. And I just thought well I would do it and it was fine." (P4)

"I actually felt quite euphoric and quite keyed up afterwards." (P4)

"The fact that they were quite quick you just got it done and then you felt that euphoria afterwards." (P6)

4.6.2.4 Higher order theme 3: Negative impact of the high-intensity interval training intervention

The negative effects focused on the participant's experiences during the intervention. Negative experiences can be broken down into impact on symptoms, the dose of exercise, and the mode of exercise.

4.6.2.4.1 Negative impact on symptoms

Despite some participants reporting a positive impact on fatigue and energy levels, participants did experience some exacerbation of symptoms. Participants discussed feeling nauseous during sessions and feeling wiped out.

"I sometimes felt sick. A couple of times I went deaf. That was the only thing that worried me really because that is a symptom I get. One of the times it lasted all day." (P1)

"I had some muscle aching but also generally wiped out." (P11)

"Yes, there was one session towards the end when I went home, I couldn't get out of the car to go to the supermarket so I had to go home." (P11)

4.6.2.4.2 The dose of exercise

Participants felt that as the sessions progressed, they became too long. By the end of the intervention, participants were completing ten HIIT repetitions. One participant felt that eight intervals were the ideal number, but ten was too much.

"It started to get quite tedious. My optimum number was 8 [intervals]. 8 felt like a challenge and 10 felt hideous. I left feeling slightly deflated that it had been so hideous." (P4)

4.6.2.4.3 The mode of exercise

Some participants would have preferred other modes of exercise than the exercise bike. Participants discussed how uncomfortable the bike was, and this may have impacted their enjoyment of the sessions.

"I do wish bikes were more comfy. I literally had a sore bum for the first couple of weeks." (P2)

"The bike was horrible. I hated the bike." (P9)

4.6.2.5 Retention

One person dropped out of the study because of time constraints and the distance they had to travel. The participant completed baseline measures and one week of exercise sessions (n=2 sessions). The participant's exercise session data was not included in the analysis. The remaining 10 participants completed all phases of the study.

4.6.2.6 Attendance at exercise sessions and compliance with the training protocol

Through the 6-week intervention, there was a maximum of 12 sessions for each participant. In total, there were 132 sessions available during the study. Participants attended 115 sessions (87%). For the HIIT sessions, there was a mean attendance of 10.5(± 3) sessions. Reasons for not attending exercise sessions included: illness, work commitments, and injury. One person dropped out of the study after attending two exercise sessions. Participants were encouraged to reach 85–95% HRmax during each interval. Of the 115 attended sessions, 106 (92%) achieved an 85–95% average HRmax for the intervals. The mean rate of perceived exertion for the intervals was 16.5 (± 1.2), which corresponds to hard/very hard on the rate of perceived exertion scale.

4.6.3 Safety

There were 27 events recorded during the study. One event was deemed an adverse event. A participant suffered glute and lower back pain while on the bike, which resulted in the termination of the immediate exercise session and missing two further sessions. Eight participants experienced an exacerbation of symptoms during exercise sessions. Table 13 shows the category of adverse event and the number of sessions it occurred. Exacerbation of symptoms included tingling in extremities, fatigue, blurred vision, partial deafness, and weakness down one side. The participants previously experienced exacerbated symptoms; no new symptoms were discovered. All exacerbated symptoms returned to normal shortly after the exercise sessions.

Table 13: Adverse event categories and frequency

Adverse event	Frequency (number of sessions)
Pain	5
Nausea	5
Deafness	2
Tingling feeling in extremities	8
Blurred vision	2
Weakness in legs	4
Fatigue	1
Total	27

4.6.4 Estimating intervention effect

Outcome scores for all outcome measures are shown in Table 14. These include data for 10 participants who completed the intervention. As the study was not designed to measure intervention effects, only descriptive statistics are presented. Mean changes for all outcomes showed positive improvements. Although some individual components of quality of life saw decreases, overall quality of life, mental health, and physical health showed positive mean change.

Table 14: Differences in secondary outcomes

Characteristics	**Baseline**		**Follow up**		**Mean difference (95% CI)**
	Mean (SD)	**N**	**Mean (SD)**	**N**	
Physical activity (GLTEQ)					
GLTEQ score	45.8 (24.6)	10	55.5 (21.9)	10	9.7 (-12.2 to 31.6)
Fatigue (MFIS)					
Physical	14 (7.2)	10	10.6 (7.8)	10	-3.4 (-10.5 to 3.7)
Cognitive	12.1 (8)	10	11.6 (7.4)	10	-0.5 (7.7 to 6.7)
Psychosocial	1.6 (1.5)	10	1.6 (1.6)	10	0 (-1.5 to 1.5)
Total MFIS	27.7 (15.2)	10	23.8 (15.4)	10	-3.9 (-18.3 to 10.5)
MSQoL-54					
Physical health	84.5(14.6)	10	83.5 (14.9)	10	-1.0 (14.9 to 12.9)
Role limit physical	62.5 (44.1)	10	57.5 (47.2)	10	-5.0 (-47.9 to 37.9)
Role limit emotional	90 (31.6)	10	93 (21.1)	10	3 (22.2 to 28.2)
Pain	71.8 (5.8)	10	83.7 (15.8)	10	11.9 (0.7 to 23.1)
Emotional wellbeing	79.2 (10.8)	10	82.4 (10.2)	10	3.2 (-6.7 to 13.1)
Energy	44(21.4)	10	53.4 (20.3)	10	9.4 (-10.2 to 28.9)
Health perceptions	47.5 (21.5)	10	50.5 (24.7)	10	3.0 (-18.8 to 24.8)
Social functions	88.3 (13.7)	10	85.8 (13.1)	10	-2.5 (-15.1 to 10.1)
Cognitive function	75.2 (22.2)	10	73 (22.4)	10	-2.2 (-23.2 to 18.8)
Health distress	76.5 (14.2)	10	78 (17.2)	10	1.5 (-13.3 to 16.3)
Sexual function	73.3 (34.2)	10	77.5 (36.4)	10	4.2 (-29.0 to 37.4)
Change in health	55 (32.9)	10	62.5 (24.3)	10	7.5 (-19.7 to 34.7)
Sex satisfaction	61.1(30.9)	9	55.6 (27.3)	9	-5.5 (-34.6 to 23.6)
Overall quality of life	72.5 (13.5)	10	75.7 (11.7)	10	3.2 (-8.7 to 15.1)
Physical health component	120.8 (32.5)	10	126.2 (37.4)	10	5.8 (-27.1 to 38.7)
Mental Health component	79.6 (13.2)	10	81.8 (9.9)	10	2.2 (-8.8 to 13.2)
Fitness					
VO2 Max (ml/kg/min)	23.5 (9.2)	10	25.8 (9.4)	10	2.3 (-6.4 to 11.0)

GLTEQ= Godin Leisure Time; MFIS= modified fatigue impact scale; SD= standard deviation; CI= confidence interval; MSQoL= MS Quality of Life; VO2max = maximal oxygen uptake

4.7 Discussion

The discussion is adapted from Humphreys et al. [217]

This study aimed to evaluate the feasibility of delivering HIIT to people with low MS-related disability. The participant perspectives provide insights into patients' experiences following a HIIT intervention and add to the evidence from previous research [229].

Participants reported apprehension and fear before participating in the study, mostly related to their perceived ability to undertake the exercise prescription. Fear and apprehension is the most common barrier to exercise reported in PWMS [256], which is supported by our finding from the HIIT intervention. Friends and family who stressed concern for the participant's health reinforced apprehension in some participants. This underlines the critical role that family can play in encouraging or preventing people with multiple sclerosis from exercising[27] and the importance of their inclusion in future interventions. Despite their apprehension, the participants still consented to participate in the study [256]. One key reason for participating was because their consultant recommended the study. HCPs significantly influence the health behaviours of patients[257], which can shape a patient's behavioural intention [258].

As the intervention progressed, participants discussed strong feelings of achievement after completing the sessions. Proving to themselves that they could do the exercise had positive effects on their confidence. Although it was not measured in this study, the increased confidence to complete the exercise suggests participants had increased exercise self-efficacy. Self-efficacy is a person's belief in their ability to perform a given behaviour successfully[259]. Research has documented the linear relationship between self-efficacy and objective physical activity in PWMS [260]. Recent research also found that anxiety significantly moderated this association[261]. Self-efficacy is a central construct of the Social-Cognitive Theory (SCT)[262], one of the most applied theoretical frameworks for understanding and optimising physical activity behaviour[263]. Drawing from constructs of the SCT (behavioural capability, observational learning, expectations, self-efficacy)[262], the HIIT intervention appeared to improve the participant's beliefs in their capabilities and the consequences of the behaviour (expectations). When a person has completed a task, they develop knowledge of one's ability to complete similar tasks in the future[264]. Participants' condition-related symptoms (e.g., fatigue) or perceived barriers (fear of exacerbation of symptoms) can affect their perceived capabilities and expectations of exercise behaviour, reducing self-efficacy. Data here suggests that building SCT constructs (behavioural capability, observational learning, expectations, self-efficacy) into the design of HIIT exercise interventions for PWMS might help engage and sustain their participation. However, this would need to be explicitly explored in future research.

Pre-intervention apprehension reported by participants was not unfounded. Six out of the ten participants reported feeling nauseous, exhausted, or uncomfortable during a session, none of which resulted in the termination of the session. In healthy populations, sprint intervals have been shown to cause feelings of exhaustion and severe fatigue lasting 10-to-20 minutes[265]. Eight participants reported incidents of mild symptom exacerbation during the sessions. Symptom exacerbations included tingling in extremities, blurred vision, partial deafness, and weakness down one side. These exacerbations highlight the immediate effects exercise can have on MS symptoms. Approximately 60-80% of PWMS experience a reversible occurrence of symptoms in situations that increase their body temperature (Uhthoff Phenomenon), for example, vigorous exercise[266]. One previous study examined the safety of a single exercise session in 34 persons with MS and observed temporary sensory changes (e.g., numbness, pain, tingling) [267]. Over 40% of participants experienced a temporary increase in sensory symptoms, 44% experienced an increase in the intensity of sensory symptoms, and 29% experienced an increase in both number and intensity immediately postexercise [267]. However, these changes did not have any negative effects on fatigue or function [267].

Due to the expected temporary change of symptoms during exercise these events were not deemed an adverse event. Therefore the present study reported two adverse events, a muscle strain during an exercise session and an acute episode of fatigue. The participants rested and were able to continue the study. Previous HIIT studies in PWMS have also shown fewer adverse events. According to Campbell and colleagues[229], only one of the seven studies in their review reported any adverse events. From the study in question, seven participants experienced adverse events in the high-intensity groups compared to none in the lower-intensity continuous exercise group[218]. None of the studies included in the review by Campbell and colleagues [229] defined an adverse event. This makes comparing the number of events with the present study difficult. For this study, we did not include a threshold at which exercise would be defined as safe or unsafe but reviewed each event to determine if the protocol needed to change.

Additionally, Collett and colleagues [218] as with the present study, were specifically exploring safe, effective exercise intensity. In future studies, it is essential to ensure the participants understand the immediate effects of exercise [256]. Symptom exacerbation should also be documented throughout any research study [256].

The attendance at the exercise sessions was high (87%), which is similar to previous research on other conditions, such as cardiometabolic disease (82-85%) [266] and type 2 diabetes

(90%) [268]. Participants also adhered to the high-intensity protocol with 92% compliance. This level of compliance suggests that participants were undeterred by the symptom exacerbation they experienced during the intervention. Several participants discussed having positive feelings after completing the sessions. Overall, exercise capacity improved in the participants over the six-week HIIT intervention. This increase in fitness is consistent with other conditions such as diabetes, stable angina, and heart failure [269]. Participants also showed improvements in physical health, mental health, and overall quality of life, supporting previous research findings[270]. Although, as previously stated, the study was not designed to measure intervention effects.

Participants discussed the positive and negative experiences of participating in the intervention, highlighting the potent nature of HIIT [265]. Participants reported improved perceptions of fatigue, consistent with previous research [192]. Some participants discussed how the intervention had changed their energy levels, resulting in them being able to exercise more, socialise, and spend time with family, which previously had been restricted. However, participants discussed how uncomfortable they felt during sessions and how tedious they became. Despite the positive experiences, the negative perspectives suggest that the sessions were unpleasant or not enjoyable. Enjoyment is a key predictor of long-term exercise adherence[271]. Enjoyment is a crucial predictor of long-term exercise adherence [272]. Research investigating the effect and enjoyment of HIIT found that HIIT was rated as less pleasant and less enjoyable than moderate-intensity exercise [273]. These results question the long-term appeal and sustainability of HIIT.

Additionally, the present study was conducted in a laboratory setting, supervised by an experienced research team (including the PhD candidate). The likelihood of a participant independently completing HIIT at the correct intensity is low, especially if the sessions are not enjoyable [271]. These results question the long-term appeal of HIIT [274]. The benefit of HIIT is the time-efficient improvements in fitness [275]. HIIT could be used as a short-term option to boost an individual's fitness levels, but alterations are needed to make it more appealing long term.

4.7.1 Strengths and limitations

This study was a single-group pilot study aiming to determine HIIT's potential feasibility, acceptability, and safety for PWMS. Strengths of the study include the addition of perceptions of HIIT from the participants. Using qualitative interviews produced insight into the participant's experiences of the intervention, which enabled a more in-depth exploration of the feasibility of HIIT than would have been gained from quantitative methods only. Further strengths include thoroughly supervising participants through the study to measure and ensure safety. The laboratory setting of the study allowed the monitoring of intensity and any potential adverse events.

However, the findings must be considered in light of the small sample size and lack of a control group. Future intervention studies should include a control group and different exercise intensities. It is possible that participants recruited for this study were more motivated to engage in exercise than people from the general MS population. Only people with mild MS-related disability were recruited for this study, and within this group, there was heterogeneity in physical fitness, physical activity levels and body weight. Further research is needed to understand the impact and perspectives of high-intensity interval training in people with higher MS-related disability. Despite these weaknesses, the study's primary aim was to explore the perspectives and experiences of HIIT with PWMS. In this regard, the study design was suitable for this purpose. Qualitative investigation is a valuable tool to evaluate the suitability of an intervention.

4.7.2 Implications for the physical activity guidelines

The current PAGs[25] for PWMS do not discuss high-intensity or vigorous exercise. This study indicates that HIIT is a feasible intervention for people with low MS-related disability. This adds to the promising evidence for the safety and effectiveness of HIIT in PWMS [229]. Further research is required before HIIT can be considered for inclusion in the guidelines, but the data here is nevertheless encouraging. In general, clinical guidelines advise on effective and good-value healthcare [160] and cannot be considered inclusive if it potentially harms certain groups [276]. However, a limitation of the guidelines is that the recommendations can erroneously determine what is best for patients[277]. The research suggests that an individual can exercise safely at higher intensities. Therefore, if a PWMS is experienced in exercising at higher intensities, they should be encouraged to continue to do so.

4.8 Conclusion

PWMS have routinely been advised to avoid exercise due to perceived adverse effects on symptoms such as muscle weakness, reduced mobility, poor balance, and fatigue[278]. Mild-to-moderate intensity exercise is now accepted as safe and beneficial for PWMS[279], manifesting in high-intensity interval training becoming an area to explore for this population [229]. Our findings support research that suggests that HIIT is a safe form of exercise for PWMS [280], but negative experiences question the appeal of HIIT as a long-term exercise mode[218]. This study has identified several significant points to consider in future trials. Participants found the sessions tedious and felt uncomfortable, so whilst this study suggests that HIIT is a safe form of exercise for PWMS, questions remain regarding the appeal in PWMS.

5 A scoping review of community-based exercise for people with multiple sclerosis

5.1 Overview

Chapter 2 identified the evidence for the effectiveness of exercise for PWMS. The effectiveness of exercise led to the development of exercise guidelines for PWMS. The exercise guidelines were developed to make exercise for PWMS more accessible. However, the guidelines provide little detail on how to apply the guidelines (e.g., where to exercise) for PWMS to engage in exercise. Additionally, the guidelines do not provide strategies to support long-term adherence to exercise or the appropriate professionals to seek support. This chapter outlines the need to develop evidence-based exercise interventions in the community for PWMS.

In this scoping review, I aimed to explore the existing body of knowledge on community-based exercise programs specifically tailored for individuals with MS. By examining the available literature, I intended to provide a comprehensive overview of the context, development, implementation, and potential efficacy of community-based interventions for PWMS.

From the review, I aimed to gain an understanding of the existing knowledge and identify gaps that warrant further investigation. This review served as a valuable stage for my thesis. By understanding the current landscape of community-based exercise interventions, I could use the findings to target and refine the subsequent research in this thesis. In this chapter, I will synthesise the literature, including the characteristics of community-based exercise programs, the outcomes reported, and the barriers and facilitators to program implementation for PWMS. These findings will be discussed further in succeeding chapters.

5.2 Introduction and rationale

So far, the studies included in this thesis have explored the limitations of the PAGs for PWMS. Chapter 3 explored the inclusivity of the guidelines, and Chapter 4 explored the prescription of exercise and the acceptability of HIIT. This study aimed to conduct a scoping review of published peer-reviewed studies investigating community-based exercise programmes for PWMS. Colquhoun and colleagues define a scoping review as; a form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting, and synthesising existing knowledge[281]. Scoping reviews differ from systematic reviews, as shown in Table 15[282]. A criticism of a scoping review is the lack of attention to the quality of the studies included in the analysis[283]. However, a scoping review allows greater flexibility than a traditional systematic review or meta-analysis[283]. Related literature can be explored through general questions focusing on summarising the breadth of evidence rather than answering defined questions.

Additionally, a scoping review can allow for a diverse range of relevant literature that includes various methodologies. Scoping reviews include theoretical and narrative reviews, grey literature, and qualitative and quantitative research[283]. Scoping reviews help examine emerging evidence on a subject[284]. They can report on the type of evidence that addresses and informs practice in the field and how the research has been conducted[284].

Table 15: Comparison between systematic and scoping reviews [282]

Systematic review	Scoping review
• Focused research question with narrow parameters • Inclusion/exclusion criteria defined at the outset • Quality filters are often applied • Detailed data extraction • Quantitative synthesis is often performed • Formally assess the quality of studies and generate a conclusion relating to the focused research question	• Research question (s) are often broad • Inclusion/exclusion criteria can be developed post hoc • Quality is not an initial priority • May or may not involve data extraction • Synthesis is more qualitative and typically not quantitative • Used to identify parameters and gaps in a body of literature

5.2.1 Behaviour change theories and models

Currently, there is a disconnect between evidence of benefits and rates of participation in exercise among PWMS [200]. This disconnect might be due to insufficient physical activity and exercise promotion[200]. A possible explanation is that few studies have applied behaviour change theories with exercise interventions to maximise participation [200]. Interventions that are developed with theory are found to be more effective than interventions with a theoretical underpinning[285]. In the theory phase, evidence is accumulated, and a theoretical basis for the intervention is developed and modelled in the next phase [286]. There are three main reasons for advocating using theory in designing interventions.

(1) Interventions are likely to be more effective if they target causal determinants of behaviour and behaviour change; this requires understanding these causal determinants, e.g., theoretical mechanisms of change.

(2) Theory can be tested and developed by evaluations of interventions only if those interventions and evaluations are theoretically informed.
(3) Theory-based interventions facilitate understanding what works and thus are a basis for developing better theories across different contexts, populations, and behaviours [286].

Nevertheless, selecting a theory to inform an intervention is difficult because there are more than 20 theories, each with multiple theoretical constructs [287]. Examples of widely used behaviour change theories are outlined below.

5.2.1.1 Social Cognitive Theory

The social cognitive theory (SCT)[288] proposes that personal, behavioural, and environmental factors operate as interacting determinants of each other [289]. Not only does the environment affect behaviour, but behaviours also affect the environment[289]. A central construct of SCT is self-efficacy, which is an individual's confidence in successfully performing a behaviour[290]. Bandura proposed that self-efficacy is formed and affected by four primary sources of information: performance accomplishments (mastery), experiences (modelling), verbal persuasion and physiological states (emotional response) [291].

Although self-efficacy strongly influences behaviour, it is not the sole determinant[288]. Outcome expectations are the second SCT construct and represent one’s judgment of the likely consequences after performing or not performing a particular behaviour [292]. There are three classifications of outcome expectations

(1) Physical (i.e., bodily sensations and material gains or losses)
(2) Social (i.e., anticipated approval or disapproval)
(3) Self-evaluative (i.e., how one expects they will feel about themselves after performing a behaviour) [292].

For PWMS, the SCT is the most applied theory to increase physical activity. However, as discussed previously, most studies do not use a formal process by which the theory was applied to the intervention. Additionally, SCT is not typically used as extensively as it could be in developing interventions, with studies often assessing one or two components of the model, such as self-efficacy [293]. If interventions do not describe how they applied theory, it is challenging for researchers to replicate the effective components in future interventions [294].

5.2.1.2 Self-determination theory

Self-determination theory (SDT) distinguishes between two sources of motivation: intrinsic (autonomous) and extrinsic (controlled) [204]. SDT suggests that intrinsic motivation is based on striving to satisfy the psychological needs of competence, autonomy, and relatedness [1]. Autonomy is characterised by an internal locus of control and the perception that behaviours are freely chosen [295]. Competence is characterised by mastery and the perception of effectiveness in what we do [295]. Relatedness is a construct characterised by satisfaction and involvement with the social world [295].

Extrinsic motivation refers to doing an activity for instrumental reasons or to obtain some outcome separable from the activity [296]. For example, when a person engages in an activity to gain a tangible or social reward or to avoid disapproval, they are extrinsically motivated [296]. According to SDT, intrinsic and internally regulated behaviour leads to greater engagement and persistence than extrinsic or externally controlled [297]. This is important as intrinsic motivation has been shown to associate with better physical and psychological health outcomes [297].

5.2.1.3 Theory of planned behaviour and Theory of reasoned action

The theory of planned behaviour (TPB) [203] extends the theory of reasoned action [289]. The theory of reasoned action states that intentions are the best predictors of actual behaviour[289]. Intentions are influenced by a person's attitude towards a behaviour and what is normative regarding the behaviour (subjective norm) [289]. TPB extends the theory of reasoned action by arguing that intentions cannot be the sole predictors of behaviour, especially when people might lack control over the behaviour [289]. Therefore, in addition to attitudes and subjective norms, TPB states that perceived behavioural control will also predict behavioural outcomes. Perceived behavioural control is the perceived difficulty or ease of enacting a behaviour [298].

5.3 Study aim

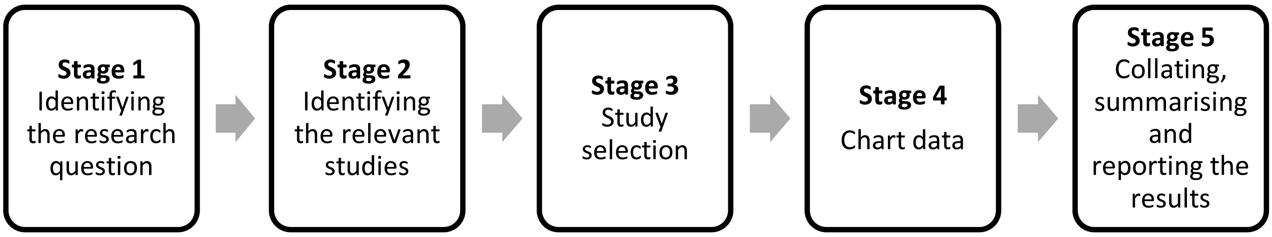
This review aimed to evaluate the evidence of community-based exercise interventions for PWMS. The review results will then inform the development of a community-based intervention for PWMS.

5.4 Methodology

5.4.1 Study design

This scoping review followed the framework proposed by Arksey and O'Malley[299] and then advanced by Levac and colleagues[300]. This study included the critical phases of the framework (Figure 5).

Figure 5: Framework for conducting a scoping review [299,300]



5.4.1.1 Stage One: Identifying the review question

Scoping study research questions are broad, focusing on summarising the breadth of evidence[300]. Although scoping studies are broad, Levac and colleagues[300] recommend combining a broad question with an articulated scope of inquiry. This includes defining the concept, target population and health outcomes of interest to focus the search strategy. This review evaluates the effect of community-based exercise interventions on the uptake and maintenance of exercise in PWMS. The scoping review addresses the following questions:

(1) What are the characteristics of community-based exercise interventions for PWMS?
(2) Are BCT incorporated into the interventions?
(3) Are community-based exercise interventions acceptable, safe, and effective for PWMS?
(4) What do PWMS see as the crucial aspects of a community exercise intervention?

5.4.1.2 Stage two: Identifying relevant studies

A systematic literature search was conducted to identify studies that reported the results of community-based exercise programmes for PWMS. The PhD candidate established the search strategy, which the PhD supervisors checked. PubMed, SCOPUS, Science Direct, and Web of Science databases were searched for publications between 2005 and 2018. Searches will be restricted to publications from 2005 due to this being the date of the first Cochrane review suggesting the health benefits of exercise for PWMS[101]. The PhD candidate iteratively developed an extensive list of primary and secondary search terms (Table 16). The primary search terms focused on core MS and exercise-related terms (e.g., multiple sclerosis, exercise, community). The secondary terms included a broader set of keywords such as behaviour change and promotion. The filtering methods included the date range and language (English) to narrow the results.

Table 16: Search terms for the scoping review

Primary search terms			Secondary search terms
Search term 1	Search term 2	Search term 3	Search term 4
Community-based or community or home-based or	Exercise or physical activity or fitness or gym or aerobic or strength training	Multiple sclerosis or MS	Behaviour change or motivation or promotion

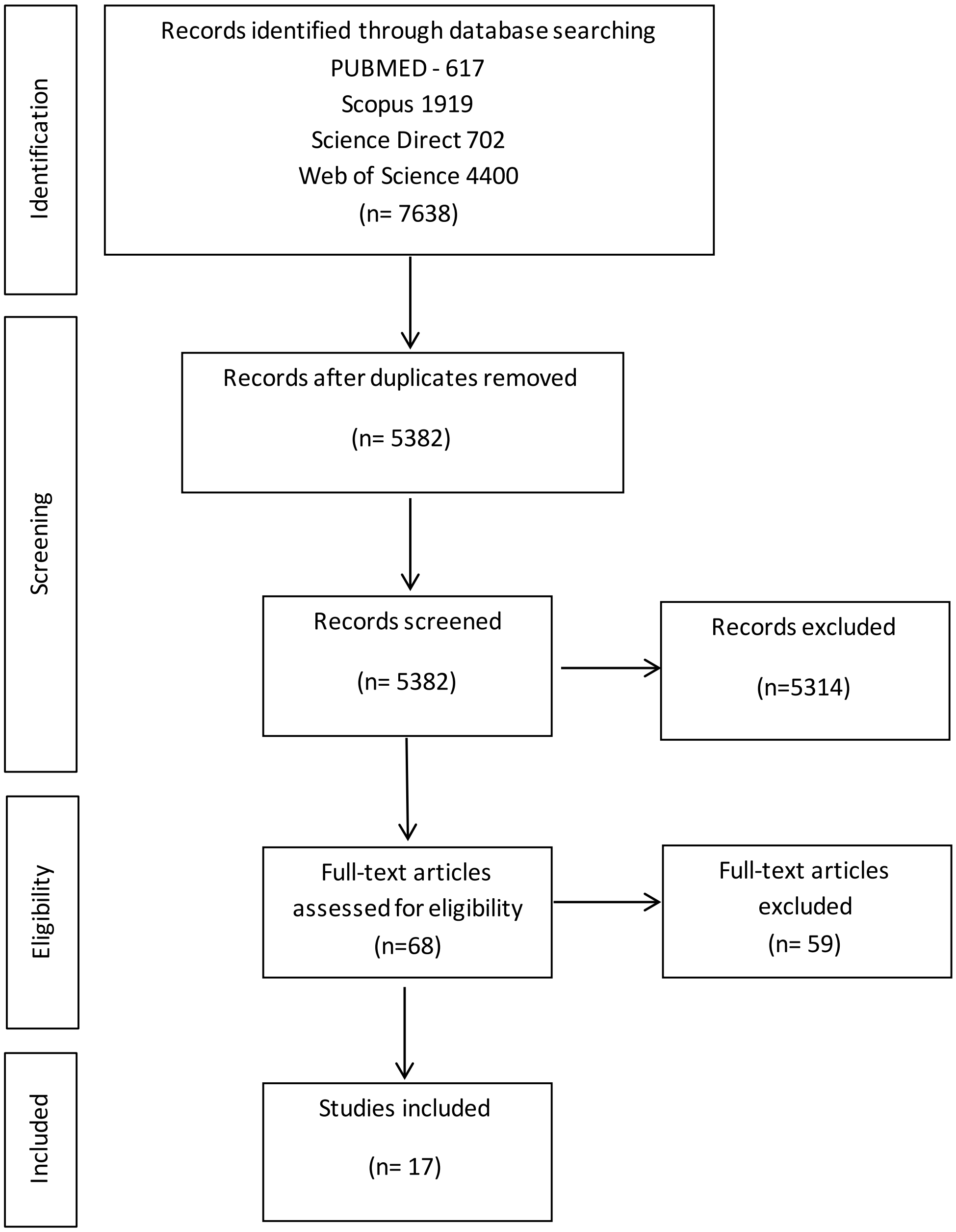
5.4.1.3 Stage Three: Study selection

Once identified, studies were imported into RefWorks web-based bibliographic software. The PhD candidate removed duplicates and screened titles, followed by abstracts, to identify papers that potentially meet the review criteria. To be included, studies had to meet all of the following criteria:

(1) Published in English
(2) January 2005 - November 2018
(3) Include participants with a confirmed diagnosis of MS
(4) Participants aged ≥ 18
(5) Identified as a community-based program, defined as explicit use of the word "community", and/or utilising a community-based setting non-clinical setting (i.e. fitness/leisure centre, community centre, home)
(6) Research that aimed to address exercise behaviour
(7) Research that reports exercise levels as the primary or secondary outcome using a validated measure
(8) Research that explores participants' perceptions of participating in community-based exercise

Full-text papers were obtained for studies that satisfy the criteria. Then the PhD candidate screened the full text. Any uncertainty regarding the inclusion of a study was discussed with a second reviewer (AC). An adapted PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) flow chart (Figure 6) presents the study selection numbers.

Figure 6: PRISMA flow chart



5.4.1.4 Stage Four: Charting of data

Data was charted in table form to record key information from the study. Key information included:

- Author(s)
- Year of publication
- Origin/country of origin (where the study was conducted or published)
- Aims/purpose
- Study population and sample size

- Methods (design, location/setting)
- Intervention details (type, duration, frequency, intensity)
- Outcomes (primary and secondary measures)
- Key findings that relate to the scoping reviews question(s)

5.4.1.5 Stage Five: Collating, summarising, and reporting the results

Levac and colleagues recommend three steps at this stage to increase consistency with which researchers undertake and report scoping review methods[300]:

(1) Analysing the data - descriptive numerical summary analysis and qualitative thematic analysis.
(2) Reporting results - Producing the outcome that addresses the research questions.
(3) Applying meaning to the results - Discuss implications for future research, practice, and policy.

5.4.2 Qualitative synthesis

The purpose of synthesising qualitative studies is to develop a deeper understanding of the phenomenon under investigation and explore perceptions and attitudes from the participants' perspective[301]. The number of different methods for synthesising qualitative research is increasing, but no method for synthesising qualitative research has become well established[302]. Popular methods include meta-ethnography, grounded theory, and thematic synthesis[301].

Noblit and Hare developed meta-ethnography in 1988[303]. Meta-ethnography is one of the most frequently used methodologies for qualitative evidence synthesis in health and social care research[304]. It involves selecting relevant studies to be synthesised, reading them repeatedly and noting down key concepts[305]. These concepts become the raw data to be synthesised[305]. Meta-ethnography is a method that involves induction and interpretation and, in this respect, resembles the qualitative methods of the studies it aims to synthesise[306]. It is suited to producing a new interpretation, model or theory that goes beyond the original study[304].Glaser and Strauss introduced grounded theory in 1967[307]. Grounded theory involves collecting data that is 'grounded' in actual data. Essential methods and assumptions of grounded theory include simultaneous phases of data collection and analysis; an inductive approach to analysis, allowing the theory to emerge from the data; the use of the constant comparison method; the use of theoretical sampling to reach theoretical saturation; and the generation of new theory[302].

Thematic synthesis combines and adapts approaches from both meta-ethnography and grounded theory[302]. Thematic synthesis uses techniques commonly described as 'thematic analysis' to formalise the identification and development of themes[308]. The framework approach [47] was used to synthesise the qualitative data, as discussed in Chapter 1. Per framework analysis, the results sections of the studies were transferred verbatim into NVivo software for qualitative data analysis.

Generating themes is the most controversial stage as it depends on the reviewer's judgment and insights[308]. Generating the themes is described as 'going beyond' the content of the original studies. This was achieved by using descriptive themes to answer the review questions. The focus of the qualitative synthesis was specified to explore PWMS's perspectives on community-based exercise programmes. Any study that did not meet the synthesis topic was eliminated from the review.

5.5 Results

The database search identified 7638 potentially eligible articles. See Figure 6 for the number and reasons for exclusion through the screening process. A total of 18 studies met all the inclusion criteria and were included for data extraction[18,158,309-324]. One study[317] was a secondary analysis of the primary study[316] and, therefore, will be discussed as one study leaving 17 studies for analysis. Four studies [320,321,323,324] were refined interventions from the original protocol[310].

5.5.1 *Programme characteristics*

Articles were published between 2005 and 2018. Studies included randomised controlled trials [309,310,312-314,316,319,321-323] and pre-post cohort studies with two or more follow-ups[18,158,311,318,320]. Ten studies were described as pilot or feasibility studies [158,310-312,314-316,318,319,322]. Table 17 provides a detailed summary of each study.

Table 17: Summary of included studies

Citation	Participants: total number; gender (male/female); age	Disability level	Type of MS	Frequency	Intensity	Time (duration and length of intervention)	Type (of activity/exercise)	Community location	Led by	Guidelines?	Behaviour change theory	Physical activity
Hayes (2017)[316]	65; 10/55; 42.6 (9.6)	Measure: EDSS; median 3.3, IQR (0.7)	Benign 4 RRMS 27 SPMS 1 PPMS 1 Don't know 4	Moderate intensity aerobic exercise 2 times per week and strength training for major muscle groups 2 times per week	Aerobic: 100 steps per minute measured with pedometers; Strength 1-2 sets 10-15 reps	30 minutes; 10 weeks	Aerobic and strength training	Multicentre; community delivery	Physiotherapist	Latimer Cheung (2013)	SCT education	Measure: GLTEQ; pre-post Δ in PA: *p*=0.01, *d* = 0.31
Mandelbaum (2015)[311]	10; 3/5; 49.5 (11.8)	Measure: PDDS; mean 1.1, SD (1.2)	RRMS 7 SPMS 1	2 classes per week and one practise session at home		60 minutes per class; 30 minutes for home practice; 4 weeks	Salsa dance intervention	Not specified	Professional Dance Instructor	Not specified	Not specified	Measure: GLTEQ; pre-post Δ in PA: *p* = 0.01; *d* = 0.34
Thomas (2017)[315]	30; 3/27; 49.3 (8.7	Measure: APDDS; mean 4.2, SD (1.1)	Benign 1 RRMS 21 SPMS 5 PPMS 1 Don't know 2	Participant directed	Participant directed	Participant directed	Nintendo Wii	Home-based	Physiotherapist	Not specified	MI; SCT; SDT; and incorporates behaviour change techniques	Measure: GLTEQ; pre-post Δ in PA: statistical significance not reported, *d* = 0.7

Citation	Participants: total number; gender (male/female); age	Disability level	Type of MS	Frequency	Intensity	Time (duration and length of intervention)	Type (of activity/exercise)	Community location	Lead by	Guidelines?	Behaviour change theory	Physical activity
Elsworth (2011)[309]	99 (24 with MS); 51/48; 56 (12.9)	Not specified	Not specified	Number of sessions was determined by the individual.	The intensity of sessions determined by the individual	Length of session determined by the individual	Gym based exercise	Gym - IFI	Fitness instructor with support from a physiotherapist	Based on general public guidelines (at least 5 a week)[325].	Intervention includes Physical Activity Support System (PASS); information, practical advice and support.	Measure: PASE; pre-post Δ in PA: p = 0.11, d = 0.26
Kinnett-Hopkins (2018)[158]	32; 2/29; 51.6 (9.4)	Measure: PDDS; mean 1.5, SD (4)	RRMS 26 SPMS 1 PPMS 3	Aerobic training 2x week; strength - 2x week	1-2 sets, 10-15 reps up to 10 exercise	10-30 minutes aerobic training; 12 weeks	Aerobic and strength training	Internet/Home-based	not clear	Latimer Cheung (2013)[25]	SCT; Behavioural coaching	Measure: GLTEQ; pre-post Δ in PA: p = 0.01, d = 1.5
Learmonth (2017)[314]	57; 2/55; 48.4 (9.7)	Measure: EDSS; median 1.5, IQR (3.5)	RRMS 51 SPMS 1	Aerobic training - 10-30minutes 2x week; strength - 2x week	1-2 set 10- 15 reps up to 10 exercise	10-30 minutes aerobic training; 16 weeks	Home-based resistance and strength training	Internet/Home-based	Physio	Latimer Cheung (2013)[25]	SCT; Behavioural coaching	Measure: GLTEQ; pre-post Δ in PA: p = 0.01; d = 0.64
Turner (2016)[313]	64; 41/23; 53.2 (12.4)	Measure: Mobility items of the performance scales; Mean 2.5, SD (1.4)	RRMS 42; Other 22	Long-term goal of achieving or exceeding physical activity guidelines of 90 minutes or more of moderate activity per week.	Participant directed	Long-term goal of achieving or exceeding physical activity guidelines of 90 minutes or more of moderate activity per week.	Physical activity DVD with examples of in-home exercises for multiple physical ability levels. Or self-selected exercise	Home-based	Study therapist trained in MI	Not specified	MI based Telephone counselling	Measure: GLTEQ; pre-post Δ in PA: p = 0.732; d = 0.92
Citation	**Participants: total number;**	**Disability level**	**Type of MS**	**Frequency**	**Intensity**	**Time (duration and**	**Type (of activity/exercise)**	**Community location**	**Lead by**	**Guidelines?**	**Behaviour change theory**	**Physical activity**

	gender (male/female); age					length of intervention)						
Tallner (2016)[312]	126; 32/94; 40.8 (9.9)	Measure: EDSS; mean 2.7, SD (0.8)	RRMS 109 SPMS 17	Strength training 2 times per week; endurance training once per week.	2-3 sets per exercise; 11-16 RPE	12 weeks	Internet-based exercise training (e-training) for PWMS	Internet/Home-based	Physiotherapist	Dalgas et al 2008[107]	Internet support; the application of theories, and models of behavioural change, considering needs, preferences, motives, and perceived barriers	Measure: Baecke; pre-post Δ in PA: *p* = 0.001; *d* = 0.33
Learmonth (2011)[319]	32; 9/23; 51.6 (8.0)	Measure: EDSS; mean 5.98, SD (0.87)	Not specified	Twice per week	Varied	60 minutes per class	Leisure centre-based circuit training class; Participants completed a circuit of 8–12 different exercises for 1 minute each, having a rest (of a minimum of 1 minute) before moving to the next exercise.	Leisure centre-based exercise class	One physiotherapist and one fitness instructor	ACSM exercise management for persons with chronic disease and disabilities[326]	Nothing specified but included goal attainment scale	Measure: PhoneFITT; pre-post Δ in PA: *p* = 0.001; *d* = 1.05
Plow (2014)[322]	30; 0/30; 47.5 (9.5)	Measure: PDDS; mean 1.9, SD (1.5)	Not specified	Three-to-five days per week	Moderate	30-to-45 minutes	The prescribed exercise program consisted of indoor cycling, stretching, balance, and strength training.	Community-based in metropolitan area	Lead author	Not specified	The intervention was guided by SCT and transtheoretical model.	Measure: GLTEQ; pre-post Δ in PA: *p* = 0.02; *d* = 1.08
Citation	**Participants: total number; gender (male/female); age**	**Disability level**	**Type of MS**	**Frequency**	**Intensity**	**Time (duration and length of intervention)**	**Type (of activity/exercise)**	**Community location**	**Lead by**	**Guidelines?**	**Behaviour change theory**	**Physical activity**

Pilutti (2014)[324]	82; 20/62; 49 (9.1)	Measure: PDSS; Median 2.5, IQR (3.5)	RRMS 65; SP 10; PP 7	Participant directed	Participant directed	Participant directed	Internet intervention based on SCT	Internet/Home-based	Highly trained doctoral students or a postdoctoral fellow	Not specified	SCT	Measure: GLTEQ; pre-post Δ in PA: *p* = 0.01; *d* = 0.77
Motl (2011)[310]	54; 5;43; 46(10)	Measure: PDDS; mean 2.5, SD(1.5)	Not specified	Participant directed	Participant directed	Participant directed	Internet intervention based on SCT	Internet/Home-based	Study coordinator	Not specified	SCT	Measure: GLTEQ; pre-post Δ in PA: *p* = 0.01; *d* = 0.72
Feys (2013)[18]	57; 9/33; 43.5 (10)	Measure: PDDS; mean 2.1, SD (0.8)	RRMS 33; PP 4; SP 5	Participant directed	Participant directed	Participant directed	One day education program about exercises and sports.	Self-directed exercise	physiotherapists and researchers	Not specified	Not specified	Measure: GLTEQ; pre-post Δ in PA: *p*= 0.08; *d* = 0.28
Plow (2011)[318]	30; 7/23; 43.2 (9.3)	Measure: PDDS; mean 1.4; SD (1.1)	RRMS 30	3 times per week	Participant directed	10-30 minutes; 14 weeks	Wii-Fit exercise programme consisting of yoga, balance, strength, and aerobic activity.	Home-based	Not specified	Not specified	No theory specified but included fort nightly phone calls to discuss barriers and goal setting.	Measure: PADS; pre-post Δ in PA: p = 0.001; d = 0.65 (at 7 weeks)
Dlugonski (2012)[321]	45; 6/39; 46.7 (9.6)	Measure: PDDS; median 1.0; Range (0-6)	RRMS 45	Participant directed	Participant directed	Participant directed; 12 weeks; (6 months)	Internet intervention based on SCT	Internet/Home-based	Health behaviour coach	Not specified	SCT	Measure: GLTEQ; pre-post Δ in PA: *p*= 0.001; *d* = 0.98
Citation	**Participants: total number; gender (male/female); age**	**Disability level**	**Type of MS**	**Frequency**	**Intensity**	**Time (duration and length of intervention)**	**Type (of activity/exercise)**	**Community location**	**Lead by**	**Guidelines?**	**Behaviour change theory**	**Physical activity**
Dlugonski (2011)[320]	21; 2;19; 46.4 (8.1)	Measure: PDDS; median 1.0; Range (0-5)	RRMS: 21	Participant directed	Participant directed	Participant directed; 12 weeks	Internet intervention based on SCT	Internet/Home-based	Study coordinator	Not specified	SCT	Measure: GLTEQ; pre-post Δ in PA: *p* = 0.07; *d* = 0.43 Measure: IPAQ; pre-

												post Δ in PA: *p* = 0.03; *d* = 0.6
Sandroff (2014) [323]	82; 19/57; 49.5 8.3)	Measure: PDDS; Mild to moderate disability (data not reported)	RRMS 60	Participant directed	Participant directed	Participant directed; 6 months	Internet intervention based on SCT	Internet/Home-based	Study coordinator	Not specified	SCT	Measure: IPAQ; *p* = 0.03; mild disability *d* = 1.63, moderate disability *d* = 0.24

The studies included 778 PWMS (range 10-126); most participants had relapsing-remitting MS (80%). Two studies did not specify the type of MS[309,319]. One study included various neurological conditions, including MS and therefore, did not specify the type of MS or level of MS-related disability [309]. All remaining studies included participants with mild-to-moderate MS [18,158,310-318,320-324]. To measure the participant's disability levels, four studies used the EDSS[237] [312,314,316,319]. Eleven studies used the PDDS[18,158,310,311,316,318-324] or an adapted version (APDDS)[315]. The PDDS is a self-report disability measure mapped to the EDSS[327]. One study used the mobility item of the performance scale, which is highly associated with the EDSS (r=.9)[313].

Sixteen of the seventeen studies reported reasons for exclusion/non-enrolment[18,158,309,310,312-324]. Common reasons were not eligible, declined/not interested, unwilling to travel, illness, other commitments, and too high baseline activity. All studies reported the number of participants lost to follow-up [18,158,309-324]. The average programme completion rate was 84% ±10.6 (range 61%-98%).

Programme duration was *median* = 12 weeks (IQR 3 weeks). The duration of interventions ranged from one education day[18] to 12 months[315]. Nine studies involved 12-week interventions [158,309,310,312,313,319-322].

Six of the seventeen interventions were delivered by physiotherapists [18,312,314-316,319]. A professional dance instructor delivered one intervention[311]. Two studies included behavioural coaches/therapists[313,321]. One study reported that the lead author, a highly trained researcher, delivered the exercise prescription[322]. Five studies reported internet-based interventions, and support was provided by the lead author, study coordinator, or doctoral students [158,310,320,323,324] Two studies reported the use of fitness instructors with the support of a physiotherapist[309,319].

Six studies based their exercise prescription on established exercise guidelines. Four studies used guidelines explicitly developed for PWMS [158,312,314,316]. Three studies [158,314,316] based their intervention on the MS exercise guidelines developed by Latimer-Cheung and colleagues [25]. Tallner et al. [312] based their intervention on the recommendations developed by Dalgas and colleagues [107]. Elsworth et al. [309] based their intervention on the recommendations from the Chief Medical Officer's report, at least five a week[325]. Learmonth and colleagues [319] used the ACSM guidelines for people with chronic disease or disabilities[326] to develop their exercise prescription.

Ten studies explicitly specified the use of behaviour change theory [158,310,314-316,320-324]. All ten studies based their interventions on the social cognitive theory (SCT) [158,310,314-316,320-324]. SCT and the transtheoretical model[322] guided the intervention from Plow and colleagues.

Thomas and colleagues[315] drew on frameworks and theories such as motivational interviewing, social cognitive, cognitive behavioural, and self-determination theory. Seven studies did not specify the behaviour change theory underpinning the interventions [18,309,311-313,318,319]. Tallner et al., [312] and Learmonth et al. [319] did not specify a behaviour change theory, but the interventions include behaviour change techniques such as training participants, one-to-one online support, exercise booklets, and goal setting, respectively. Turner and colleagues' [313] intervention included physical activity counselling grounded in the principles of motivational interviewing but was not underpinned by a behaviour change theory. Elsworth and colleagues [309] discussed the development of a Physical Activity Support System but did not specify the theories involved in the development. Mandelbaum and colleagues [311] state that dance classes are a method to facilitate self-efficacy, autonomy, relatedness, enjoyment, and social engagement.

5.5.2 Efficacy/effectiveness and safety

Ten studies (59%) reported whether any adverse events occurred or not during the intervention [158,309,311,313-316,318,321,324], of those three reported no adverse events [311,313,321]. In total, 56 (7%) participants reported an adverse event, and no adverse events were considered serious. Two studies reported exacerbation of MS symptoms (n= 7), such as increased fatigue, vision problems, and drop foot [158,314].

Eleven of the seventeen studies measured physical activity using the GLTEQ [158,310,311,313-316,320-322,324]. Other measures of physical activity included the German version of the Baecke Questionnaire[312], Physical Activity Scale for the Elderly[309], Physical Activity Scale for Individuals with Physical Disabilities[18] and PhoneFITT [319]. Dlugonski and colleagues[320] compared the use of GLTEQ and the IPAQ. Fifteen studies reported improved physical activity levels from pre-to-post intervention ($p<0.05$)[158,309-312,314-324]. The average effect size was moderate $d= 0.74 \pm 0.33$ (range=0.26-1.5). Five studies achieved a small effect size ($d \leq 0.5$)[18,309,311,312,316]. Twelve studies achieved a moderate to large effect size ($d \geq 0.5$) [158,310,313-315,318-324].

5.5.3 Participant perspectives

Seven qualitative studies were included in the review [328-334], and Table 18 provides a detailed summary of each. The qualitative studies included 152 participants with MS. The studies included participant perceptions of interventions at community venues (e.g., leisure centres, MS Society branch)[328-330]. Two studies discussed experiences of home-based games console activity (e.g., Nintendo Wii, X-Box Kinect)[331,332]. One study explored the perceptions of PWMS after participating in a home-based intervention[333]. One study includes participants' perceptions of physical activity support of an experienced community-based physiotherapist (Blue Prescription)[334].

Table 18: Summary of qualitative studies

Citation	**Participants: total number; gender (male/female); age**	**Disability level**	**Type of MS**	**Community location of intervention**	**Analysis**
Clarke and Coote (2015) [335]	14; gender not specified; 53.9 (±13)	Not specified	11 RRMS, 3 SPMS	Multicentre	Thematic analysis
Learmonth (2013)[329]	14; 4/10; 51	EDSS 6.1	Not specified	Leisure centre	General inductive approach
Plow and Finlayson (2014) [331]	30; 7/23; 43.2 (±9.3)	Mild to moderate	13 RRMS	Home-based, Wii Fit	Pre and post-interviews. Inductive-category and theme development approach
Palacios-Cena (2016) [332]	24; 11/13; 36.7 (±8.1)	EDSS 4	16 RRMS, 3 SPMS; 5PPMS	Home-based, Kinect	Thematic analysis
Learmonth (2018)[333]	18; 0/18; 50 (±10)	EDSS 1	18 RRMS	Home-based	Inductive-category and thematic analysis
Smith (2013) [334]	27; 4;23; 51 (±11.1)	Not specified	8 RRMS, 7 SPMS, 3 PPMS, 9 unknown	Blue-prescription participants choose the activity	General inductive approach
Aubrey (2012) [330]	25; 11/14; not specified	Not specified	Not specified	Community MS Society branch	Thematic analysis

Analysis of the study's results sections uncovered four higher-level themes: (1) effects of the intervention; (2) barriers to exercise; (3) peer support; (4) structure of the programme/intervention. Table 19 shows the themes and subsequent lower-order themes.

Table 19: High-level and lower-order themes

Main themes	Subthemes
Effects of the intervention	Physical changes Changes in fatigue Build confidence and motivation
Barriers to exercise	Physical Environmental Psychological
Peer Support	Group-based Non-group based (No third lower-order theme)
Structure of the interventions/programme	The sessions Instructors

5.5.4 *Effects of the intervention*

5.5.4.1 *Physical changes*

Participants in all studies discussed the physical benefits of participating in physical activity.

"To begin with, it was really really slow…no sense of gain to start with and then somewhere one day I think,' Oh god, I can do more of these." [334]

"I found that this year was the first year in four years that I started doing a bit of gardening, it was a great feat for me to be able to finish it." [328]

5.5.4.2 *Changes in fatigue*

Participants discussed the positive changes in their perceived levels of fatigue as a result of being more active.

"I feel a lot more energetic . . . really I feel much more alert, my head feels clearer I can think things through better." [329]

"I could not move, and after several weeks of playing, I realised that I was not as tired, that I was moving again... it was like recovering the control over my body and over the disease." [332]

Other participants discussed how their fatigue didn't improve or even got worse.

"My fatigue's got worse, but my balance has improved." [329]

5.5.4.3 Build confidence and motivation

Participants from all six studies discussed how participating in more activity helped increased their confidence and motivation to continue being active.

"Well I got a lot more confident, I was going completely introverted kind of." [328]

"It also gave me self-esteem to try things and do them."[331]

5.5.5 Barriers to exercise

Barriers to participating in exercise were regularly discussed in the included studies. Barriers can be categorised as physical (e.g., limitations due to condition), environmental (e.g., transport problems), and psychological (e.g., fear of making the condition worse).

"You don't always want to be reminded about ... not your MS but ... your inability to do things". [330]

"It is difficult and expensive to go into town for rehabilitation. But if you don't do it, you worsen"[332]

"I'd be kind of worried about doing more damage than good when I wouldn't know how to use the equipment or something like that." [328]

5.5.6 Peer support

Participants spoke highly of the importance of having social support during the intervention. The social benefits of being in the group created a sense of comradery.

"If anybody with MS is carrying a load of trouble on their shoulders then they come here, many others have the same problem. We ignore the problem, amongst ourselves ... [we] enjoy things ... we all do the best we can and that's what makes it" [330]

"I think because everyone is in the same boat, it stops you from feeling sorry for yourself, feeling oh I can't do this, you see everybody else getting on with it and it inspires you to try harder." [329]

Participants from the studies involving no group-based activity also discussed how having support is essential.

"It's great for people like me to have somebody...show any interest" [334]

"It's just fun to see other people participate in it, and it's fun to see how good somebody is at something." [331]

"Before we had to suffer treatments and battle it out, be disciplined. Now all I have to do is to play and have fun with my friends and family"[332]

5.5.7 *Structure of the interventions/programmes*

Participants in the studies offered feedback on aspects of the interventions, such as the exercise sessions and the instructors.

5.5.7.1 The sessions

Some participants discussed how sessions could be too easy and would have liked to be pushed to do more.

"I have to admit ... without sounding cocky, I do find a lot of it quite easy". [330]
"When I first started the exercises I could do them easily, but I realised that many other people don't so you have to start from somewhere." [333]

Others felt that they were provided with an appropriate range of difficulties.

"I was really impressed with the fact that there were [exercise] options for different levels of difficulty and because you were writing things down [progress cards] at what level you had been exercising at. It was encouraging because after a few weeks you could look back and see, oh, yes I am getting better." [329]

5.5.7.2 Instructors

The participants discussed the importance of having a knowledgeable instructor and how it makes them feel safe. In one study, nine participants gave positive comments about how their behaviour coach was encouraging, knowledgeable, and possessed listening skills[333]

"It helps that there are so many people that are trained to help you because you feel more secure". [330]
"[the instructors] have been very professional and their knowledge has been outstanding . . . always there for moral support." [329]

5.6 Discussion

This study aimed to conduct a scoping review of published peer-reviewed studies investigating community-based exercise programmes. Seventeen studies were included providing data for 778 PWMS.

5.6.1 *What are the characteristics of community-based exercise interventions for people with MS?*

There was a significant degree of heterogeneity amongst the community interventions, with differences in location, mode of exercise, and length of the intervention. The interventions incorporated various delivery methods (duration, staff, web-based). Home-based/internet-based behavioural support programmes are the most common community-based setting for exercise interventions. Home-based exercise allows patients to minimise MS-related barriers to being physically active[336]. Barriers to attending a fitness facility include lack of accessibility (e.g., uneven terrain), costs for membership and transportation to and from the centre [336]. Studies with PWMS have primarily included participants with mild-to-moderate disability or relapsing-remitting MS. Evidence is weak for progressive forms of MS and those with severe disability[337]. Currently, there are no exercise guidelines for people with severe MS [337].

Six studies incorporated PAGs into their interventions. The guidelines developed by Latimer-Cheung and colleagues [25] were most frequently used to inform the interventions. Latimer-Cheung et al. created their guidelines using the rigorous, internationally accepted consensus approach outlined in AGREE II [25]. The AGREE II comprises 23 items grouped into six domains[338]. These domains are scope and purpose, stakeholder involvement, the rigour of development, clarity of presentation, applicability, and editorial independence [338]. The instrument is designed to assess the quality of practice guidelines across the spectrum of health, provide direction on guidelines development and guide what specific information should be reported in the guidelines [149]. Guidelines developed with this rigour provide a foundation for future exercise research and a benchmark to facilitate exercise monitoring and surveillance [151].

The most popular lead for interventions is a physiotherapist. Physiotherapy plays a significant role in the healthcare of PWMS [339]. Because fitness professionals may be inexperienced in working with people with disabilities, physiotherapists are preferred to develop fitness programmes[340]. However, current physiotherapy services are not meeting the needs of PWMS [339]. PWMS have reported dissatisfaction with the lack of information about available services, excessive waiting times for appointments and the lack of accessibility and flexibility of physiotherapy services [339]. These findings suggest that services for PWMS need to be reviewed to provide greater access to physiotherapy services or a suitable alternative. In other conditions, such as people affected by cancer, the use of 'real-world' practitioners has been recommended to enhance the scalability of community-based interventions rather than rely on the physiotherapy profession [341].

Additionally, previous research suggests that physiotherapists are not trained to prescribe exercise. One study found that 66% of lecturers of undergraduate physiotherapy do not have the knowledge or confidence to educate physiotherapy students about exercise prescription[342]. Another study found that only one-third of responders to a survey (319 physiotherapists and 270 students) could name the national physical activity recommendations[343]. To fulfil the role of exercise prescribers, physiotherapists would need to expand their role from the treatment of impairment to include health-focused practice [343].

Another option is to partner physiotherapists with exercise professionals to provide exercise support, which has been successfully used in PWMS[344].

5.6.2 Are BCT incorporated into the interventions?

Researchers have highlighted the need to embed behaviour change theory to enhance long-term change [59]. The appropriate use of theory and theoretical determinants is believed to enhance intervention effectiveness [345]. Theories are needed to explain and predict health behaviour and design and evaluate interventions [346]. Most studies in this review specified or suggested using behaviour change theory. The interventions included in this study are generally theory-informed (e.g. those that vaguely describe theory use [345]) rather than theory-driven (e.g. those that integrate theory throughout programme planning, design, and evaluation [345]). Most studies did not report using a formal process by which the intervention and theory were developed. A systematic approach to intervention development, such as intervention mapping [347], the Theoretical Domains Framework [348] or the Behaviour Change Wheel [349], could enhance the planning and reporting of theory application and contribute to evidence for appropriate behaviour change strategies [345]. The interventions tended to be informed by SCT, the most applied theory in the reviewed papers. SCT is the most consistently applied theory for understanding exercise for PWMS [260]. Previous research has highlighted self-efficacy as the significant variable from SCT to increase exercise behaviour[263]. A crucial theoretical mediator within SCT that links self-efficacy to behavioural success is goal setting [350]. People with greater confidence in their ability tend to set more challenging goals and persist to a greater extent in the face of adversity [350]. This highlights the importance of building self-efficacy in PWMS, as fear of worsening their condition is a barrier for PWMS [192].

5.6.3 Are community-based exercise interventions acceptable, safe, and effective for people with MS?

Overall, the evidence suggests that community-based exercise interventions result in a statistically significant result for increasing exercise behaviour. Participants discussed the positive changes experienced from the community-based interventions, including physical changes, improvements in fatigue, and confidence. The results suggest that community-based interventions are safe. Although participants in several studies experienced adverse events, none were serious. Exercise training is not associated with an increased risk of relapse, and adverse events are not higher in MS patients than in healthy populations [351] Safety was identified as an essential consideration for PWMS when deciding whether to exercise. PWMS have previously discussed the need to exercise in a safe environment [193].

5.6.4 What do people with MS see as the important aspects of a community exercise intervention?

Several factors need to be met for a community-based exercise intervention to be successful. For PWMS barriers to exercise include, the built environment, access to exercise equipment, access to information about programs, fatigue, emotional and psychological factors, economic factors, and transportation [352]. The relative proximity of exercise resources is related to exercise participation [353]. Eliminating the need to travel is a possible reason that home-based exercise is the most common mode of delivery for community-based exercise interventions. However, exercising under supervision in an exercise facility can have a more significant effect than exercising at a person's home without supervision [103]. Participants in the reviewed papers appear to find each mode of intervention delivery valuable in supporting them to be more physically active. It is, therefore, difficult to determine which model is preferred. Fitness instructors delivered only two of the community-based exercise programmes. The PAGs for MS were developed to increase the availability and development of more fitness programmes and facilities for PWMS [25]. The need for knowledgeable instructors was identified as a factor for the success of a community-based intervention in the qualitative synthesis. In other conditions, such as people affected by cancer, qualified professionals are central to an exercise pathway[354]. NICE guidelines stipulate minimum qualifications for exercise professionals devising exercise programmes for referral programmes[355]. These qualifications are a level four exercise referral qualification and relevant CPR training [355]. Level 4 refers to a 'specialist exercise instructor' and is endorsed by the Chartered Institute for the Management of Sport & Physical Activity (CIMSPA) [356,357]. The challenge is finding a better clinical care model in which health professionals and exercise specialists work more closely together to provide medically directed exercise programmes appropriate for each individual[358]. Carter and colleagues completed a 12-week supervised exercise programme led by experienced exercise specialists with support and input from neuro-physiotherapists. Participants valued access to knowledgeable practitioners[192]. Physiotherapists working in partnership with community physical activity providers are one way to develop the confidence of health professionals and PWMS in community-based exercise [329].

5.6.5 Strengths and limitations of the review

To the candidate's knowledge, this is the first scoping review of community-based exercise interventions for PWMS. There are also several limitations to this scoping review. I did not consider the quality of the article designs nor whether any of the modes of exercise or the applied behaviour change theories was superior. Due to the studies in this review having methodological flaws (e.g., small sample size, no comparison group), we must interpret the results cautiously. Also, I restricted the search strategy to databases that cover health and public health literature (e.g., PubMed, SCOPUS, Science Direct, and Web of Science). I could not search all science databases and restricted our search to English-language articles published from 2005 to 2018. Therefore, there is the risk that I did not identify all relevant studies. There are 24 papers included in this review (17 intervention papers and seven qualitative papers) which prohibits a comprehensive assessment of a complex research area.

5.6.6 Implications for the physical activity guidelines

Research suggests that the current PAGS for PWMS are only being used sporadically in the community. This suggests a paucity of research investigating the implementation of the PAGs in the community. PAGs provide a benchmark for community-based practitioners to facilitate and monitor exercise [151]. However, for the guidelines to be effective in the community, they should be presented along with evidence-based resources that teach and encourage people to achieve them. By engaging stakeholders (PWMS and HCPs) in the development of PAG-informed community-based interventions, I can ensure that I address any concerns and preferences, which will result in evidence-based interventions (using the PAGs) and meaningful to the potential end users (PWMS).

5.7 Conclusion

Findings from this scoping review suggest that the evidence base for community-based exercise interventions for PWMS is in its infancy. There need to be community-based practitioners capable of working with PWMS to increase the availability and access to exercise support. The NICE guidelines offer recommendations of the appropriate qualifications for exercise professional prescribing exercise for people with chronic conditions [355].

Theory-driven interventions are essential for the successful promotion of healthy behaviours. Community-based interventions should be based on the relevant theory that guides the intervention design, delivery, and evaluation. The results from the review will be used to inform the development of a community-based intervention for PWMS.

5.8 Additional papers

The scoping review aimed to explore the current literature on community-based exercise interventions for PWMS. The original search criteria for the study was for research conducted between 2005 and 2018. Whilst in the write-up phase of the research, the PhD candidate repeated the literature search to include studies conducted from 2018-2022. The search found seven eligible intervention papers [359-365] and three qualitative papers [333,366,367].

All seven intervention papers included home-based activity, possibly due to the impact of the COVID-19 pandemic during this period. However, two studies included a mix of home and venue-based interventions [364,365]. The studies by Fleming and colleagues [361,365], included a feasibility and subsequent randomised controlled trial to explore the effects of a home-based Pilates intervention. Three interventions based the exercise prescription on the MS-specific PAGs [25]. Only two studies specified the use of behaviour change theory. Baird and colleagues [360] used SCT, whilst Van Geel et al., [363] used goal setting and coaching.

The qualitative literature search found three additional papers that met the inclusion criteria [333,366,367]. Qualitative findings for interventions in a community venue (e.g. gym) included the importance of a supportive and inclusive environment [366] and the need for knowledgeable and supportive trainers [366]. Findings from home-based interventions included reduced accessibility [367]. Participants valued Pilates exercise due to its low intensity and did not exacerbate fatigue [367]. Participants from one study acknowledged the importance of having behaviour change theory throughout an intervention [333]

These additional findings from the updated literature search suggest that the evidence base for community-based exercise interventions has not significantly progressed between 2018 and 2022. The use of evidence-based guidelines and behaviour change theory are still used sporadically.

6 Exploring patient and professionals' views on the key components of a community-based exercise intervention to support PWMS to be physically active

6.1 Overview

Chapter 3 discussed a qualitative project with people with moderate-to-severe MS. Whilst there are PAGs for people with mild-to-moderate MS [25], the literature does not include recommendations for people with higher levels of MS [145]. Nevertheless, as discussed in chapter 2, despite the evidence of the beneficial effects of exercise, people with mild-to-moderate MS are inactive[368] The discrepancy between the benefits of exercise and the lack of engagement highlights an essential question in this PhD "how do we support PWMS to exercise in the community?"

This study aimed to explore the perspectives of both patients and healthcare professionals regarding the critical components of a community-based exercise intervention specifically designed to support PWMS in maintaining an active lifestyle. By gathering insights from multiple stakeholders, I was able to develop a framework that can inform the design and implementation of effective exercise interventions tailored to the needs of PWMS, which will be discussed in succeeding chapters.

To ensure the comprehensive representation of perspectives, this study involved the participation of two key groups: PWMS and healthcare professionals with expertise in MS management. A holistic understanding of the essential components of a community-based exercise intervention for PWMS can be achieved by including both patient and professional perspectives.

This study builds upon previous research investigating the benefits of physical activity for PWMS and their challenges in engaging in exercise. Incorporating the perspectives of patients and professionals expands upon existing knowledge by providing a deeper understanding of the critical components necessary for successful community-based exercise interventions.

6.2 Introduction and rationale

Chapter 5 highlighted that more work is needed to develop community-based interventions for PWMS. Despite the existence of the PAGs, community-based exercise opportunities are not widely available. As discussed in Chapter 5, for the PAGs to be implemented in the community, capable practitioners must work with PWMS to increase the availability and access to exercise support. An additional challenge for researchers and HCPs is to stimulate PWMS to independently start exercising in their community and continue to be active [18] In other health conditions, such as cardiovascular disease and stroke, multifaceted and multidisciplinary disease rehabilitation and exercise programmes are recognised as an integral part of disease care [369]. Over time comprehensive and detailed guidelines on cardiac rehabilitation have been developed [370]. There are no comparable recommendations for PWMS, highlighting a gap in research and an opportunity to develop care for PWMS.

This study aimed to explore the views of PWMS and health professionals regarding a community-based exercise programme. The research questions included: 1) what critical components are needed to create a model of community exercise for PWMS? 2) What are the needs and preferences for a future exercise programme?

6.3 Study aims

(1) To explore the views of people with mild-moderate MS and HCPs on exercise participation for PWMS

(2) To explore the views of people with mild-moderate MS-related disability and allied health professionals regarding the development, implementation, and delivery of a community-based exercise intervention

6.3.1 Objectives

(1) To explore the attitudes and barriers regarding participation in exercise.

(2) To explore the attitudes and barriers to prescribing exercise for PWMS

(3) To discuss and identify crucial components PWMS would like to see in an intervention and how this should be delivered

(4) To discuss ideas regarding the content of a community-based intervention

6.4 Methodology

6.4.1 Study design

The study adopted a qualitative design involving semi-structured interviews and focus groups to explore the design of a community-based exercise intervention. Ethical approval was granted by Sheffield Hallam University Ethics Committee (ER5147628). NHS ethical approval was not sought for this study. The PhD candidate completed the HRA decision tool, which determined that NHS REC was not required. Exclusions from NHS ethics include: Research where participants have been identified independently of the NHS but because they have a condition that was diagnosed by the NHS. Research involving NHS or social care staff recruited as research participants by virtue of their professional role.

Participants could choose a preferred mode; an interview (face-to-face or telephone) or a focus group; this allowed the project to be more accessible and practical to participants. Semi-structured interviews were chosen as they provide an evidence-based structure yet remain flexible, allowing participants to discuss topics that naturally emerge through conversation. All participants provided informed written consent before involvement in the trial. Discussion groups were led by a researcher experienced in facilitating group discussions (PhD candidate). The semi-structured interviews and focus groups followed schedules (Appendix H and I) to ensure that the same topics were covered across all modes of data collection. The research team developed the interview schedules.

6.4.2 Setting

Interviews were scheduled at a time and place convenient to the participant. Telephone interviews were also an option for participants. Focus groups were held at a venue within the participant's local area.

6.4.3 Participants

Adults (over 18 years) with a diagnosis of MS were invited to participate in this study. Potential participants were purposefully sampled from community-based MS clinics in Sheffield and Rotherham, the local community, and Facebook groups. An individual with mild-to-moderate MS-related disability was the targeted strategy. The PDDS [180] measure was used to determine the disability level of participants. The PDDS is a simple questionnaire that strongly correlates with the EDSS [238]. Interested individuals were given a participant information sheet. The lead researcher (PhD candidate) contacted the person later to see if they would like to participate. Potential participants had the opportunity to ask questions and clarify any issues.

Collaborating with the Sheffield Teaching Hospitals and local MS clinics identified a comprehensive list of vital professional stakeholders. Professionals were those individuals who have a role in the treatment and management of PWMS or who work closely with PWMS in the community and could have a role in recommending PWMS to a future community-based exercise intervention. The lead researcher (PhD candidate) contacted the professional stakeholders via email. Individuals who replied to the emails expressing an interest in participating were contacted within 48 hours by telephone to schedule an interview or focus group.

6.4.3.1 People with MS

Participants (n=10) were recruited from community neurological therapy centres in Sheffield and Rotherham. Characteristics of PWMS are displayed in Table 20.

Table 20: Characteristics of PWMS

Participant ID	Gender	Age (y)	PDDS
P1	Female	48	2
P2	Female	40	1
P3	Male	37	1
P4	Female	28	1
P5	Female	52	2
P6	Female	56	2
P7	Female	46	5
P8	Female	30	1
P9	Male	59	5
P10	Male	45	3
	Female = 70%; Male 30%	Mean = 44 ±9.9	Mean = 2.3

6.4.3.2 Professionals

Professionals (n=9) were approached from community neurological therapy centres in Sheffield and Rotherham. Professionals included consultants (n=1), MS specialist nurses (n=3), physiotherapists (n=4), and rehabilitation specialists (n=1). Characteristics of professionals are displayed in Table 21.

Table 21: Characteristics of professionals

Participant ID	Gender	Age	Job role
HCP1	Female	52	MS Nurse
HCP2	Female	41	Neuro Physiotherapist
HCP3	Female	51	Neuro Physiotherapist
HCP4	Female	26	Rehabilitation Specialist
HCP5	Female	28	Neuro Physiotherapist
HCP6	Female	54	MS Specialist Nurse
HCP7	Female	49	Neuro Physiotherapist
HCP8	Female	45	MS Specialist Nurse
HCP9	Female	55	Neurologist
	Female = 100%	Mean 45 ±10.3	

HCP= HEALTHCARE PROFESSIONAL

6.4.4 Data collection

Two focus groups (n=3 and n=4) for professionals and PWMS were held at a community facility. Each focus group lasted up to 60 minutes. The lead researcher (PhD candidate) conducted 12 interviews: six with PWMS and six with health professionals. Interviews with PWMS lasted between 15 and 45 minutes (median = 27 minutes). Interviews with professionals lasted between 24 and 44 minutes (median = 31 minutes). All interviews and focus groups were audio-recorded. The audio recordings were transcribed verbatim by an independent source and checked for accuracy by the researcher (PhD candidate).

6.4.5 Data analysis

Framework Analysis (chapter 1) was used to analyse the data generated from focus groups and interviews [371]. Framework Analysis is a practical approach for analysing rich data in pragmatic health services research[371]. NVivo Version 10 data analysis software was used to facilitate the framework analysis as this is a valid and reliable tool, enhancing the data analysis procedure[372]. A second researcher then independently reviewed the thematic framework to improve the reliability of the data. Themes were discussed and refined before a consensus was agreed.

6.5 Results

Results are displayed according to higher-order and lower-order themes from the data, in line with the framework analysis technique [371]. Table 22 illustrates these higher-order themes and corresponding subthemes. Three higher-order themes were identified across PWMS and HCPs. Specifically, views on exercising for PWMS, barriers to exercise and critical factors for an exercise service were identified as higher-order themes. Appendix J and K are examples of coding frameworks. Quotes are included to illustrate the themes for PWMS and HCPs.

Table 22: Higher and lower order themes

Higher-order themes	Lower-order themes
Views on exercise for PWMS	The benefits of exercise Negative experiences from exercise
Barriers to participating in exercise for PWMS	The physical effects of MS The debilitating effects of fatigue Fear of making their condition worse There are challenges to promoting exercise to PWMS, and is not often a priority
Critical factors to ensure a community-based exercise service is effective for PWMS	We need to create a sociable environment Deliverers of the service must be appropriately trained Participants may need to be stratified by level of disability Improving physical function is an important outcome

6.5.1 Theme 1: Views of exercising for PWMS

PWMS recognised the value of exercise and described this in terms of physical and psychological benefits. Participants also raised some negative experiences regarding exercising.

6.5.1.1 The benefits of exercise

PWMS discussed how exercising could help manage their condition, alleviate symptoms, and possibly slow their functional decline. Some participants (n=2) felt that exercise helped their psychological well-being.

"I feel better in general; the symptoms seem to subside slightly, or I notice them less. They become easier to live with." (P1, female, 40)

"I like walking, and some poor souls with MS don't have that skill, so I walk as much as possible, so I don't lose the ability." (P5, female, 52)

"I want to be high up so that as I decline, I'm declining from a higher functioning system. Now hopefully I could go longer, that was my logic. Probably true actually." (P9, male, 59)

"It's more a state of mind as well, I think. The state of mind, it makes you a bit more positive." (P8, female, 30)

It was evident during the interviews that professionals felt that exercise is essential for PWMS.

Perceived benefits included the management of MS symptoms, improved movement, quality of life, and reduced risk of comorbidities.

"Very many of the common symptoms that affect patients with MS such as limb weakness, spasticity, low mood, and MS fatigue, exercise plays an important part in improving that for patients." (HCP8, MS nurse specialist)

"To gain better movement and better life quality exercise is part of it." (HCP7, neuro-physiotherapist)

"In terms of preventing onset of comorbidities, someone's had their diagnosis at 30, what we don't want is because they become sedentary maybe their BMI gets high but by the time they're in the mid-50s they've also got type 2 diabetes and all other risk factors that come with a sedentary lifestyle as well." (HCP2, neuro-physiotherapist)

6.5.1.2 Negative experiences from participating in exercise.

Although PWMS understood the benefits of exercise, eight participants also discussed how they had negative experiences after engaging in exercise, primarily because of fatigue.

"I was supposed to feel better the next morning, but that never happened! I used to get rid of all my energy doing the exercise class and knock out the next day as well." (P7, female, 46)

"It does make you feel tired and fatigued if you do it wrong." (P10, male, 45)

6.5.2 Theme 2: Barriers to participating in exercise

Despite acknowledging that exercise is positive for their health, PWMS identified several barriers to exercising. These barriers included their condition, making them physically and psychologically unable to exercise. Participants discussed having difficulties with balance, mobility, fatigue,

6.5.2.1 The physical effects of MS

PWMS felt that the condition's impact on them physically, such as mobility (n=5), balance (n=6), and bladder control (n=1) made participating in exercise challenging.

"Apart from fatigue, impact on daily life in my case is the distance that I can go and on a really, really good day with the wind behind me and a perfect surface, I can go a mile, but on a bad day I can go nowhere." (P6, female, 56)

"I have all this stiffness, and my balance is off." (P10, male, 45)

"The one thing we're probably too polite to mention is your bladder, which in some people that is just the most horrendous symptom, no bladder control at all." (P5, female, 52)

6.5.2.2 The debilitating effects of fatigue

PWMS also discussed the effects of fatigue and how it impacts all aspects of life. HCPs also identified fatigue as a major barrier for PWMS engaging in exercise.

> *"You might get up one morning, and you feel as if you can rush through everything and get everything done and you get partway there and then boom, that's it." (P5, female, 52)*
>
> *"It's like you've run into a wall, and then it's like I'm walking through water or treacle. My mind is wanting to go three steps in front, but my legs and arms and whatever I'm trying to do won't keep up." (P6, female, 56)*
>
> *"Not having the energy to do something else. So, if you've got a limited amount of energy, you've got to ration it. It's like having a glass of beer. When you've drunk it all, it's all gone, so you've got to make sure that you have a sip to quench your thirst and a sip to make you kind of tipsy, and it's the same idea with MS really." (P7, female, 46)*
>
> *"MS fatigue, I think, is one of the biggest blockers" (HCP8, MS specialist nurse)*

6.5.2.3 Fear of making their condition worse

Fear was identified as a significant barrier to exercising. PWMS are afraid of doing too much or the wrong exercise and making their condition worse.

> *"I'm just frightened of getting really tired or whether I'm frightened that actually through exercising I might make myself have a relapse which I don't think that's true." (P5, female, 52)*
>
> *"I think on a personal level I have to say is it going to harm me?" (P9, 59, male)*

HCPs acknowledged the barriers that PWMS face when engaging in exercise. Professionals discussed how PWMS often feel self-conscious and intimidated by conventional exercise opportunities (i.e., a gym). Other barriers include fatigue, balance issues, and joint issues can affect the individual's confidence and inability to be physically active.

> *"They are often self-conscious about going to classes or gyms and worried about whether they could keep up with them." (P11, MS specialist nurse)*
>
> *"People have reported in the past feeling intimidated exercising in a normal class." (HCP8, neuro-physiotherapist)*
>
> *Even if they look well, they might have balance issues and things. Also, the whole hour is sometimes a lot for someone to do which most classes are. If they get really bad fatigue trying to do that, whole hour can be difficult. (HCP6, MS Specialist Nurse)*

6.5.2.4 There are challenges to promoting exercise to PWMS, and it is not often a priority

A further barrier to PWMS engaging in exercise is the promotion of exercise from HCPs. Some HCPs (n=3), specifically MS specialist nurses, said they did speak to patients about exercise but acknowledged that it is easier if the individual is previously or already active. Most professionals discussed how it is difficult to talk to PWMS about exercise and that, often it is not the priority.

> *"The newly diagnosed will ask am I all right to carry on exercising, and we say yeah, you know, providing there's no issues." (P11, MS specialist nurse)*
>
> *"It can be easy if the person has been previously active but someone that has not been active for a long time it is difficult to get them to see the need" (HCP9, neurologist)*
>
> *"I think in the past we were possibly wary of prescribing exercise, particularly strength work because of fears around muscle tone changes but also fatigue as well." (P12, neuro-physiotherapist)*
>
> *"We work under a very medical model, so clinical management will always take priority" (HCP9, neurologist)*

6.5.3 Theme 3: Critical factors for an exercise service

6.5.3.1 Opportunities to socialise are important to PWMS

The majority of PWMS and HCPs felt that the social aspects of exercise would be beneficial and therefore preferred group exercise.

> *"I'm quite sociable, so it's nice to go to a group. Like going to the gym on my own is always a little bit daunting and a bit boring." (P8, female, 30)*
>
> *"Getting people together and the sociable part of the exercise is vital, and people with neurodegenerative diseases will have problems with socialising and introducing new ways of socialising for them. And that's great." (P9, male, 59)*
>
> *"I think it would be nice if you want to do an exercise and you can't bring yourself to do it because you've got MS then it would be nice to think, oh I'll go to a class where I'll fit in." (P6, female, 56)*
>
> *"It might be more beneficial for the people with the condition to actually go somewhere as a class more. Because it's not only that, it's the social side of it." (HCP1, MS specialist nurse)*
>
> *"People improve because they left their home environment and groups are going are you all right today? That sort of thing, and they will always go for a coffee after. I think that's the other thing we're forgetting is the social." (HCP7, neuro-physiotherapist)*

6.5.3.2 *The need for appropriately trained personnel*

Both PWMS and HCPs stressed the importance of a service being led by a person with knowledge of MS. Physiotherapists were discussed as an ideal option, but any person with an understanding of the condition would be acceptable. Neuro-physiotherapists (n=2) suggested an ideal model would be exercise professionals supported by neuro-physiotherapists.

> *"I'm very reluctant to join a gym or anything like that without having somebody that's got the expertise and knows a bit about the condition" (P1, female, 48)*
>
> *"I think if it's something that merits a physio because if you have a condition like this, you can understand what they are, and you trust them instinctively." (P7, female, 46)*
>
> *"I think as long as they're sufficiently trained I would be happy because I don't necessarily think that I'm, I, at the moment, require physio. I'd just like people to be able to say, you know, exercise like this or try that." (P2, female, 40)*
>
> *"The physios views do carry more weight" (HCP8, MS specialist nurse)*
>
> *"They will need to work with a personal trainer. someone who has an understanding of the condition." (HCP4, rehabilitation specialist)*
>
> *"The ideal would be this, that a physio is part of the structure involved, but I don't see how an exercise professional isn't part of that structure. So I see them working alongside." (HCP7, neuro-physiotherapist)*

6.5.3.3 Groups may need to be stratified by level of disability

Professionals suggested that any exercise groups for PWMS would need to be stratified by disability levels. Professionals felt that having mixed disability levels would be difficult to manage and demotivating for some participants. Although PWMS thought group exercise would be beneficial, they also felt that any exercise group would need to be stratified by level of impairment. PWMS discussed how seeing people with higher disability than them would have a negative impact.

> *"I try to kid myself that I'm normal and try to be as normal as possible, so I wouldn't like to go to a group where there's a lot of wheelchair-bound people that sort of thing that are quite progressed with the disease really." (P1, female, 48)*
>
> *"What I would absolutely hate would be to go to a class where there were people who were more visibly limited, with limited functionality than I have, because that would serve no purpose other than to terrify me." (P2, female, 40)*
>
> *"I think it'd probably be a good idea to put people in, in groups where they're all very similar, and you can share your experiences and probably not scare the people who aren't some experiences." (P4, female, 28)*

> *"Having people who are minimally disabled and people with mobility in the same group will be very challenging." (HCP7, neuro-physiotherapist)*
>
> *"even in our clinics in waiting rooms, people will say that they don't like being sat in the waiting room. They say they always feel awful for saying it, but they're saying no I don't want to see that might happen to me." (HCP5, neuro-physiotherapist)*
>
> *"people who are early on with MS or quite well, they often don't want to mix with people whose MS is worse because they don't want to see how they might be. And I think if people went to a class where there were a lot of disabled people, they'll probably not want to carry on." (HCP6 MS specialist nurse)*

6.5.3.4 Improving physical function is an important outcome.

PWMS discussed what goals they would like to achieve from an exercise programme. The outcomes were varied but centred around functionality and improving symptoms.

> *"How fast can I open the pages of a book, do I find that difficult? How fast can I take my coins out of my wallet, because I found that difficult, and those sort of things that matter, can I carry a cup of tea and a bowl of cereal across the room to have my breakfast, that sort of measurement I think is very useful. (P6, female, 56)*
>
> *"If you were doing some form of exercise and you felt it was benefitting your symptoms, then obviously that is, that's a good thing to do." (P1, female, 48)*
>
> *"I mean improve my balance and my walking." (P10, male, 45)*

6.6 Discussion

This qualitative study explored the views of PWMS and HCPs regarding exercise for PWMS and the development, implementation, and delivery of a community-based exercise intervention. Despite HCPs and PWMS's knowledge of exercise benefits, both groups interviewed in this study identified numerous barriers that prevent PWMS from engaging in exercise. The findings presented suggest that both PWMS and HCPs support community-based physical activity. Identified critical success factors were appropriately trained deliverers, social support, and stratification of groups.

6.6.1 Exercise for PWMS

For people with mild-to-moderate MS, physical activity is safe and worthwhile. This has led to statements indicating that exercise training is one of the best approaches for managing MS that can be included in comprehensive care [373]. Overall, professionals and PWMS agreed that exercise is beneficial for PWMS. Professionals discussed how exercise could help manage MS symptoms, improve quality of life, and reduce the risk of developing comorbidities. Additionally, PWMS identified benefits such as helping to manage the condition, alleviate symptoms, and slow their functional decline.

Results from this study highlighted the ambivalence PWMS and HCPs feel toward exercise in this population. MS is a variable disease, and a person can have several symptoms that affect their ability to be physically active. Kayes and colleagues [198] stated that due to the variable nature of the condition, the decision to be physically active is made daily. In the present study, PWMS discussed effects such as poor balance, high levels of fatigue, and poor bladder control. Additionally, PWMS expressed fear in different ways; participants spoke of the fear of exacerbating MS symptoms through exercise, fear of being given exercise advice from an exercise specialist inexperienced in working with PWMS, and fear of being in situations with people with higher MS impairment than themselves. These views are consistent with previous research showing that PWMS felt poorly informed about exercise and perceived a lack of appropriate services [330].

Physical activity promotion by HCPs is known to influence physical activity behaviour in a range of clinical populations [374]. Discussions with HCPs suggested that exercise promotion is not a priority in MS care. It has been reported that 75% of PWMS do not have conversations about exercise with HCPs[373]. This is also an issue in other conditions, such as cancer, where 56% of clinicians do not discuss exercise with their patients [375]. A possible reason for this is a lack of education on the benefits of physical activity within medical schools[376]. Previous research found that HCPs want to receive further education on exercise promotion, as they currently feel ill-equipped to have the conversation[377]. In the present study, the main barriers for HCPs discussing exercise appear to be weariness due to the patient's MS symptoms (e.g., fatigue), prioritising medical intervention and perceived lack of interest from the patient. This echoes previous research in which HCPs related physical activity to the person's condition, framing risks and benefits in this context[378]. A biomedical focus on physical activity by HCPs could lead to overemphasising the physical and functional aspects of physical activity and ignoring the social and psychological benefits [374,378]. HCPs can play a crucial role in changing the behaviour of people with chronic conditions [379] by emphasising the benefits for overall health and quality of life as well as symptom management and assuring that it will not worsen their MS [380].

Uptake of exercise is an issue for PWMS, with fewer than 20% of PWMS engaging in sufficient levels [381]. Increases in exercise behaviour correspond with decreased rates of change in functional limitation [382]. Therefore, connecting PWMS to exercise opportunities early in their MS care could significantly impact the progression of their condition. Introducing exercise early in the disease course could be a window of opportunity where disease-modifying therapy is particularly effective [239].

6.6.2 Critical factors for a community-based exercise intervention for PWMS

Presently, community-based physical activity opportunities for PWMS are limited [256]. Progress in cardiac and stroke rehabilitation could serve as examples to help accelerate community-based accessibility [383,384]. Cardiac rehabilitation programmes have become a fundamental part of standard care in modern cardiology [385]. This was not always the case as early cardiac rehabilitation pioneers experienced opposition to advocating physical activity for patients[385]. Over the past 50 years, cardiac rehabilitation has evolved into a multidisciplinary approach focusing on patient education, individually tailored exercise training, and the patients' overall well-being[383]. However, even when offered, only a minority of eligible patients attend cardiac rehabilitation programs.

MS participants felt the social side of exercise is vital, in line with previous research [192,329,335]. Once diagnosed, PWMS can feel isolated; helping them get out of the house and meet other people in a supportive environment is desired. Nevertheless, the present study's data suggest that an exercise class's group dynamics must be managed carefully. The PWMS felt anxious about being in a group with people with higher levels of impairment because of the progressive nature of MS. Previous research has highlighted the anxiety PWMS feel towards future disability, and a significant motivator to being active is avoiding impairment/disability[386]. ‘Move it or lose it’ is a commonly used expression by PWMS, highlighting the potential to conflate exercise promotion with the prevention of disability [386]. HCPs also felt that without stratification, the classes would be unmanageable. Due to the varied nature of MS, people can have vastly different symptoms, including people with mild impairment from MS [387]. PWMS expressed a desire that exercise programmes in a group setting still be tailored to the individual, for example, to help people with balance issues or unilateral imbalances. This finding is consistent with previous recommendations that PWMS require an individual plan that starts with a functional assessment, and any issues found in the assessment will then determine the mode of exercise prescribed [110].

In the present study, PWMS indicated that they did not trust exercise professionals' skill and knowledge levels in the fitness industry. The importance of quality instructors is supported by previous qualitative research in other conditions, such as cancer [329]. HCPs also voiced apprehension about PWMS exercising under the supervision of exercise professionals. Both groups felt that a physiotherapist should see PWMS, which matches the findings from Chapter 3. Additionally, most community-based interventions are led by physiotherapists. However, several health professionals felt there are no reasons exercise professionals should not see people with mild-to-moderate MS in community exercise facilities as long as the instructor is appropriately trained. This is supported by researchers who feel the needs of PWMS can be met by fitness instructors in gyms providing a non-medical environment for exercise participation [388]. This recommendation was limited to individuals with MS who can walk independently or use one stick to walk outside [388]. One health professional suggested that physiotherapists are often too cautious with patients and that many PWMS do not need physiotherapist support but would benefit from physical activity and exercise advice. PWMS most desire physiotherapy services [339], because they value professionals/leaders who have specialist, accurate knowledge about their conditions [389]. The challenge is to find a better clinical care model in which HCPs and exercise specialists work more closely together to provide medically directed exercise programmes that are appropriate for everyone [358]. Carter and colleagues [390] completed a 12-week supervised exercise programme that was led by experienced exercise specialists and had support and input from neuro-physiotherapists. Participants valued this access to knowledgeable practitioners [192]. Physiotherapists working in partnership with community exercise providers is one way to develop the confidence of HCPs and PWMS about community-based exercise [329].

6.7 Summary and conclusion

6.7.1 Strengths and limitations

Conducting interviews and focus groups with PWMS and HCPs meant this study could explore the stakeholders' views on a potential community exercise intervention. The open-ended nature of the interview schedules allowed the participants to raise the issues that were significant to them. Nevertheless, the sample was small and drawn from a single UK city. All participants participated in the study by choice; therefore, it is possible the project only spoke to people with positive views towards physical activity. Additionally, all HCPs involved in the study were female, presenting a gender bias. Caution should therefore be applied in generalising these findings to other populations.

Furthermore, as the research is qualitative, researcher bias could have affected how data is interpreted and analysed. The primary researcher has worked extensively within exercise for PWMS research. By the researcher acknowledging this bias and agreeing to use peer evaluation of findings, the potential for researcher bias is reduced, and the credibility of results is increased [391]. At the end of chapter 9, a short personal reflection section will be included that critically discusses these assumptions and their possible impact on the research.

6.7.2 Implications for the physical activity guidelines

The PAGs for PWMS recommend that people with mild-to-moderate MS participate in at least 30 minutes of moderate-intensity aerobic exercise plus muscle strengthening exercise twice weekly. However, as discussed in the current and previous chapters, PWMS face several multi-level barriers to participating in exercise or physical activity, such as fatigue, mobility issues, pain, fear, transportation, facility and equipment access, and appropriate training amongst fitness professionals. Given these barriers, it is unsurprising that PWMS are less active than the general population [27,157,159]. PAGs should be formulated by considering the benefits, risks, barriers, and preferences of the people whom the guidelines are targeting. For example, in the current chapter, the participants discussed how an exercise programme should be individually tailored and paced, primarily because of the varied and unpredictable nature of MS. Future iterations of the guidelines should include findings from qualitative research to ensure barriers, facilitators, and preferences are described.

6.7.3 Conclusions

The current study progresses the understanding of patient barriers and enablers to physical activity for PWMS. Physical activity is now accepted as safe and beneficial for mild-to-moderate MS. However, there is a need to build on research findings and increase the accessibility to physical activity for this population. Future community programmes should consider working more closely with local physical activity providers, increasing the knowledge and skills of fitness professionals, and providing PWMS with practical support to help physical activity be part of their everyday lives. With the evidence supporting exercise for PWMS, it is now time to make exercise support a part of standard care [392].

7 Developing a theory-informed community-based exercise intervention for people with multiple sclerosis

7.1 Overview

Previous chapters in this thesis have explored the limitations of the PAGs for PWMS. Chapter 5 explored community-based exercise interventions for PWMS and identified the need to develop evidence-based community interventions for PWMS. Chapter 6 presented data relating to PWMS and HCP's perceptions of barriers and enablers to physical activity for PWMS, and the key concepts required to develop an intervention.

To address these challenges, I felt there was a growing need for theory-informed, community-based exercise interventions that are specifically tailored to the unique needs and preferences of individuals living with MS. The following chapter aims to develop a theory-informed community-based exercise intervention for PWMS in response to this need. The intervention was developed using the UK Medical Research Council (MRC) guidance steps for developing complex interventions[393] and the behaviour change wheel (BCW) [59].

The MRC guidance emphasises the importance of using theory in intervention design. However, it does not provide any suggestions on how to do this-[394]. As discussed in Chapter 5, the social cognitive theory is the most used behaviour change theory in the MS literature. However, these interventions have been used in a top-down approach with minimal detail on the process of developing the intervention using theory [294].

There are over 100 behaviour change theories with no clarity on how to select an appropriate theory to impact the intended behaviour[395]. The BCW has been developed to provide a detailed framework for developing behavioural interventions [59]. The MRC guidance and the BCW will provide a transparent 'bottom-up' approach to intervention development. Additionally, the BCW includes the COM-B and the theoretical domains framework, which provide numerous theoretical constructs to use that one singular model could not.

The development of this theory-informed community-based exercise intervention builds upon previous chapters in this thesis, which have explored the experiences, barriers, and facilitators to exercise among individuals with MS. By incorporating the insights and findings from these studies, the intervention seeks to address the identified barriers and leverage the facilitators to promote sustained engagement in exercise in the community.

The comprehensive understanding of behaviour change provided by the BCW and the incorporation of qualitative research findings allowed for the development of an evidence-based intervention. Following chapters will build upon this foundation by evaluating the acceptability and potential impact of the developed intervention, exploring potential modifications or adaptations to meet specific subpopulations' needs, and identifying strategies to facilitate the implementation and dissemination of the intervention in diverse community settings.

7.2 Introduction

Policymakers, health professionals, patient groups, the public, designers, and researchers develop interventions, programmes, or innovations to improve health [396]. The UK MRC guidance for developing complex interventions emphasises the importance of using theory when designing interventions[393]. Chapter 5 outlined the main reasons for advocating the use of theory. These include 1) more effective interventions, 2) enhanced evaluation, and 3) increased understanding of what works. In Chapter 5, ten studies included behaviour change theory, specifically the SCT. However, the studies did not report using a formal process by which the intervention and theory were developed together.

Currently, there is conflicting evidence on the use of theory in intervention design. Some evidence suggests that reporting the use of theory results in larger effects[397], whilst others found no effects from applying theory in intervention design[345]. One review found that the studies which reported using theory to inform intervention design (n=2) had less impact than the interventions which did not report a theory base [398]. A further review highlights the potential for inconsistencies in applying theories to interventions [293]. Of the 190 studies included in the review, 56% (n=107) were explicitly based on theory. However, less than 10% of the 107 interventions (n=10) reported targeting all the constructs within a specified theory [293]. The review also found no difference in outcomes whether a theory was applied or not[293]. Several frameworks have been developed to design and evaluate complex interventions that give the theory a central role in the process [399]. One of these approaches is intervention mapping.

7.2.1 Intervention Mapping

Intervention mapping is a planning framework that provides a systematic process for practical, step-by-step decision-making for intervention development, implementation, and evaluation [400]. The steps and procedures included in intervention mapping provide a system for integrating theory, empirical findings from the literature, and information collected from the target population [347]. Intervention mapping consists of six steps[401].

(1) Develop a logic model of the problem on a needs assessment
(2) State program outcomes and objectives – a logic model for change

(3) Develop the program plan, including scope, sequence, change methods, and practical applications
(4) Produce the intervention, including program materials and messages
(5) Plan program use, including adoption, implementation, and maintenance
(6) Develop an evaluation plan

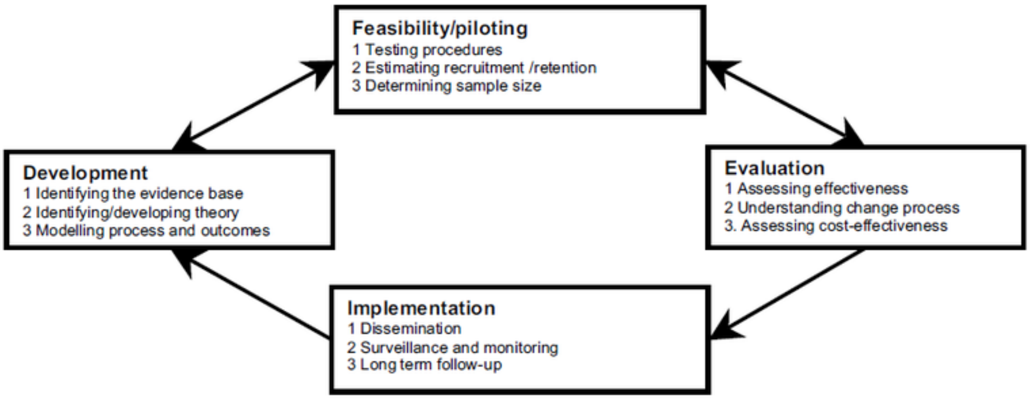
A limitation of intervention mapping is that it requires a significant investment of time and financial resources to implement [402]. Additionally, intervention mapping does not cover the full range of intervention options that may be important [349,396].

7.2.2 MRC Framework

The MRC published guidance on developing and evaluating complex interventions in 2006[393], with revisions made to the framework that was published in 2000 [403]. The guidance was being updated whilst this PhD was being completed. The latest version was published in 2021[404]. Additionally, process evaluation is now included in this framework and guidance on this has been published [405]. The MRC guidance focuses on four key phases: development; piloting/feasibility; evaluation; implementation (Figure 7). Each phase includes three steps to complete. This chapter will focus on the development phase of the MRC guidance.

The first step in the development phase is to identify the evidence base. The second step is identifying and developing the latest theory to underpin the intervention. The third step is to the process and outcomes of the intervention. These three steps must be completed before feasibility and piloting or a full-scale trial is completed. This allows for identifying intervention weaknesses and further iterations of the intervention design before a full trial is conducted [393].

Figure 7: Phases of the development of complex interventions



7.2.3 Behaviour Change Wheel

The MRC complex interventions framework does not suggest the most appropriate theory for intervention design nor how to implement a theory [294,394]. The lack of guidance creates the potential for intervention designers to miss critical theories from the vast number of theoretical models [394]. The behaviour change wheel (BCW) has helped to address this gap[59].

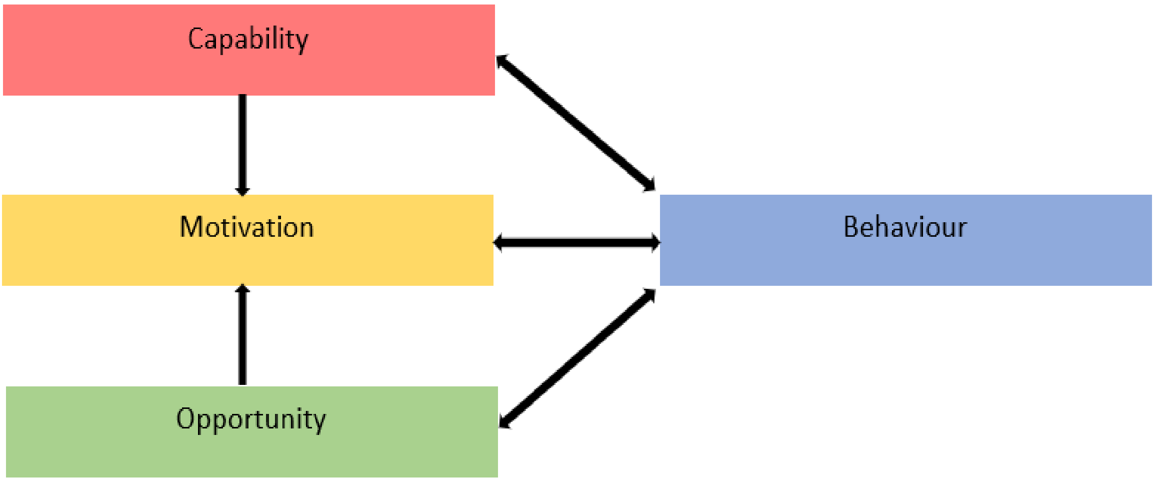
The main strength of the BCW, which includes the COM-B, Theoretical Domains Framework (TDF), and the intervention functions, is that it provides a wide range of theoretical constructs allowing researchers to ‘cherry pick’ relevant constructs from a variety of models[59]. Creating an intervention on a single model does not allow this flexibility. Using a broad theoretical framework for behaviour change, rather than a single model or theory, is a more thorough method of examining potential barriers, enablers, and possible mechanisms linking them to the target clinical behaviour [406].

To develop the BCW, Michie and colleagues[59] reviewed existing frameworks according to three criteria:

(1) comprehensiveness
(2) coherence
(3) links to an overarching model or behaviour

The review included 19 frameworks covering nine intervention functions and seven policy categories. The authors developed a new framework (BCW) from this. At the core of the BCW is the COM-B model (Figure 8), in which behaviour change is determined by requiring a shift in a person's capacity (C), opportunity (O), and motivation (M). The central idea of the model is that for any behaviour to occur, there must be the capability to do it, the opportunity for the behaviour to occur, and sufficient motivation to perform the behaviour [349].

Figure 8:The COM-B model



Each component of the COM-B model can be divided into two parts. Capability considers if an individual has the psychological (e.g., knowledge, skill) and physical capability (physical strength, skill) to engage in a behaviour[59]. For example, as discussed in chapter 6, PWMS often do not feel they can exercise because of their condition. Opportunity includes social opportunity, factors such as social norms or support, and physical opportunities such as time, resources, and location. Motivation includes reflective motivation, the individual's beliefs and goals, and automatic motivation, which considers habits and desires. As shown in figure 1 by the arrows, capability and opportunity can influence motivation [59].

The COM-B is at the core of the BCW [407] (and maps directly on the TDF (Figure 10)) [408]. The TDF provides a comprehensive, theory-informed approach to identifying determinants of behaviour. The TDF is a synthesis of 33 behaviour and behaviour change theories clustered into 14 domains [408]. The TDF is a theoretical framework rather than a theory; it does not propose testable relationships between elements but provides a theoretical lens to view the cognitive, affective, social, and environmental influences on behaviour [408]. The 14 domains of the TDF are knowledge, skills, memory, attention and decision processes, behavioural regulation, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, intentions, goals, reinforcements, environmental context, and resources, and social influences [407].

Unlike intervention mapping, the BCW encourages intervention designers to consider all the possible behaviours that might be needed to meet the aims of the intervention and select potentially relevant intervention functions and behaviour change theories as appropriate.

Figure 9: The Behaviour Change Wheel

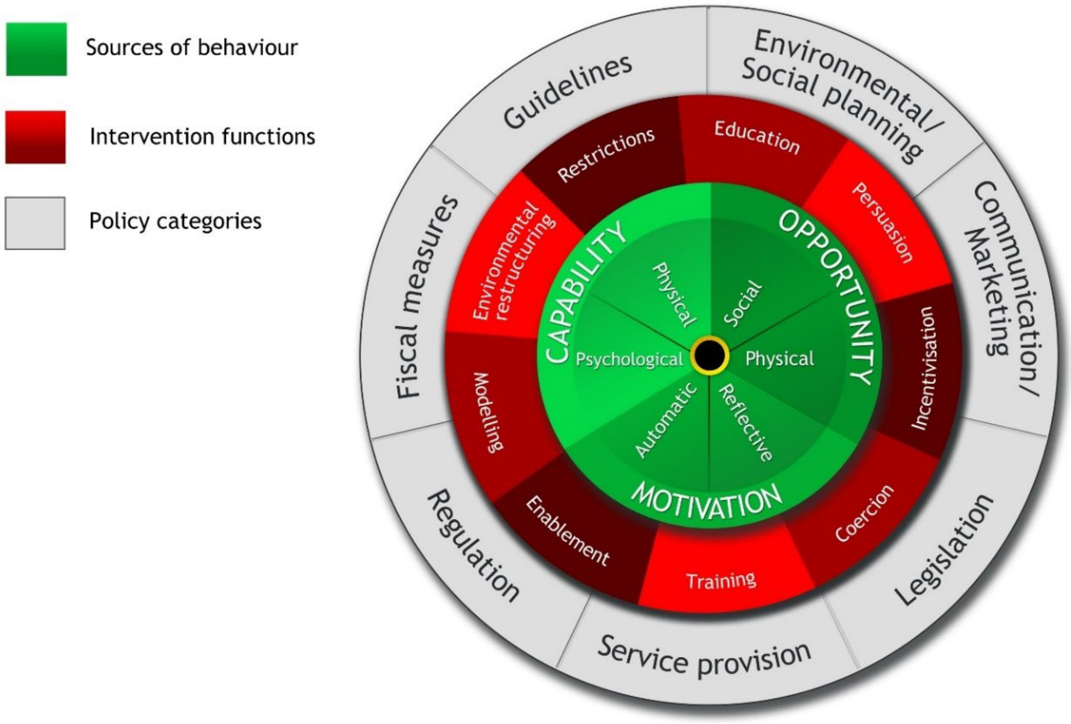


Figure 10: Theoretical domains framework domains mapped onto the COM-B model

The two outer layers of the BCW (Figure 9) include nine intervention functions and seven policy categories [59]. Intervention functions are categories of ways that an intervention can change behaviour. When developing an intervention, all the intervention functions must be considered. The policy categories can support the delivery of the intervention functions. Having selected the intervention functions and policy categories most likely to be effective in changing the targeted behaviour, these can be linked to more specific behaviour change techniques (BCTs) [409]. A BCT is defined as an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour (the "what" rather than the "how" of intervention) [409]. The taxonomy, generated by multi-disciplinary experts, aims to provide a standardised language regarding BCT to enable transparent reporting in interventions [409]. Once the BCTs have been chosen for the intervention, the mode of delivery needs to be decided. At the concept stage of intervention development, the APEASE criteria can be applied to make critical decisions about the mode of delivery[349]. The APEASE criteria is an acronym for Affordability, Practicality, Effectiveness/cost-effectiveness, Acceptability, Safety/side-effects, and Equity [349].

7.2.3.1 Positives and negatives of the BCW

Since the BCW was developed in 2011[59], it has been used extensively to develop interventions to change a broad range of health behaviours. Examples include improving adherence to treatments [410], medication management [394], substance abuse [411], acute mental health therapy [412], and smoking cessation [413]. Regarding physical activity and exercise behaviour, the BCW has been used to develop interventions to reduce sedentary behaviour at work [414], increase physical activity levels in cardiovascular disease [415] and cancer [416], and increase the delivery of physical activity advice from HCPs[417,418]. The BCW has also been used to develop a web-based physical activity resource for PWMS [294].

Despite the wide-ranging application of the BCW, there are challenges associated with its use [394]. During the development process, the researcher must make a series of subject and pragmatic decisions which can seem at odds with the scientific approach [394]. Additionally, the BCW is time-consuming, and the volume of choice can be overwhelming[417]. However, the BCW provides a highly systematic and structured approach [394], which can improve the replicability of an intervention and assist in its evaluation [417]. Also, the BCW allows developers to access multi-factor models and more than one theory of change [411]. Ogden [419] argued that the BCW's standardised approach to patient behaviour, theory, and practice is not feasible or desirable if health psychology is to retain its creativity and professional respect [420]. Attempting to build a Theory of Everything of behaviour change will impair the effectiveness of behaviour change science and its ability to progress [421]. Although, incorporating multiple theories encourages the researcher to consider the complexity of designing behaviour change interventions to gain a broad understanding [421]. Overall, the systematic process of the BCW enables it to provide a more robust starting point for the development of interventions than was possible before its creation [59].

7.3 Study aim

This study aimed to describe the process of developing a community-based physical activity intervention for PWMS.

7.3.1 Objectives

(1) To map the MRC Framework onto the BCW to enhance the generalisability and clarity of the intervention design [394].
(2) Complete the steps of the MRC guidance and BCW using five sources of data, including extant literature, a scoping review and three original research studies.
(3) Develop theory-based content to support engagement in a community-based exercise intervention.

7.4 Methods and results

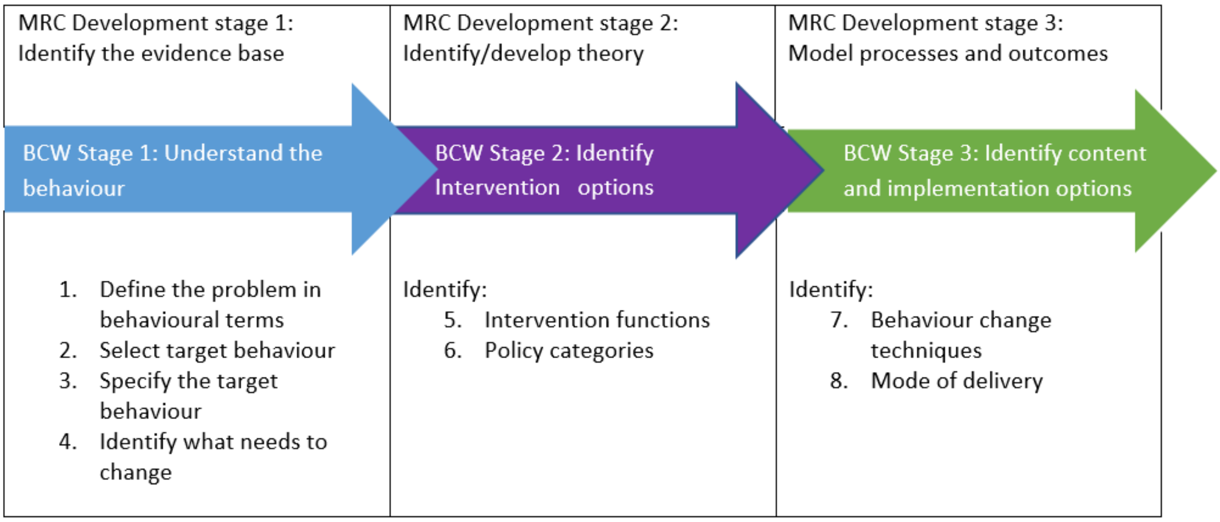
The methods and results have been presented together to provide clarity for the reader.

7.4.1 The rationale for the proposed frameworks

As discussed in previous chapters, getting PWMS to exercise more is likely to be challenging. Chapters 4, 5 and 6 highlight the interacting components and barriers for PWMS, resulting in the need to develop a complex intervention. The MRC guidance and the BCW were used as complementary frameworks to develop the community-based intervention to address these complexities. Figure 11 presents the MRC, BCW stages, and BCW steps.

The MRC and BCW have the potential to complement each other well. The MRC guidance focuses on the process of designing an intervention, providing advice on the broader overarching steps required to develop an intervention but does not provide guidance on how to incorporate theory and evidence [393 422]. The BCW focuses on developing the content of an intervention, building on the MRC guidance by offering a practical guide on how to incorporate theory into the intervention development[59,285]. Therefore, combining the two approaches provides an extensive framework for designing an intervention.

Figure 11: Combined use of the MRC framework and the BCW



7.4.2 Process for developing the intervention

The BCW guide [349] provides worksheets to aid the development of behaviour change interventions. These worksheets were completed using information from the research programme. Critical information from the worksheets is presented in the thesis, with examples of the completed worksheets provided as appendices (Appendix L to Q). Table 23 displays the data sources used to inform the development of the community-based exercise intervention. These included two qualitative studies (chapters 3 and 6) scoping review (chapter 5), and a mixed-methods study (chapter 4). Data from Chapter 3 was included due to the participants in that study including individuals at the higher limit of moderate MS-related disability. Therefore, the PhD candidate felt that the thoughts and experiences of these participants were still relevant and appropriate to consider in the intervention development process.

Table 23: Summary of included data sources

Data source title	Methodology	Thesis chapter
1. "Not falling in public would be nice": Exercise for people with moderate-to-severe multiple sclerosis disability	A qualitative study with semi-structured interviews	Chapter 3
2. Feasibility and participant perspectives of high-intensity interval training in people with low multiple sclerosis impairment.	Mixed-method feasibility study	Chapter 4
3. Scoping review of community-based exercise for people with multiple sclerosis	Scoping review	Chapter 5
4. Exploring patient and professionals' ideas to form the development of a community-based exercise intervention for people with multiple sclerosis	A qualitative study with PWMS and health professionals, utilising semi-structured interviews and focus groups	Chapter 6

7.4.2.1 Extracting the data

Creating the community-based exercise intervention involved the reanalysis of data from previous studies. Secondary analysis of quantitative data is regularly conducted [423]. However, secondary analysis of qualitative studies is less common [423], but there is a growing interest in the potential for this methodology [424]. A reason researchers use existing data is to answer a new question which was not the focus of the original study [425]. There are concerns about the secondary analysis of qualitative data, such as the scientific rigour of the analysis [426]. For example, secondary qualitative data analysis can involve interpreting subjective data inappropriate to its original context [426].

The secondary analysis involves reusing pre-existing qualitative data from previous research studies [424]. This chapter will include the reanalysis and synthesis of three qualitative datasets by mapping quotations from the studies onto the steps of the BCW. Secondary analysis involving comparing two or more qualitative data sets is known as 'amplified analysis' [424].

7.4.3 MRC development stage 1: identifying the evidence base; BCW stage 1: understand the behaviour

Data sources 1-3 were used for this stage and includes steps 1-4 from the BCW (Table 23).

7.4.3.1 Step 1 Define the problem in behavioural terms

Defining the problem in behavioural terms means being explicit about[349]:

(1) The target group or population involved in the behaviour
(2) The behaviour itself

I completed worksheet one using information extracted from chapters 2 and 5 of this thesis to define the problem. Chapter 2 discussed the literature for exercise and MS, including physical activity levels in this population and outlined PAGs for PWMS. The information from Chapter 2 helped us understand the problems associated with exercise for PWMS, such as barriers to exercise and limitations of the PAGs. Chapter 5 presented a scoping review of community-based exercise for PWMS.

The chosen population for the intervention was adults with mild-to-moderate MS-related disability. The behavioural problem is the low levels of PWMS meeting the recommended exercise levels. As discussed in Chapter 2, despite the benefits of exercise and the publication of exercise guidelines, PWMS are less active than the general population [155]. The completed worksheet from the BCW manual is provided in Appendix L.

7.4.3.2 Step 2 Selecting the target behaviour

For step two, I completed worksheet two (Appendix M). Firstly, I created a list of all the potential behaviours relevant to the problem identified in step one (low levels of PWMS meeting the recommended exercise levels). The second part of worksheet two required prioritising the target behaviour based on the following criteria [349]:

(1) How much of an impact changing the behaviour will have on the desired outcome
(2) How likely is it that the behaviour can be changed
(3) How likely is it that the behaviour will have a positive or negative impact on other related behaviours
(4) How easy it will be to measure the behaviour

Data from the scoping review (chapter 5) was used to complete step two. Firstly, I created a list of target behaviours that could affect the behaviour specified in BCW stage one. For this intervention, I decided that PWMS required access to exercise opportunities in the community. The number of barriers facing PWMS when engaging in exercise can be reduced by providing exercise opportunities. Opportunities to exercise in the community include home-based, reduction in sedentary behaviour, internet-based interventions, or community-based exercise classes. As discussed in Chapter 5, eliminating the need for PWMS to travel eliminates a significant barrier. Consequently, home-based interventions are the most common community-based intervention for this population. However, home-based exercise does not provide the opportunity for PWMS to socialise. After creating the list of target behaviours, I then considered each behaviour and the barriers and enablers for the behaviour (Figure 12). This process involved completing worksheet 3 (appendix N) for each opportunity to complete the behaviour (home-based, reduction in sedentary behaviour, internet-based interventions, or community-based exercise classes). The top strategies selected to reduce barriers for PWMS engaging in exercise were providing exercise opportunities in a community-based facility, access to knowledgeable fitness instructors and physiotherapists, and peer support.

7.4.3.3 Step 3 Specifying the target behaviour

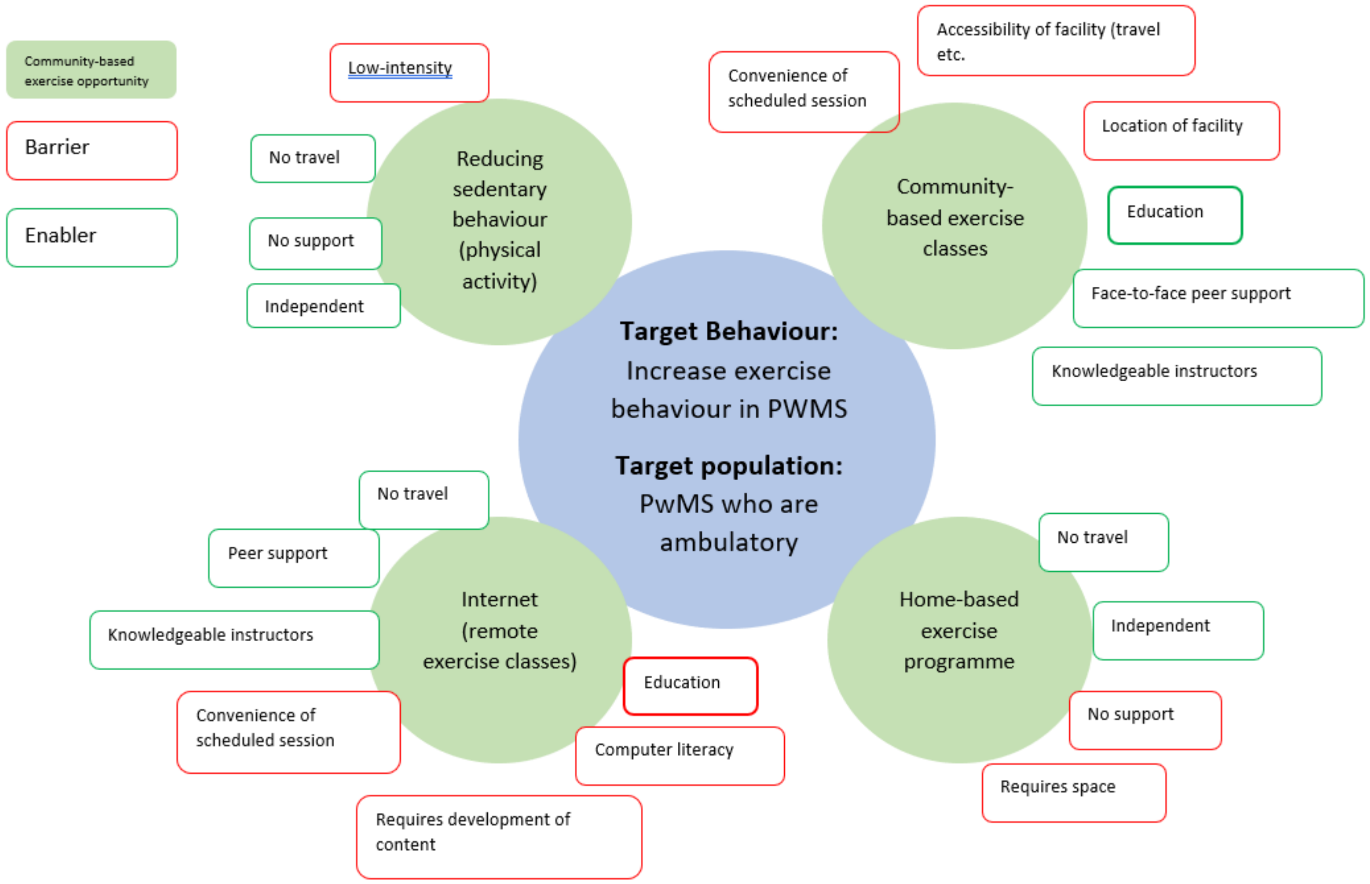
After selecting the behaviour in step two, step three required specifying the behaviour in detail and context [349]. For step three, I completed worksheet three, assisted by the developed guidelines [25] (discussed in Chapter 2), the scoping review (Chapter 5), and qualitative data from interviews with people with higher MS-related disability (Chapter 3). Worksheet 3 requires the intervention designer to specify behaviour in terms of:

- Who needs to perform the behaviour?
- What does the person need to do differently to achieve the desired change?
- When will they do it?
- How often will they do it?
- With whom will they do it?

The target population for the intervention was PWMS who are ambulatory, with or without a walking aid, due to the different needs of individuals with higher MS-related disability (outlined in Chapter 3) and the limited research in the higher disability population [427]. Figure 12 showcases the barriers and enablers model, which defines the target behaviour, the target population, the target behaviour options and the barriers and enablers to each.

Appendix N contains worksheet 3, highlighting who needs to do what, when, where, how often, and with whom for two community-based exercise behaviours.

Figure 12: Model of barriers and enablers for performing the behaviour



7.4.3.4 Step 4 identify what needs to change

In step three, I specified the target behaviour that I wish to change, and step four required identifying what needs to change to achieve this. In step four, I completed worksheets 4 and 4a. I used qualitative data (chapter 6) and data from the scoping review (chapter 5) to complete the worksheets. Data was mapped onto the different domains of the COM-B model (worksheet 4, Table 24), the chosen COM-B model domains, and TDF (worksheet 4a, Table 25). By mapping data from the different studies, I developed a comprehensive theoretical understanding of what needs to change for PWMS to exercise in the community. The model (Figure 12) and Worksheet four (Table 24) guided the completion of the behavioural analysis to estimate what needs to change to achieve the target behaviour (increased community-based physical activity).

Our behavioural diagnosis (Table 24) indicated that to achieve the target behaviour, there is a need for change in several domains of the COM-B model (physical capability, psychological capability, physical opportunity, social opportunity, reflective motivation, automatic motivation). Table 25 presents the results of Worksheet 4a. Worksheet 4a provides a more detailed understanding of the behaviour using the TDF to expand on the COM-B components I identified in Worksheet 4 (Table 24). Our data identified the following TDF domains as important; knowledge, cognitive and interpersonal skills, behavioural regulation, environmental context and resources, social influences, beliefs and capabilities, optimism, beliefs and consequences, intentions, goals, reinforcement, and emotion.

Table 24: Worksheet 4 - Identify what needs to change

COM-B components	What needs to happen for the target behaviour to occur?	Is there a need to for change?	Evidence of the need to change	Chapter source
Physical capability	Have the strength and stamina to be able to perform the behaviour	Change needed; the intervention will be scalable to all fitness levels	"Well, it's the fact that we all were suffering from MS however it shows itself and everybody's got different problems."(P5)	Chapter 3 (Person with MS)
Psychological capability	Have the confidence and knowledge to perform the behaviour	Change needed as PWMS do not feel they can perform exercise	"When I started this study I did not feel as though I had the energy levels required for strenuous or even moderate levels of exercise." (P6) “I’m just frightened of getting really tired or whether I’m frightened that actually through exercising I might make myself have a relapse which I don’t think that’s true." (P5, female, 52)	Chapter 4 (Person with MS) Chapter 6 (Person with MS)
Physical opportunity	Have the time to perform the behaviour	No change needed	N/A	
	Have a location to perform the behaviour	Change needed as opportunities for PWMS are limited	“People improve because they left their home environment and groups are going are you all right today?” (P17, neuro-physiotherapist)	Chapter 6 (health professional)
	Have access to knowledgeable instructors	Change needed as there are no neurological fitness qualifications	“I’m very reluctant to join a gym or anything like that without having somebody that’s got expertise and knows a bit about the condition” (P1, female, 48)	Chapter 6 (Person with MS)

			“They will need to work with a personal trainer. someone who has an understanding of the condition.” (P14, rehabilitation specialist)	Chapter 6 (health professional)
	Have the correct clothing (trainers etc.) to perform the behaviour	No change needed	N/A	
Social opportunity	See other PWMS performing the behaviour	Change needed as MS exercise groups are rare	“Getting people together and the sociable part of exercise is vital and people with neurodegenerative diseases will have problems with social, socialising and introducing new ways of socialising for them. And that’s great.“ (P9, male, 59) “It might be more beneficial for the people with the condition to actually go somewhere as a class more. Because it’s, it’s not only that, it’s the social side of it.” (P11, MS specialist nurse)	Chapter 6 (Person with MS) Chapter 6 (health professional)
	Have the behaviour recommended/endorsed by health professionals	Change needed as exercise is not routinely promoted	“We work under a very medical model so clinical management will always take priority” (P19, neurologist) "I think you always put your trust in the people who are supposed to know more than you. So if he recommended it regardless of my personal view on something I think I'd probably give it a crack." (P2)	Chapter 6 (health professional) Chapter 6 (Person with MS)
Reflective motivation	Hold beliefs that they can perform the behaviour	Change needed	“I’m just frightened of getting really tired or whether I’m frightened that actually	Chapter 6 (Person with MS)

			through exercising I might make myself have a relapse which I don’t think that’s true." (P5, female, 52)	
			"Because there's always the worry that you're going to hurt, hurt yourself more."(P3)	Chapter 3 (Person with MS)
	Believing that consistent exercise will be beneficial	No change is needed as PWMS understand the potential benefits	“I feel better in general; the symptoms seem to subside slightly or I notice them less. They become easier to live with.” (P1, female, 40)	Chapter 6 (Person with MS)
			"I feel much better and able to cope with everything." (P11)	Chapter 4 (Person with MS)
			"It's like you're independence and everything."(P14)	Chapter 3 (Person with MS)
Automatic motivation	Understanding that they may feel symptom exacerbation, but this will only be temporary	Change needed	“I think on a personal level I have to say is it going to harm me?” (P9, 59, male)	Chapter 6 (Person with MS)
	Have an established routine for the behaviour (scheduled sessions)	Change needed	“You might get up one morning and you feel as if you can rush through everything and get everything done and you get partway there and then boom, that’s it.” (P5, female, 52)	Chapter 6 (Person with MS)
Behavioural diagnosis of the relevant COM-B components	Psychological capability, physical opportunity, social opportunity, reflective motivation, automatic motivation			

Table 25: Worksheet 4a - Identify what needs to change using the TDF

COM-B	TDF	Relevance of the domain	Evidence of the relevance of the domain	Chapter source
Physical Capability	Training	Relevant as PWMS need to increase fitness levels		
Psychological capability	Knowledge	Relevant as PWMS need to know how to perform exercise and at what frequency, intensity, time, and type	“I think as long as they’re sufficiently trained I would be happy because I don’t necessarily think that I’m, I, at the moment, require physio. I’d just like people to be able to say, you know, exercise like this or try that.” (P2, female, 40)	Chapter 6 (Person with MS)
	Cognitive and interpersonal skills	Relevant as PWMS need to develop their ability to plan, pace, and self-manage PA.	"Sometimes, I push myself too hard."(P12) "You know, you push yourself, but don't push yourself so far that your body takes two days to recover!"(P6)	Chapter 3 (Person with MS) Chapter 3 (Person with MS)
	Memory, attention, and decision processes	Relevant as PWMS need to remember good experiences from exercise, enhancing capability.	I don’t know [why I stopped], because I always felt better. When I’d done my exercises I could, as I said I had more energy, I felt, whether it was just, you know, mood lift” (P4, female, 28)	Chapter 6 (Person with MS)
	Behaviour regulation	Relevant as PWMS need to develop skills of goal-setting and self-monitoring	“If you were doing some form of exercise and you felt it was benefitting your symptoms then obviously that is, that’s a good thing to do.” (P1, female, 48)	Chapter 6 (Person with MS)
Physical opportunity	Environmental context and resources	Relevant as PWMS need access to appropriate environment and resources (i.e. equipment and instructors) to perform PA	“The ideal would be this, that a physio is part of the structure involved, but I don’t see how an exercise professional isn’t part of that structure. So I see them working alongside.” (P17, neuro-physiotherapist)	Chapter 6 (health professionals)

Social opportunity	Social influences	Relevant as PWMS require access to PA opportunities that encourage social interaction. Groups also need to be stratified depending on their disability level	“Getting people together and the sociable part of exercise is vital and people with neurodegenerative diseases will have problems with social, socialising and introducing new ways of socialising for them. And that’s great.“ (P9, male, 59) “people who are early on with MS or quite well, they often don’t want to mix with people whose MS is worse because they don’t want to see how they might be. And I think if people went to a class where there were a lot of disabled people they’ll probably not want to carry on.” (MS specialist nurse)	Chapter 6 (Person with MS) Chapter 6 (health professionals)
Reflective motivation	Professional/social role and identity	Relevant as PA is not universally endorsed by care team and people in the community.	“It can be easy if the person has been previously active but someone that has not been active for a long time it is difficult to get them to see the need” (P19, neurologist)	Chapter 6 (health professionals)
	Beliefs and capabilities	Relevant as PWMS can lack confidence in participating in PA	“I was supposed to feel better the next morning, but that never happened! I used to get rid of all my energy doing the exercise class and knock out the next day as well.” (P7, female, 46)	Chapter 6 (Person with MS)
	Optimism	Relevant as optimism can be low in PWMS	“I want to be high up so that as I decline, I’m declining from a higher functioning system. Now hopefully I could go longer, that was my logic. Probably true actually.” (P9, male, 59)	Chapter 6 (Person with MS)
	Beliefs and consequences	Relevant as PWMS can express fear of being active	"My mum and dad are very protective. So, they kept saying oh don't overdo it, you'll end up hurting yourself." (P2)	Chapter 4 (Person with MS)

		and address the negative beliefs	"My husband was supportive and keen for me to do it and thought I would enjoy it." (P4) “I think in the past we were possibly wary of prescribing exercise, particularly strength work because of fears around muscle tone changes but also fatigue as well.” (P12, neuro-physiotherapist)	Chapter 4 (Person with MS) Chapter 6 (health professionals)
	Intentions	Relevant as PWMS need support to formulate a plan to be more active and implement PA goals	“I think it would be nice if you want to do an exercise and you can’t bring yourself to do it because you’ve got MS then it would be nice to think oh I’ll go to a class where I’ll fit in.” (P6, female, 56)	Chapter 6 (Person with MS)
	Goals	Relevant as PWMS need to explore desired outcomes and realistic goals	"I just wanted to feel fitter. So it was an opportunity to actually do something in a controlled environment." (P11)	Chapter 6 (Person with MS)
Automatic motivation	Reinforcement	Relevant as PWMS need to establish a routine of PA, which is difficult with the condition. Reinforce habits and routines	“Not having the energy to do something else. So, if you’ve got a limited amount of energy you’ve got to ration it. It’s like having a glass of beer. When you’ve drunk it all, it’s all gone, so you’ve got to make sure that you have a sip to quench your thirst and a sip to make you kind of tipsy and it’s the same idea with MS really.” (P7, female, 46)	Chapter 6 (Person with MS)
	Emotion	Relevant as PWMS have expressed fear of PA and this needs to be addressed There is a need to promote positive emotions towards PA and a sense of fun	"When I started this study I did not feel as though I had the energy levels required for strenuous or even moderate levels of exercise." (P6)	Chapter 4 (Person with MS)

7.4.4 MRC development stage 2: identifying/developing theory; BCW stage 2: Identify intervention options

7.4.4.1 Step 5 Identify intervention functions

I extracted relevant results from chapters 4, 5, and 6 to identify essential intervention functions for a community-based exercise intervention. Results were deemed relevant if they added to the understanding of exercise behaviour in PWMS and could be altered in a community-based intervention. Results extracted from the data sources were mapped onto the COM-B and TDF. The COM-B and TDF highlight what needs to change to generate the desired change in behaviour [349]. Table 26 shows the links between the COM-B, TDF, and the intervention functions.

Table 26: Links between COM-B, TDF, and intervention functions

COM-B	TDF	Intervention functions
Physical capability	Physical skills	Training
Psychological capability	Knowledge	Education
	Cognitive and interpersonal skills	Education
	Memory, attention and decision processes	Training Environmental restructuring Enablement
	Behavioural regulation	Education Training Modelling Enablement
Reflective motivation	Professional/social and role identity	Education Persuasion Modelling
	Beliefs and capabilities	Education Persuasion Modelling Enablement
	Optimism	Education Persuasion Modelling Enablement
	Beliefs and consequences	Education

		Persuasion Modelling
	Intentions	Education Persuasion Incentivisation Coercion Modelling
	Goals	Education Persuasion Incentivization Coercion Modelling Enablement
Automatic Motivation	Reinforcement	Training Incentivisation Coercion Modelling Enablement
	Emotion	Persuasion Incentivisation Coercion Modelling Enablement
Physical opportunity	Environmental context and resources	Training Restriction Environmental restructuring Enablement
Social opportunity	Social influences	Restriction Environmental restructuring Modelling Enablement

The results from step four were then mapped onto the COM-B and the intervention functions. Intervention functions were selected according to the APEASE criteria as recommended by Michie and colleagues[349]. Where possible, I used evidence from professionals and patient interviews to support the APEASE criteria. If data was unavailable, I made the selection based on judgement, and the supervisory team then reviewed the selections.

Intervention functions included education, persuasion, incentivisation, training, environmental restructuring, modelling, and enablement. Table 27 (worksheet 5) presents the intervention functions.

Table 27: Worksheet 5 - Intervention Functions

Candidate intervention functions	**Does the intervention function meet the APEASE criteria?**
Education	Yes
Persuasion	Yes
Incentivisation	Yes
Coercion	No
Training	Yes
Restriction	No
Environmental restructuring	Yes
Modelling	Yes
Enablement	Yes
Selected intervention functions:	Education, persuasion, incentivisation, training, environmental restructuring, modelling, enablement

7.4.4.2 Step 6 Identify policy categories

Step six of the BCW aims to consider what policies would support implementing the intervention functions identified in step five. The BCW identifies seven policy categories communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning, and service provision.

The next step in developing an intervention strategy is to consider what policies would support the delivery and implementation of a community-based intervention. The BCW identifies seven policy categories [349]. To select the appropriate policy categories, I mapped the categories onto the selected intervention functions (see Appendix O). The selected policy categories were communication/marketing, service provision, and environmental/social planning.

7.4.5 MRC development stage 3: model processes and outcomes; BCW stage 3: Identify content and implementation options

In stage two, I identified the relevant intervention functions and policy categories. The chosen intervention functions are education, persuasion, incentivisation, training, environmental restructuring, modelling, and enablement. In stage three, I identified the intervention content, such as choosing the appropriate BCTs and mode of delivery (e.g., face-to-face or online).

7.4.5.1 Stage 7 Identify behaviour change techniques

In step seven, I identified BCTs based on the intervention functions selected in step five. Having identified the intervention functions and policy categories required for PWMS to achieve the target behaviour, the next step was to identify which BCTs underpin the interventions and which mode of delivery is appropriate for the intervention [349]. I used the definition and labels of BCTs that are included in the BCT Taxonomy version 1 (BCTTv1) [409]. A BCT is an active component of an intervention designed to change behaviour [349].

Proposed BCTs were matched to the selected intervention functions. BCTs are presented in worksheet 7 (Table 28) and were selected according to the APEASE criteria. BCTs identified during the qualitative data analysis from interviews with HCPs and PWMS are highlighted in bold. I identified 13 BCTs to support implementing a community-based exercise programme for PWMS. Table 28 shows each chosen BCT, a description of how it will be used and how it meets the components of the COM-B model. Appendix P highlights the BCTs chosen using the APEASE criteria.

Table 28: Worksheet 7: Chosen BCTs, a description of how it will be used, and how it meets the components of the COM-B model

			Capability				Opportunity		Motivation					
			Physical	Psychological			Social	Physical	Reflective					Auto
BCT	Functions	Text description	Skills	Knowledge	Memory, attention & decision process	Behavioural regulation	Social influences	Environmental context and resources	Beliefs about capability	Beliefs about consequences	Social/professional role & identity	Optimism	Goals	Emotions
Information about health consequences	Education, persuasion	Participants were told of the possible benefits regular exercise		▨						▨				
Feedback on behaviour	Education, persuasion, incentivisation, training,	Verbal feedback will be given to participants throughout the supervised exercise session. At the start of each session the exercise professionals will discuss how each individual felt after the previous session.							▨	▨	▨			
Feedback on outcome(s) of the behaviour	Education, persuasion, incentivisation, training,									▨		▨		▨
Self-monitoring of behaviour	Education, incentivisation, training, enablement	Participants will be informed of the physical activity guidelines and encouraged to build towards achieving them. They will attend one supervised session per week and perform one unsupervised session.			▨	▨		▨						
Credible source	Persuasion	Participants were supervised by two experienced exercise		▨			▨							

Demonstration of the behaviour	Training, modelling	professional who specialise in chronic conditions. The exercise professionals also had contact with neuro-physiotherapists to contact for advice.	▨											
Instruction on how to perform a behaviour	Training		▨											
Behavioural practice/rehearsal	Training	The participants will attend a class once a week to perform the exercise behaviours	▨											
Adding objects to the environment	Environmental restructuring	Participants will be given thera-bands to use at home and instructions on how to use them safely		▨				▨						
Goal setting (behaviour)	Enablement	At the initiation of the exercise programme participants will be asked to set SMART goals that they would like to achieve. Goals will be reviewed at the start of each supervised session and at the end of the programme				▨							▨	
						▨					▨		▨	
Action planning	Enablement				▨	▨			▨				▨	
Verbal persuasion about capability	Persuasion	The exercise professionals will spend time with each individual. Exercise will be graded to suit all levels and abilities			▨	▨			▨					
Social support (emotional)	Enablement	The supervised exercise sessions will be group based and have a social session at the end with free tea and coffee.					▨		▨		▨		▨	▨

7.4.5.2 Step 8 Mode of delivery

The mode of delivery was selected after considering the relevant findings presented in chapter five and practical issues identified in the qualitative data collected in chapter 6. For step eight, I completed worksheet eight (appendix Q). In worksheet eight, I identified the modes through which the intervention would be delivered. Based on the preferences of PWMS, face-to-face group delivery was selected for the intervention. Distance delivery at a population level, such as print media (written materials), outdoor media (billboards, posters), digital media (internet, mobile phone app), and broadcast media (TV, Radio) or individual level, such as phone (text messages), and email were deemed not appropriate or undesirable. The agreed intervention was a face-to-face group programme delivered by two experienced exercise professionals with knowledge of MS and behaviour change. The optimal group size was set between 8 and 12 patients. This group size was deemed manageable for the instructors to offer sufficient individual support and ensure patient safety during sessions. Due to the level of resources (e.g. cost and access to the venue), sessions were set to one supervised session per week and one unsupervised session. An outline of the intervention is presented in Table 29. Appendix R lists the selected BCTs, their BCT taxonomy codes, and which session they were introduced.

The session content was guided by data generated from previous studies and chosen based on preferences of PWMS and HCPs, as indicated in focus groups and workshops (chapter 6). The content was also informed by existing literature (Chapter 2) and guided by the PAGs for PWMS. The supervisory team and the instructors delivering the intervention reviewed the intervention content.

Table 29: Overview of the intervention content

Week number	Pre exercise session discussion	Supervised exercise session	Home tasks and support materials
1	• Introduction to the programme, aims and objectives • Discussions: experiences of exercise • Discussions: Benefits of exercise for PWMS • Introduction to goal setting	• Demonstration of exercises • Patient choice of exercise levels • Example aerobic exercises: static bike, step ups, shuttle walk • Example strength exercises: TRX row, light dumbbell exercises, wall squats	• Participants given a TheraBand and instructions on exercises to use • Task: consider what form of activity individual can do for unsupervised exercise • Task: Participants encouraged to write down how they feel the day after the session.
2	• Discuss how the participant felt after previous session • Introduce pacing and energy management	• Demonstration of exercises • Patient choice of exercise levels • Introduce Borg scale for self-monitoring of exertion	• Task: Goal setting, establish a baseline for chosen unsupervised exercise
3	• Discuss how the participant felt after previous session • Review goals	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions
4	• Discuss how the participant felt after previous session • Review progress, and discuss barriers and potential solutions	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions
5	• Discuss how the participant felt after previous session • Review progress	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions

6	• Discuss how the participant felt after previous session • Discuss progression of supervised and unsupervised exercise	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions • Refresher on the use of TheraBand if participants are using them
7	• Discuss how the participant felt after previous session • Begin discussion of exercise options long-term	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions
8	• Discuss how the participant felt after previous session • Reminder of the PA recommendations, are participants closer to the recommended levels?	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions • Reminder of unsupervised exercise progressions
9	• Discuss how the participant felt after previous session	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• Continue with unsupervised exercise sessions
10	• Discuss how the participant felt after previous session • Discuss what support participants need to be active long-term • Review individual goals	• Demonstration of exercises • Patient choice of exercise levels • Progression of exercise as appropriate	• End of intervention celebration

7.5 Discussion

This chapter describes the methods used to design a community-based exercise intervention for PWMS. I demonstrated a systematic approach to developing the intervention, incorporating health professionals' perspectives and people with varying degrees of MS-related disability. The process should optimise the safe delivery of a disease-specific exercise programme. If shown to be effective, both the method and the intervention can be adapted for community-based exercise interventions for other clinical populations.

Although other exercise interventions for PWMS have used theory, such as the social cognitive theory, these interventions often do not detail the process of how the theory was used in the process of intervention development [294]. The MRC framework and the BCW allow for enhanced transparency to intervention development and, subsequently, future repetition of the intervention [394]. Transparency of intervention components is crucial within exercise research, as it helps researchers to enhance replicability and trust in interventions [428]. Therefore, this chapter contributes to the exercise for MS and other chronic disease literature by enhancing our understanding of developing theory-informed community-based interventions.

I identified 13 BCTs to support the delivery of a community-based exercise intervention. The intervention includes constructs from more than one theory. For example, the SCT [263] is often used in interventions for PWMS (as discussed in Chapter 5). The intervention includes techniques to improve skills (demonstration of behaviour), educate participants (Information about health consequences), and improve beliefs about capabilities (feedback of behaviour, goal setting, action planning). These theories draw from constructs of the SCT (behavioural capability, observational learning, expectations, self-efficacy). BCTs such as social support, credible source, information on health consequences, demonstration of the behaviour, and instruction on how to perform the behaviour all draw on constructs from the TPB [203]. Furthermore, information about health consequences, feedback on behaviour, action planning and goal setting all draw on constructs of the Health Belief Model [429] and social support, behavioural practice/rehearsal, and feedback on behaviour draw from constructs of the SDT [204]. This highlights a benefit of the BCW process as it allows the intervention developer to apply constructs from several behaviour change models[59].

7.5.1 Strengths and limitations

The main strength of the intervention development process is its systematic and rigorous methods. The combined use of the MRC framework and the BCW allowed for the gathering of data from numerous sources, such as existing literature, primary research, perspectives of PWMS across the spectrum of disability levels, and perspectives of HCPs.

Although the intervention has been developed using a systematic approach, there remains a significant element of subjectivity in selecting intervention content [406]. The choice of BCTs from the many options was based on the evidence developed from this programme of research. However, the decisions still had to be made that relied on the judgement of the research team. The candidate's background as an exercise professional, primarily with clinical populations, must also be considered.

Although using the BCW to develop an intervention has its strengths (as discussed above), the intervention design process is lengthy. The process included completing the data sources, scoping review, and subsequent proof of concept (chapter 8). The intervention has yet to be assessed for effectiveness, which would require a fully powered trial. It is beyond the scope of this research programme to test the theory-based intervention against a control group [399]. Therefore, the study will not be able to assess whether the multiple theory-based intervention is more effective than single theories. This timeframe of development and testing must be considered for future funding applications in which the BCW is proposed.

7.5.2 Implications for the physical activity guidelines

Chapter 7 has highlighted the complexity of developing a community-based intervention for PWMS. The PAGs for PWMS do not provide any information on behaviour change theory or how it can be applied to support PWMS increase their activity levels. This chapter has also highlighted how the recommendations provided in the guidelines are just one component required to create an environment where PWMS feel capable, have the opportunity, and the motivation to engage in exercise. Therefore, it is critical to develop an ecosystem within the community that supports PWMS to overcome these barriers (e.g. including strategies to increase self-efficacy), and the PAGs are just one resource in this process. Future research is needed on implementing the PAGs with behaviour change programmes to help increase and maintain exercise levels long-term.

7.6 Summary and conclusion

This chapter has presented a systematic process for developing a community-based exercise intervention for PWMS. The process involved the MRC complex interventions framework and the BCW. The existing evidence and exploratory data presented comprise two parts of the development phase from the MRC guidelines. Combining the two approaches provided an extensive framework for designing an intervention adding to the quality of the intervention and progressing what is currently known about intervention development.

The next phase of development is the modelling process and outcomes. Chapter 8 will present a proof-of-concept study, which includes a preliminary exploration of the acceptability of the proposed intervention.

8 Exploring the acceptability of a community-based exercise intervention for people with multiple sclerosis

8.1 Overview

This thesis aimed to understand the experiences, preferences, and support needs of PWMS using the PAGs as a guide. Three limitations of the guidelines were stated as 1) the inclusivity of PWMS, 2) the exercise prescription, and 3) the application of the guidelines. To explore the application of the guidelines, Chapter 5 described a scoping review of community-based interventions, and Chapter 7 described the systematic development of a community-based exercise intervention for PWMS. The process combined the MRC guidance [393] and the BCW [430]. The developed intervention incorporated data generated in each of the chapters in the thesis. This included three original research studies and a scoping review.

The implementation of the intervention in the community occurred through a collaborative effort involving multiple stakeholders. Key stakeholders included researchers, healthcare professionals specialising in MS, community facilities, and community exercise organisations. The intervention was intended to be set up as an exercise referral scheme. HCPs could refer MS patients to the community-based intervention to access exercise support.

The following chapter will evaluate the acceptability of the community-based intervention in a proof-of-concept study to identify weaknesses and undertake refinements. Evaluation is critical in determining whether the intervention has had the desired outcomes[349]. The following chapter will outline the implementation of the intervention and present preliminary results of the feasibility and acceptability of the intervention. The information presented in this chapter will provide recommendations for the future development of the intervention and inform the initiation of a pilot study as recommended by the MRC guidance [393]. The chapter will begin by reiterating the need for community exercise options for PWMS.

8.2 Introduction and rationale

Exercise is a safe, effective, low-cost intervention for managing MS-related disability [431]. Numerous Systematic reviews and meta-analyses have reported that exercise training promotes improvements in aerobic capacity, muscular strength, balance, walking performance, and gait kinematics, reducing fatigue and depression [103,108,112,432-434]. There is also evidence that exercise can reduce the rate of relapses and slow disability progression [200].

Despite the reported benefits, only 20% of PWMS meet the public health guidelines for moderate to vigorous physical activity [157]. The low participation rates highlight a disconnect between the evidence of the benefits of exercise and levels of inactivity among PWMS[200,435].

Such an observation highlights the need for developing accessible opportunities for PWMS to engage in exercise [200], such as providing exercise support in the community [436]. Indeed, a key issue identified regarding the long-term adoption of exercise behaviour is the gap between direct healthcare services and community-based exercise support and programs [436,437]. Chapter 5 described the current literature involving community-based exercise for PWMS.

People with disabilities (including PWMS) have limited access to fitness and leisure facilities[192,438]. Barriers to access include inexperienced staff, insufficient resources to pay for the program, transportation costs, and lack of social support from friends or family [438]. Findings from Chapter 6 reinforced these barriers for PWMS, and Chapter 3 highlighted how the barriers are enhanced for people with high MS disability. Currently, there are often no connections between healthcare and community-based health programmes meaning PWMS would have to seek support themselves [438]. Furthermore, community-based fitness facilities often do not have support systems (e.g., knowledgeable staff, accessible equipment, adaptive programs) to accommodate PWMS [438]. As well as these external barriers, PWMS perceive their condition as a limitation in improving their health [196]. A finding consistent throughout this thesis (discussed in chapters 3, 4, and 6) is how fear is a barrier to exercise for PWMS. Therefore, expecting PWMS to exercise independently or seek support is unlikely. As a result, PWMS find it challenging to integrate or reintegrate into community exercise following their diagnosis [439]. The aim should be to make it as easy as possible to help PWMS engage in exercise.

Opportunities to safely exercise in the community will help individuals with neurological conditions, such as MS, maintain or improve health [440]. Even minor improvements in accessibility could substantially reduce the access barriers discussed above [438]. Previous research has recommended a healthcare-recreation partnership model for increasing access to exercise programmes in the community[441], which involves physiotherapists supporting fitness instructors to deliver exercise programmes in leisure facilities [441]. Previous research has successfully combined the expertise of fitness instructors with physiotherapists in PWMS[390], which was received favourably by the participants[192]. Chapter 6 explicitly aimed to explore the ideas and aspirations of the target population to help design a community-based intervention. Interviews with HCPs focus groups and interviews with PWMS helped identify crucial factors for a community-based intervention, including the need for knowledgeable instructors.

8.3 Study aims

The study aims were to explore the feasibility and acceptability of a behavioural theory-driven community-based exercise intervention for PWMS.

8.3.1 Objectives

1. (1) To explore the feasibility of the mode of delivery of the intervention
2. (2) Explore the acceptability of completing a range of potential outcome measures for use in future evaluations
3. (3) Develop a refined exercise programme model.

8.4 Methodology

8.4.1 Study design

A proof-of-concept study was conducted to assess whether the community-based exercise intervention was acceptable to PWMS. A mixed-methods approach was used to collect and analyse qualitative and quantitative data. The evaluation was independent of the delivery of the exercise programme. Ethical approval was granted by Sheffield Hallam University Ethics Committee (ER5147628).

8.4.2 Intervention

8.4.2.1 Referral

An integral component of community-based exercise interventions is health professional referral. This step encourages communication between primary and secondary healthcare (e.g., physiotherapists, nurses, consultants, and GPs) and community-based exercise providers. The delivery team (Functional Fitness) and the PhD candidate had several meetings with local rehabilitation services to develop these relationships. Additionally, the programme did not want to rely solely on referrals from health professionals. The team promoted the project via GP surgery, MS centres, and social media (Facebook). It was also decided that PWMS could self-refer into the programme to maximise accessibility.

After receiving a referral, all potential participants were contacted by a member of the project team and the programme was explained to them, and they were provided with a participant information sheet (sent via email). The information sheet stated that the study would explore the delivery and acceptability of a community-based exercise intervention for PWMS. Interested individuals who met the inclusion criteria (see Table 30) were invited to attend an initial session to give informed consent and undergo baseline measures.

It was crucial to understand the reasons for not participating to help determine the acceptability of the intervention. Individuals who declined were asked to indicate why they did not want to participate.

Table 30: Inclusion criteria

Inclusion
Aged over 18
PDDS score of less than 6
Clinical diagnosis of MS

8.4.2.2 Venue

The venue chosen for the programme delivery was based on several factors, including ample free parking, accessibility for bus routes, abundant space in the room, easy access to facilities, and space for social interaction. The chosen venue was Park Rehabilitation Centre (PCR), a community hub in Rotherham. This was to create a healthcare-recreation partnership model recommended in previous research[441]. PCR offers therapy services, such as physiotherapy and occupational therapy, and acts as a community venue for activities such as dance classes, exercise classes and swimming lessons for children.

8.4.2.3 Qualified deliverers

Both professionals and PWMS in chapter 6 stressed the need for experienced deliverers of an exercise programme, preferably physiotherapists. Given the established benefits of exercise, there is a need for exercise professionals who can provide appropriate programming[442]. Unfortunately, an exercise qualification for neurological conditions was not available during this study. The Wright Foundation has since created a level four qualification for neurological conditions.

Functional Fitness delivered the exercise sessions for the intervention. Functional fitness/training is a broad and confusing concept and one of the most misunderstood terms in the fitness industry [443]. This is due to its combined use in rehabilitation and sports performance [443]. In this context, 'functional' means to restore or maintain function. Functional Fitness is a team of exercise specialists with experience in delivering exercise programmes for people with health conditions including cancer, stroke, COPD, falls prevention, and mental health. Functional fitness staff were given an awareness-raising session (delivered by the candidate) to build their knowledge and understanding of MS. An example of the awareness-raising content is presented in Appendix S and covers topics such as exercise training, guidelines, and special considerations. Two instructors supervised each session to ensure participant safety.

8.4.3 Exercise programme overview

Following is a summary of the exercise sessions, including frequency, intensity, time and type (FITT). The exercise guidelines for PWMS determined FITT [25]. All sessions followed the same overall format; the session began with a short discussion of a particular topic (i.e.

introduction to goal setting, pacing and energy management) and a discussion of how the participant felt after the previous session (for an outline of the designed intervention, see Table 30. Following the discussion, the participants completed the exercise class and then finished with a social gathering with tea and coffee. In total, each session lasted approximately 90 minutes. Including the assessment sessions, the intervention lasted 12 weeks. The intervention length was chosen because this was the median length of the interventions included in the scoping review (Chapter 5).

8.4.3.1 Frequency

Sessions were once a week for ten weeks on a Monday afternoon at a community facility. Participants were encouraged to engage in one self-directed exercise session in their leisure time, although this was not recorded. Participants were provided with resistance bands for home-based exercise but could choose their preferred mode of activity.

8.4.3.2 Intensity

Participants were instructed to complete exercises at a low-to-moderate level, depending on how they felt that day. Participants were encouraged to work at 12-14 on the Borg rating of perceived exertion scale. Each station lasted 30-60 seconds, with participants encouraged to aim for 10-15 repetitions of strength exercises. Throughout the session, participants were encouraged to rest if required.

8.4.3.3 Time (duration)

Each session lasted 60 minutes, including a 10-minute warm-up, 40 minutes of activity (including rest time between activities), and a 10-minute cooldown. Time was incorporated at the end of the sessions to socialise.

8.4.3.4 Type of exercise

The programme was a circuit-based class that offered aerobic, strength, and balance exercises. Aerobic exercises included walking, cycling, and arm cranking. Strength exercises included wall press-ups, squats, sit-to-stand, lift-to-press, balance, and core exercises. All exercises were adapted to each individual's ability. The circuit included ten exercises, allowing 2 minutes per station (including the rest period). Exercises were set up in an alternating pattern (e.g. upper body, lower body, aerobic, core, balance) to ensure maximal restoration time. The hall was set up with laminated cards to illustrate suggested graded exercises. Each card had instructions on what to do and how to progress the exercise. At the start of each exercise session, the instructors demonstrated how to perform each exercise. Equipment used for the sessions included suspension trainers (TRX), ViPRs for increasing movement load, TheraBands, and light dumbbells.

8.4.4 Data collection

At the initial assessment, participants were asked to provide demographic information, such as age, gender, MS disease duration, and employment status.

8.4.4.1 Programme evaluation

The primary outcome of the study was the acceptability of the intervention. At the end of the intervention, participants were asked to attend a focus group to discuss their experiences. Appendix T shows the interview schedule used for the focus group. A telephone interview was offered as an alternative if participants could not attend the focus group. It was essential to hear the views and experiences of participants who withdrew from the intervention. Therefore, anyone who left the study was invited to conduct a telephone interview.

8.4.4.2 Outcome measures

The study explored possible outcome measures that might be used in the future piloting of community-based exercise interventions. The outcomes were chosen based on the length of the questionnaire, the time it takes to complete (participant burden), and the perceived importance of the outcomes. Participants in chapters 3, 4, and 6 all discussed how fatigue is a debilitating effect of their condition. Participants also declared functional improvements as a key motivator for exercise. Outcome measures were completed at the initial session (week 1) and the follow-up session (week 12). The outcome measures are presented in Table 34.

8.4.5 Approach to data analysis

For consistency with previous chapters, framework analysis was used to analyse the qualitative data [371]. Data was collected via one focus group (n= 7 participants) and three telephone interviews. NVivo Version 11 data analysis software was used to facilitate the framework analysis[444]. Appendix U presents an example from the coding framework.

Outcome data were entered into Microsoft Excel and analysed using descriptive statistics to summarise changes in outcome measures. The results are presented as medians and minimum and maximum values unless specified. Due to this being a proof-of-concept study with no comparison arm, it was not powered to identify intervention effectiveness. As a result, inferential statistics were not performed on the data.

8.5 Results

8.5.1 Participants

8.5.1.1 PWMS

A total of 18 participants expressed an interest in the community intervention. Of these, 10 (55%) volunteered to participate in the study. However, one participant withdrew after completing baseline measures, but before attending the first exercise session. Nine participants (n=6 female) consented to take part in the study. Participant demographic information is presented in Table 32.

Table 31: Participant demographics

ID	Gender	Age	Ethnic group	Work status	PDDS	Access into the intervention
01	Male	66	White British	Retired	6	Advertisement in GP surgery
02	Female	55	White British	Permanently sick/disabled	2	Social Media
03	Female	59	White British	Permanently sick/disabled	5	Social media
04	Female	61	White British	Permanently sick/disabled	5	Local newspaper advertisement
05	Female	57	White British	Permanently sick/disabled	5	Social media
06	Male	44	White British	Employed - Full time	3	Physiotherapist referral
07	Female	62	White British	Retired	3	Word of mouth
08	Male	45	White British	Permanently sick/disabled	1	Social Media
09	Female	46	White British	Employed - part-time	5	Word of mouth
10	Male	44	White British	Employed - Full time	2	Physiotherapist referral
		53.9 ±8.4			3.7 ±1.7	

PDDS= PATIENT DETERMINED DISEASE STEPS

8.5.2 Acceptability

8.5.2.1 Attendance and attrition

The programme offered a maximum of ten exercise sessions (one session per week for ten weeks). The sessions were well attended, with a median attendance of 9 (range= 7 - 10). Four participants attended all ten sessions. Three participants attended seven sessions which was the lowest level of attendance. Three participants were employed (n=2 full-time) but were permitted to attend by the employers to assist in managing their condition.

8.5.2.2 Participant experience

Table 33 presents the higher- and lower-order themes derived from the qualitative interviews with participants following the programme. Participants discussed the positives and negatives of participating in the programme. The themes highlight the difficulties PWMS face when increasing the amount of physical activity they do. PWMS often enjoy physical activity and social interaction but are affected by their physical and psychological condition [445].

Table 32: Higher and lower order themes from PWMS

Higher-order themes	Lower-order themes
Thoughts on the design of the community-based intervention	• The social aspect of the community-based intervention was vital • The content of the exercise sessions was initially worrying • Having a trained, knowledgeable instructor was valuable • Referral into the community-based intervention was not well designed
Overall experiences of participating in the community-based intervention	• Positive effects of exercise • Negative effects of exercise • Barriers to continuing to exercise following the completion of the intervention

8.5.3 Theme 1: Thoughts on the design of the community-based intervention

8.5.3.1 The social aspect of the community-based intervention was vital

Participants discussed how social interaction in the group was an essential factor. All participants discussed the importance of making friends, having fun, and talking to people in a similar position to themselves.

> *"Doing it on my own, I find it boring. In a group, you have people such as [P1] because he pushes himself, it makes you push yourself. I mean, he is amazing. If he can do that then I can do it. " (P9, female, 40)*

"After that first meeting, I walked out of here, and I thought it's going to be good this. We had a laugh even at that session, and nobody knew each other, but everybody gelled. I thought, yeah this is going to be good." (P2, female, 55)

"It gave me the confidence to do a different type of exercise but knowing that there were people around that weren't going to criticise me." (P3, female, 59)

8.5.3.2 The content of the exercise sessions was initially worrying

The content of the exercise sessions was different from what the participants were expecting. Initially, several participants questioned whether they were capable of doing the exercises.

"When I first saw it, I was like oh god, I won't be able to do that." (P5, female, 57)

"Yeah, I was like horrified when he showed us. He pulled straps and was like, we are going to do this. I was like ha no way." (P4, female, 61)

"It was a different type of exercise to what I thought we'd be doing. I thought it would be like a treadmill or a bike like you do when you go to physio. I thought it would just be basically like physio stuff." (P7, female, 62)

8.5.3.3 Participants soon realised they were capable of doing the exercises

After taking part in the intervention, the participants understood the reasons for the exercises. Several participants discussed how the exercises were challenging but enjoyable.

"I preferred the fact it wasn't treadmill or a bike. You can stand on a treadmill or exercise bike as long as you want, but you're not building any core strength, just burning calories. We were doing more functional moving." (P3, female, 59)

"Well, it was definitely better than coming in to use treadmills. Doing exercise this way I could feel how it was working and feel why I was doing it." (P2, female, 55)

8.5.3.4 Having trained and knowledgeable instructors were invaluable

The participants were very pleased with the instructors who ran the programme. Participants were looking for a friendly, approachable, knowledgeable, experienced, and empathetic instructor. Knowing MS was an essential attribute for the instructor. This gave the participants confidence.

"The instructor is so good, he explains things well, and he doesn't make you feel embarrassed or intimidated, and that is half the battle." (P7, female, 62)

"The good thing is he can tailor it so he can make it harder for you. Make it different for everyone's ability. So you not all doing the same thing." (P1, male, 66)

"Good instructors adapt to the situation they don't just say this is what we are doing. You can't do that with MS without even looking at them." (P8, male, 45)

8.5.3.5 Referral into the community-based intervention was random and not well designed.

The intervention was unable to establish a reliable referral pathway for participants for HCPs such as neurologists or MS nurses. Participants entered the service via numerous routes such as social media (n=4), local newspaper advertisements (n=1), physiotherapist referral (n=2), advertisement in local GP (n=1), and word of mouth (n=2) as participant 2 encouraged two individuals to join to the class

"My wife went to the doctors, and she heard about it." (P1, male, 66)

"There was a post on Facebook." (P5, female, 57)

"I just got a referral from the physio to join your sessions." (P6, male, 44)

"I saw it in the local paper. I thought I have nothing to lose just come and if I don't like I don't come back. And I love it, absolutely love it." (P4, female, 61)

"If it wasn't for [P2] I wouldn't have known." (P9, female, 46)

8.5.4 Theme 2: Overall experiences of participating in the community-based intervention

8.5.4.1 Positive effects of exercise

Participants discussed how they had benefitted from the programme. Some felt they had benefitted physically, including walking better and further. Others felt the programme had improved strength and balance.

"Some people can do the exercise better than others. The walking for me that's the hardest thing. I can do all the others, but walking up and down I have really got to stretch myself to make my legs stretch out. Otherwise, I am shuffling. Which is a positive that I have learnt, lift your foot put your heel down." (P1, male, 66)

"It has taught me to walk straight and tall whereas before I was that scared you are always staring at your feet."(P5, female, 57)

"I have felt that I can do more rather than less. So I have been on trips out whereas I would have been reluctant to do it before."(P3, female, 59)

"Yes, a couple of days after the missus would say my walking was a little bit better, and I had a bit more strength.." (P6, male, 44)

8.5.4.2 Negative effects of exercise

Participants also discussed how they felt exhausted because of the exercise. Participants would have to factor the exercise into their day to allow themselves the energy to engage. They would then go home and have to lie down for the afternoon. Participants discussed how fatigue management is a constant aspect of their lives. Because of their fatigue, they must plan all parts of their lives to ensure enough energy.

> *"After the sessions, I would say to the missus I am not going to be doing very much now. She'd know that I had used up my energy and would need more help in the evening. During it as well was quite tiring." (P6, male, 44))*
>
> *"I was laid out the next day, but I came back, and I thought if I can't do it I can't do it, but I want to be incorporated in it." (P9, female, 46)*
>
> *"You have got to think ahead at all times. Even having a shower, you have to organise it." (P7, female, 62)*

8.5.4.3 Motivation to continue exercising following the completion of the intervention

Participants were not confident in their ability to continue to exercise after completing the 10-week intervention. Several participants felt that 10-weeks was insufficient and would prefer a continuous programme. Participants stressed that they would be willing to pay to attend a weekly exercise class.

> *"It's a bit more difficult at home. We have been given bands to do some. But the sessions are there, and you know you are going to do it. It is planned and part of your routine." (P2, female, 55)*
>
> *"It needs to be sustained ten weeks is not enough. It drives people to do more than they do in their normal lives." (P6, male, 44)*
>
> *"Ten weeks just seems to be the magic number, and I don't know, it just feels like it's been plucked out of nowhere really I think what's more important is what the strategy for what happens at the end." (P4, male, 44)*
>
> *"I would probably pay three to four quid for an exercise class in an hour rather than thinking about doing it myself at home." (P9, female, 46)*

8.5.5 Outcome measures

Outcome scores at baseline and post-intervention are shown in Table 34. The table includes data for nine participants who completed the intervention. Data for the participant who withdrew was removed before the analysis. Completion rates for all measures were 100%.

Compared to baseline, participants undertook physical activity on more days after the programme (baseline median = 2 days per week; follow-up median = 4 days per week). As seen in Table 34, median weekly physical activity levels increased from 132 MET minutes at baseline to 231 MET minutes of exercise post-intervention. The median total MFIS improved from 48 at baseline to 45 at follow-up. Physical fatigue had the largest change, reducing from 28 to 20. Quality of life was measured using the median visual analogue scores (VAS). The VAS increased from 50 to 70 after the programme. Self-efficacy improved from 11.25 at baseline to 40 at follow up. The median distances for the 6MWT test improved by 80 metres at follow-up. Participant grip strength increased in the right hand from baseline to follow-up, and the left-hand grip strength had a negligible reduction in the median score.

Table 33: Outcome measures

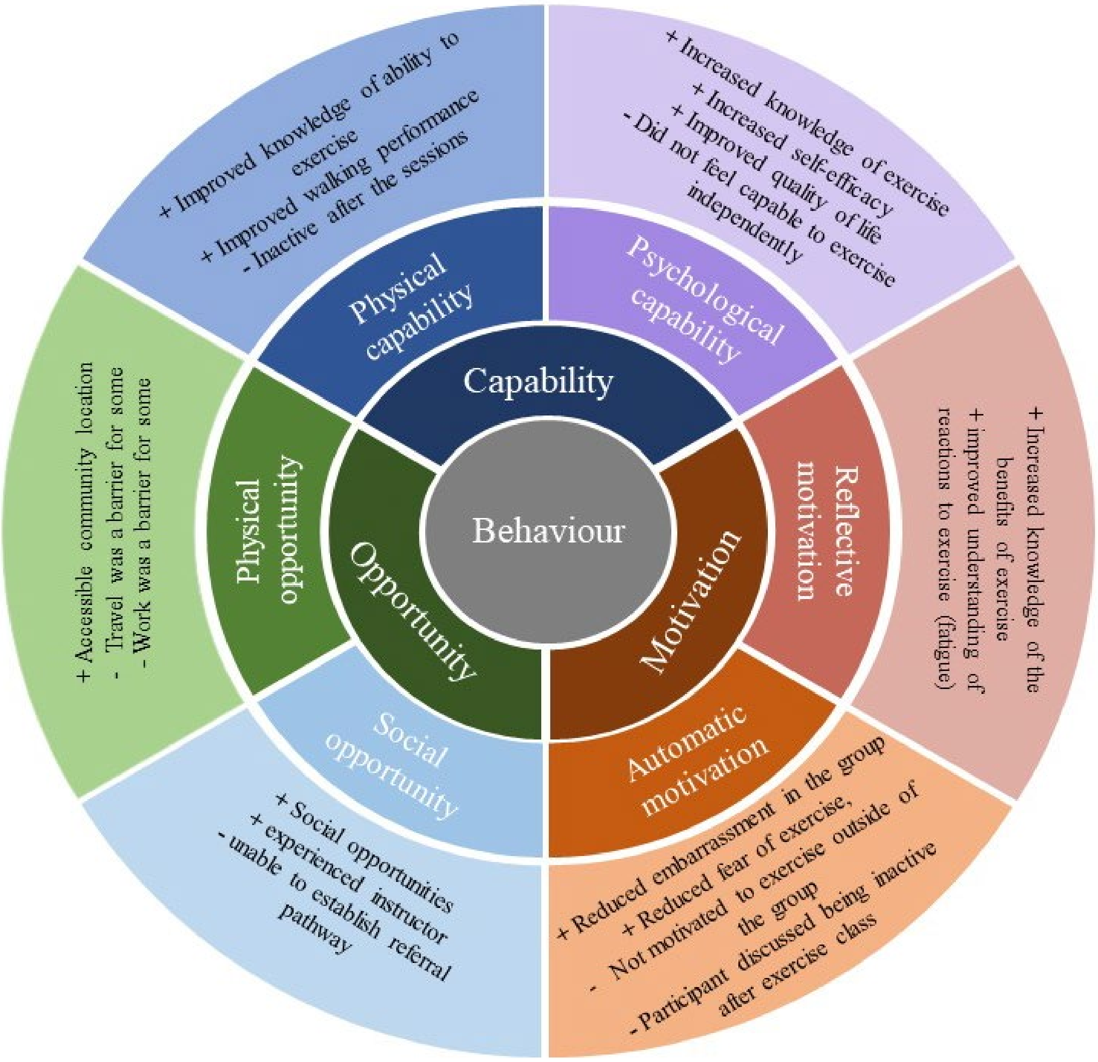
Measure	**Baseline**		**Follow up**		
	Median (Minimum and maximum values)	N	Median (Minimum and maximum values)	N	*Change in scores*
Physical activity					
IPAQ	132 MET minutes (0 - 693)	9	231 MET minutes (0 - 1440)	9	+99 MET minutes
Fatigue					
Physical	28 (14 - 31)	9	20 (12 - 28)	9	-8
Cognitive	19 (0 - 28)	9	20 (0-28)	9	+1
Psychological	4 (2 - 7)	9	4 (2 - 7)	9	No change
Total MFIS	48 (32 - 64)	9	45 (14 - 53)	9	-3
Quality of Life					
VAS	50 (30 - 80)	9	70 (55-70)	9	+20
Self-efficacy					
Exercise self-efficacy scale	11.25 (0 - 56.3)	9	40 (0 - 70)	9	+28.75
Functional tests					
6MWT	440 metres (80 - 780)	9	520 metres (240 - 810)	9	+80 metres
Grip strength (right hand)	23.5 (19.5 - 43.25)	9	25 (16.5 - 40.3)	9	+1.5
Grip strength (left hand)	18.8 (8.75 - 40.25)	9	18.5 (12.5 - 42.5)	9	-0.3

IPAQ=International physical activity questionnaire; Met= metabolic equivalent; VAS=Visual analogue scale; MFIS= Modified fatigue scale; 6MWT= six minute walk test

8.6 Discussion

The findings from this study suggest that the format, content, and processes of a community-based exercise intervention for PWMS were acceptable to the study population. High attendance (median: 9; range 7-10) and low attrition (n=1) rates, positive participant experiences, and improvements in outcome measures provide evidence of acceptability. The intervention was deemed safe as there were no adverse events during the intervention. However, three participants discussed how they experienced increased fatigue levels the day after the exercise sessions. A central part of the development of the intervention was the COM-B model. Figure 13 frames the results from the evaluation, both positive and negative, in the context of the COM-B constructs.

Figure 13: Evaluation results framed in the COM-B Constructs



+ = positive results; - = negative results

8.6.1 Capability

These results suggest that the participant's psychological and physical capability was improved. However, outside of the supervised sessions and at the end of the intervention, they did not feel capable of self-managing their exercise and wanted continued support through supervised sessions. This highlights a crucial area of research for this population; developing strategies to increase self-management and long-term exercise adoption in PWMS.

Similar to results found in the HIIT intervention (Chapter 4), participants discussed apprehension about the mode of exercise. Participants doubted their capability to perform the exercises, with results highlighting the importance of self-efficacy for PWMS when deciding to participate in the exercise. The behaviour techniques applied in the intervention (i.e., behavioural capability, observational learning, expectations, self-efficacy)[201] aimed to improve the participant's beliefs in their capabilities (e.g., feedback on behaviour) and included techniques to improve their skills (e.g., demonstration of behaviour). Behaviour change interventions incorporating these constructs have been shown to reduce sedentary behaviour in PWMS [446]. Specifically, self-efficacy is positively associated with physical activity and reduced sedentary behaviour in PWMS [447]. Self-efficacy is vital in increasing exercise levels in PWMS [260]. Once PWMS believe they can exercise, they are more likely to engage in the behaviour.

Similar to previous studies [192,375] and aligning with Chapters 3, 5 and 6, participants discussed how important it was to have knowledgeable instructors leading the intervention. The need for trained instructors (credible source) was a critical factor addressed in Chapter 7. However, the instructors who delivered the exercise intervention did not have a recognised qualification for prescribing exercise for people with neurological conditions such as MS. However, the instructors were experienced in delivering exercise to clinical populations and were provided with an MS awareness-raising session. The instructors were well-liked and trusted by the participants. However, one participant acknowledged that the instructors did not have much knowledge of MS but appreciated how the instructors were open to learning. These results highlight that community-based exercise does not have to be delivered by physiotherapists. Upskilling exercise professionals will provide increased opportunities for PWMS to be active in the community. Future research should aim to build HCPs' and PWMSs' trust in the expertise of exercise professionals.

Quantitative results from this programme suggest that the programme could improve the physical capability of people with mild to moderate MS. Questionnaire completion rates (100%) suggest that the measures were acceptable and were not too burdensome for the participants. The small sample size limits the strength of the evidence presented here; nevertheless, outcomes did improve for most measures. This provides preliminary evidence that the exercise programme is safe and effective in improving the physical, psychological, and social well-being of PWMS. Participants experienced a range of benefits from the programme, including increased exercise levels, self-efficacy, and walking distance, reduced physical and total fatigue, and improved quality of life.

PWMS consider walking an essential bodily function [448]. To measure walking performance, I used the 6MWT. When the 6MWT is used, a standard is required to determine if a real change occurred, defined as the Minimal Clinically Important Difference (MCID)[449]. An improvement of 54 meters has been the value most used as the minimum change 6MWT that results in clinically meaningful change [450]. In other conditions, it has been reported as 14-35.4 metres [449]. In MS specifically, it has been reported as 22 metres [448]. The median difference in 6MWT in the programme was 80 metres suggesting that this group had clinically meaningful changes in their function. This supports the use of 6MWT in future community-based programmes.

8.6.2 Opportunity

The intervention offered the participant a physical opportunity (location, time, and resources) to exercise. The intervention was designed to be as accessible as possible for PWMS. The intervention was delivered at a community facility with ample parking and an accessible entrance (automatic doors, no stairs). The exercise sessions were delivered in a spacious ground floor hall with space between exercise stations and abundant seating available for participants to rest. The exercise sessions were delivered in the early afternoon, identified as the participants' preferred time in Chapter 6. However, times and locations were not convenient for everyone. Travelling around work commitments was a problem for some, which will apply to other PWMS. Future studies should explore this to further our understanding of intervention acceptability.

Participants valued social opportunities offered by the intervention, with supervised practical sessions boosting confidence and motivation and interaction with other MS patients providing peer support, fun, and vicarious learning. Vicarious learning is a mechanism that can improve self-efficacy[451]. Providing vicarious opportunities can foster an environment to support peer modelling, social engagement, and motivation [451]. Peer support and camaraderie with other PWMS have been highlighted as essential facilitators for exercise among PWMS [192,452]. Previous research demonstrated that group-based exercises eliminate feelings of isolation and loneliness [210].

Additionally, social support is seen as a catalyst for behaviour change, highlighted in most theoretical frameworks such as social cognitive theory[190]. The sessions' format appeared to help increase coping skills and provide peer support and encouragement. All participants discussed how they struggle with low confidence, especially in an exercise environment. Feelings of embarrassment are barriers for PWMS to engage in exercise. Participants discussed feeling intimidated and judged when they go to conventional fitness environments. These findings emphasise that creating a supportive social environment is vital to a community-based exercise intervention. However, not all PWMS want to exercise in group-based settings, as evidenced by data from Chapters 3 and 6. People with higher MS disability preferred the option of home-based exercise. Also, participants in Chapter 6 discussed how they would not want to exercise in groups with people with higher disability than themselves.

The programme could not establish a referral pathway from HCPs, limiting the opportunity for more PWMS to access the intervention. Potential participants (n=18) were referred via various methods (self-referral, social media, newspaper adverts, and word of mouth). The study received two referrals from physiotherapists but no referrals from other health professionals (i.e., MS nurses). Health professionals are often under time pressures, so referral to an exercise programme is a low priority, resulting in missed opportunities to refer patients. Referral into an exercise programme depends on a health professional starting a discussion with the patient and then completing, signing, and sending a referral form[453]. Completing cumbersome paperwork is a barrier to HCPs referring to a programme[454]. A short referral form is preferred when referring to physical activity support to ensure that referring a patient is quick and straightforward [375]. This will increase the likelihood of a HCP engaging in a programme [455]. Future community-based exercise referral programmes for PWMS should factor in time to develop an effective referral process. HCP require a clear understanding of who is suitable for the programme [455]. A lack of information about the eligibility criteria or the nature of the intervention and a lack of feedback about the patient's progress are significant factors that negatively affect health professional engagement [454,456]. Therefore, regular communication between the HCPs and programme delivery staff is essential. In hindsight, it was perhaps unrealistic to expect NHS clinicians to refer to a new community-based intervention. Previous research has highlighted lack of trust as a barrier for a HCP referring a patient to a service [349]. A referral to a service was identified as an endorsement of that service [349]. Future proof of concept studies should allow NHS clinicians to support recruitment to a specified research study to ensure clinical engagement.

HCPs have a valuable role in helping patients navigate the health system into community-based provision [457]. Part of the referral role for health professionals is to give ‘permission’ for patients to engage in exercise [457]. Due to this, health professionals often have concerns about patient safety when referring to a community-based exercise programme [454] A survey found that 48% of physicians were concerned with certified exercise professionals [458]. This may suggest a lack of understanding of the level of knowledge of certified exercise professionals or a disregard for the qualifications in general [458].

Further work to develop communication and integration between HCPs and the fitness industry is required[459]. A partnership between community-based interventions and the health service sector would allow the formal development of referral pathways. Promoting the programme or inviting health professionals to visit the sessions might help develop trust and initiate referrals.

8.6.3 Motivation

Participants expressed that the intervention was a motivating experience and encouraged them to be more active. Elements of reflective motivation were described, such as altered beliefs in their ability and desire to achieve exercise goals. Descriptions of positive emotional responses suggested the potential for the intervention to influence automatic motivation to exercise sessions, such as improved mood and reduced fear. Although, participants discussed managing their fatigue by resting for the remainder of the day following the session. This behavioural compensation is a potential area for further research to investigate if exercise training decreases NEPA. Additionally, future studies could explore different approaches to meeting the guidelines, for example, aiming to cumulate 60 minutes of aerobic activity across the week rather than two 30-minute sessions per week.

All participants felt positive effects from participating in the intervention. Participants discussed how the intervention had improved their walking ability and the distance they could walk. Some participants felt they could do more and had increased strength. Despite the positive experiences, participants also experienced high levels of fatigue post-exercise. To help manage their fatigue, participants discussed how they had to rest for the remainder of the day following the session, affecting the completion of usual daily activities. People who participate in structured exercise training compensate behaviourally by decreasing their non-exercise physical activity (NEPA) [460]. Older adults may be more susceptible to the negative impact of exercise training on NEPA due to increased fatigue and functional impairment [460]. This is also the case for PWMS, as fatigue plays a substantial role in NEPA compensation [461]. This possibly explains why PWMS were previously advised not to exercise to preserve energy[107]. MS-related fatigue is aggravated by deconditioning and disuse. Excessive fatigue combined with low fitness levels leads to reduced levels of activities of daily living [462]. It is, therefore, possible that the increased fatigue experienced post-exercise will decrease as the participants' fitness levels increase.

Additionally, MS-related fatigue has been observed to increase the perception of leg fatigue following exercise [463]. Therefore, recovery from exercise may be an essential consideration for prescribing tolerable exercise programmes in PWMS [463]. More research is needed to investigate NEPA compensation in PWMS following structured exercise sessions.

Participants unanimously agreed that maintaining self-managed exercise after completing the intervention would be challenging. The group identified the programme's short-term (10 weeks) nature as an issue. These findings compare with previous qualitative research where PWMS stated how difficult it was to maintain self-regulated exercise [192]. Participants reported honouring appointments (related to supervised exercise), weekly structure, enjoyment, and feelings of guilt as essential facilitators for engaging in exercise [192]. After the programme, the participants reported that they still did not feel capable of exercising in conventional environments (e.g., fitness facilities). The issues of feeling self-conscious, judged, and out of place were not overcome by participating in the programme. Future interventions need to consider increasing the confidence of PWMS to exercise in conventional environments. It seems the studied intervention positively impacted the participant's capability to exercise, but only in the small group environment. This suggests that PWMS require a group-based exercise programme of indefinite length to facilitate long-term exercise adoption.

8.6.4 Feasibility of Outcome Measures:

When designing exercise intervention studies, selecting appropriate outcome measures is vital to capturing meaningful data. Outcome measures should be easily accessible and cost-effective, allowing researchers to collect data efficiently, especially in a community setting. Accessibility can be determined by factors such as availability of equipment, ease of administration, and participant burden. All outcome measures were acceptable as all participants completed all questionnaire questions. The 6MWT was deliverable because the exercise venue had a large sports hall. Other community venues may need more space to deliver the test as intended. In future community-based interventions, I would include exercise self-efficacy. Self-efficacy has been identified as a crucial component in exercise engagement for PWMS. Including exercise self-efficacy as an outcome measure in exercise intervention studies can provide valuable insights into participants' confidence levels and motivation [260].

8.7 Summary and conclusion

8.7.1 Strengths and limitations

Strengths of the community-based intervention include the combined use of literature, patient and HCP perspectives, and theoretical underpinning of the intervention. As discussed in Chapter 5, these aspects are lacking in community-based exercise interventions for PWMS. The process allowed for transparency of the intervention development and will help with the replication of the intervention. A strength of the evaluation is the use of mixed methods to help determine the acceptability of the intervention, which allows for an understanding of what works (e.g., group-based sessions led by an experienced exercise professional) and what has not worked in the intervention (e.g., referral process). These findings allow for refinement of the intervention prior to a potential future trial.

Several limitations need to be considered when interpreting the results of the evaluation. Firstly, the study sample size was small, and no comparison group was incorporated. Secondly, the study failed to create a functional referral system for the intervention. Creating partnerships between healthcare and community providers is essential for PWMS to access exercise [344,436,440]. However, it was unrealistic to expect NHS clinicians to refer to a new community-based intervention in which they would have not developed a sufficient degree of trust. The intervention relied on PWMS to self-refer, meaning that the participants included in the study were already motivated to exercise. Therefore, the participants who would benefit most from the intervention were not recruited. Thirdly, there was a lack of diversity in the recruited participants as all participants were White British. Future iterations of the intervention will require innovations to help recruit, engage, retain, and promote health among diverse communities [464]. Previous research has suggested adapting programmes to tailor the design to the needs of a particular cultural group [465]. Finally, cost data were not collected during this study. Cost implications are essential in assessing acceptability and must be considered in future testing of this intervention.

8.7.2 Implications for the physical activity guidelines

As discussed in previous chapters, even though PAGs exist, PWMS are still largely inactive. Chapter 6 discussed how discussing exercise or physical activity was not a priority for health professionals. In this chapter, results showed that a physiotherapist referred two participants, but no referrals were received from other HCPs. No standardised referral process exists to transition PWMS from hospital or rehabilitation services into community services such as exercise programmes. Therefore, future research should explore the development of referral into community-based programmes and assess the effects of health professional referral to community-based interventions in PWMS.

8.7.3 Conclusions

The arrangement of this theory-designed community-based exercise intervention was acceptable to the group participants. Participants initially felt apprehensive about completing the exercise programme but ultimately found it a positive experience. Social interaction was a key factor in this. Allowing people to exercise in a safe, supportive environment removed several barriers to exercise participation. Following the proof of concept study, the next stage of the MRC guidance[58] is 'feasibility and piloting', which includes three stages 1) Testing procedures, 2) estimating recruitment and retention, and 3) determining sample size. An important aspect would be establishing the recruitment criteria with HCPs, an area untested in this study.

9 Summary and discussion of research findings and implications for research and clinical practice

9.1 Chapter summary

This thesis explored the suitability of the PAGs developed for PWMS. The research process has offered a deep understanding of the exercise experiences, preferences, and needs of PWMS. This led to developing, delivering, and evaluating an exercise intervention delivered in the community. The intervention was developed based on existing evidence, and the PAGs, combined with the ideas, experiences, and preferences of patients and HCPs, underpinned by a systematic theoretical framework of behaviour change. The findings from this thesis have contributed uniquely to the factors that enable PWMS to exercise safely and effectively in the community and lay the foundation for updating the PAGs for PWMS.

Throughout this thesis, the research has explored PWMS's subjective experiences and needs around exercise, which has enabled the research to contribute to gaps in the literature. To answer the research question, the PhD set out six research objectives. The thesis consisted of three associated studies, a scoping review, and culminating in the development and evaluation of a community-based exercise intervention underpinned by the BCW [349] and MRC guidance[393]. This concluding chapter presents the novel contribution of the thesis and addresses the essential question: so what? The chapter also discusses the key findings from the studies, the implications, and will conclude with reflections from the author.

9.2 Novel contributions of the thesis

The overarching research question explored in this thesis is 'using the PAGs as a guide, what works to help people with multiple sclerosis engage in exercise in the community?' The golden thread, tying together each study, was the common purpose of exploring the views of PWMS to provide context around exercise experiences, preferences, and needs. The studies in this thesis present evidence of the scale of the problem of supporting PWMS to be physically active and the additional facets required to enhance the PAGs, but also broader factors necessary to meet the exercise support needs of PWMS.

Exercise behaviour is a multidimensional behaviour that is influenced by intrapersonal (Chapters 3, 4 and 6: feeling incapable, fear of making things worse), interpersonal (Chapter 6: not wanting to exercise with people more disabled than themselves), environmental (Chapter 3 and 6: inaccessible facilities), and political factors (Chapters 5, 6 and 8: HCPs not having the time to discuss exercise). Ultimately, the research in this thesis emphasises that evidence-based PAGs are ineffective without the infrastructure in place for PWMS to enact the behaviour.

When transferring evidence into practice, PAGs are just one tool [466]. A review by Motl and colleagues[467] stated that a reason for the low participation in physical activity for PWMS is the absence of a conceptual framework and tool kit for translating the evidence into practice. The data from this thesis demonstrates the additional components required to create an ecosystem where PWMS feel capable and have the opportunities and motivation to engage in exercise. A crucial finding from this thesis is that the PAGs may exist to help support PWMS to exercise in the community, but it appears the community is not ready to provide that support. For example, despite its multiple benefits, exercise is not integrated into medical practice for PWMS, rehabilitation services are not widely available for people with higher disability MS, and exercise professionals are not trained sufficiently to support PWMS safely.

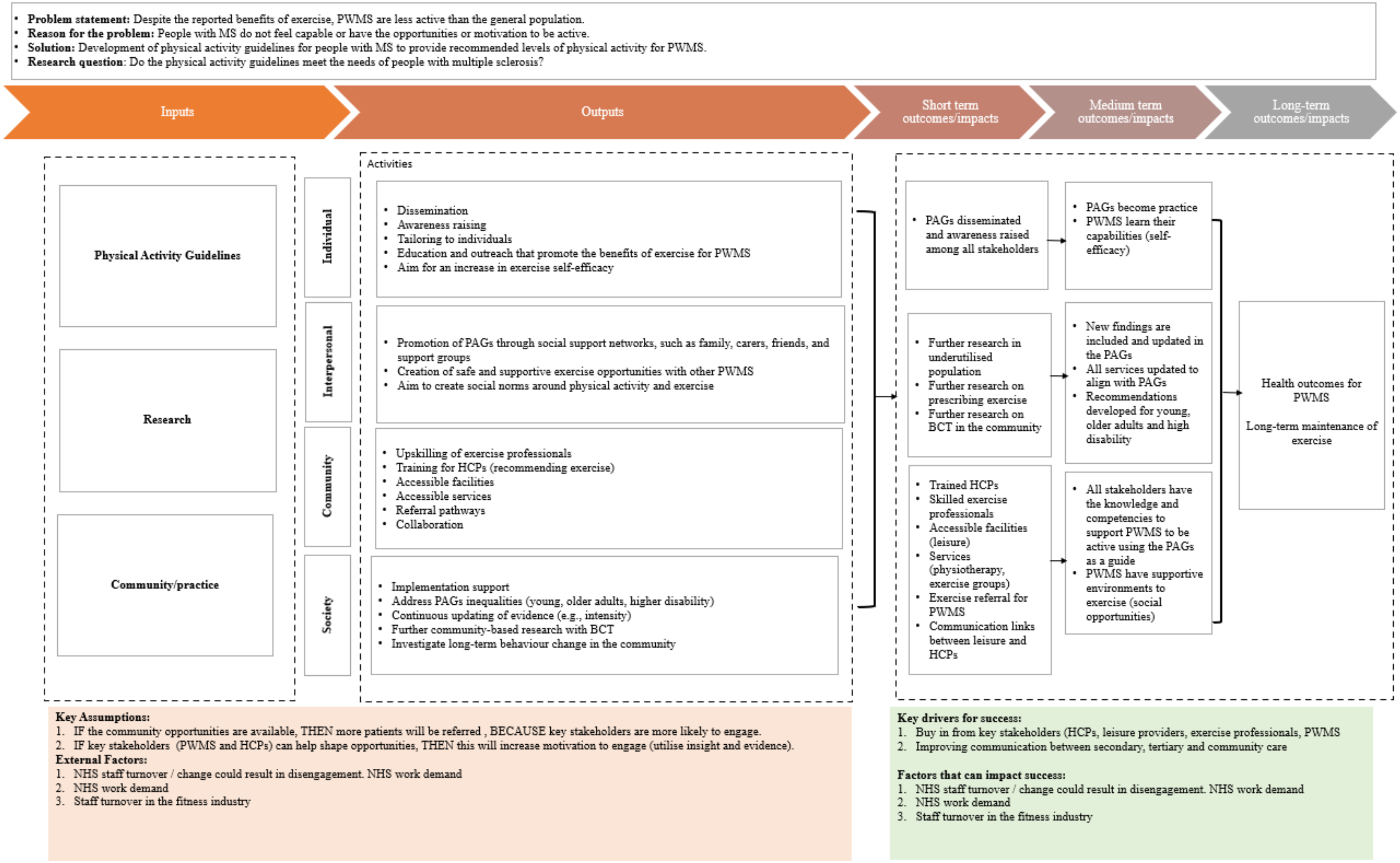
Figure 14 presents a logic model which maps the additional strategies required to provide better PAGs and create the ecosystem required to enable PWMS to exercise. The figure presents the problem statement underpinning this research, the reason for the problem, and the solution and subsequent research question explored in this thesis. The logic model uses levels of the social-ecological model to connect activities and outcomes. The logic model highlights the complexity of meeting the exercise support needs of PWMS explored in this thesis. Key drivers to improve exercise support for PWMS are increasing the engagement of HCPs and developing communication between healthcare and exercise provision. The following sections will expand on the findings of the thesis.

The social-ecological model of health highlights that the health of individuals is influenced not only by their attitudes and behaviours but also by community and societal structures [468]. Socio-ecological models of health offer a framework for health promotion initiatives as they acknowledge different levels of health behaviour [469]. This includes individual level (e.g., genetics, motivation, experience, capability), interpersonal level (e.g., interpersonal interactions, social support), community level (e.g., environment, local services, transport), and societal level (e.g., public policy, health infrastructure), all of which influence health behaviours [469].

Exercise for PWMS is an important strategy for MS management to explore within the context of socio-ecological models [470]. Using a social-ecological (i.e., addressing exercise participation across the individual, interpersonal, organisational, community and public policy) approach to understand the influences on exercise participation will offer insight into identifying the opportunities to initiate uptake in and continued participation in exercise [470]. By applying the different social-ecological levels and identifying how they interact, we can better understand the complex factors that impact exercise behaviour in people with MS. This can help develop additional strategies for promoting exercise to complement the PAGs.

- Individual Level: At the individual level, PAGs can be promoted through education and outreach efforts that emphasise the benefits of exercise, such as improved physical health, mental health, and quality of life. These efforts can target individuals of all ages and backgrounds and be tailored to their needs and interests. An important aspect is increasing an individual's capability to exercise and, ultimately, their self-efficacy. Interpersonal Level: At the interpersonal level, PAGs can be promoted through social support networks, such as family, friends, and co-workers. This can involve creating social norms around exercise and encouraging others to engage in physical activity with them. The interpersonal level can help to increase an individual's motivation to exercise.
- Community Level: At the community level, physical activity guidelines can be supported by creating safe environments that encourage access to exercise. This can include accessible facilities and services, training HCPs to discuss exercise, and upskilling community-based exercise professionals. The community level is about increasing the opportunity for PWMS to be more active.
- Society Level: At the societal level, PAGs can be supported through policy and environmental changes prioritising exercise. This can include creating policies addressing inequalities (e.g., older adults, higher disability), continuously updating evidence through research and further investigation of long-term behaviour change in people with MS.

Figure 14: Logic model for the exercise support needs of PWMS



- **Problem statement:** Despite the reported benefits of exercise, PWMS are less active than the general population.
- **Reason for the problem:** People with MS do not feel capable or have the opportunities or motivation to be active.
- **Solution:** Development of physical activity guidelines for people with MS to provide recommended levels of physical activity for PWMS.
- **Research question**: Do the physical activity guidelines meet the needs of people with multiple sclerosis?

Inputs

Physical Activity Guidelines

Research

Community/practice

Outputs

Activities

Individual

- Dissemination
- Awareness raising
- Tailoring to individuals
- Education and outreach that promote the benefits of exercise for PWMS
- Aim for an increase in exercise self-efficacy

Interpersonal

- Promotion of PAGs through social support networks, such as family, carers, friends, and support groups
- Creation of safe and supportive exercise opportunities with other PWMS
- Aim to create social norms around physical activity and exercise

Community

- Upskilling of exercise professionals
- Training for HCPs (recommending exercise)
- Accessible facilities
- Accessible services
- Referral pathways
- Collaboration

Society

- Implementation support
- Address PAGs inequalities (young, older adults, higher disability)
- Continuous updating of evidence (e.g., intensity)
- Further community-based research with BCT
- Investigate long-term behaviour change in the community

Short term outcomes/impacts

- PAGs disseminated and awareness raised among all stakeholders

- Further research in underutilised population
- Further research on prescribing exercise
- Further research on BCT in the community

- Trained HCPs
- Skilled exercise professionals
- Accessible facilities (leisure)
- Services (physiotherapy, exercise groups)
- Exercise referral for PWMS
- Communication links between leisure and HCPs

Medium term outcomes/impacts

- PAGs become practice
- PWMS learn their capabilities (self-efficacy)

- New findings are included and updated in the PAGs
- All services updated to align with PAGs
- Recommendations developed for young, older adults and high disability

- All stakeholders have the knowledge and competencies to support PWMS to be active using the PAGs as a guide
- PWMS have supportive environments to exercise (social opportunities)

Long-term outcomes/impacts

Health outcomes for PWMS

Long-term maintenance of exercise

Key Assumptions:

1. IF the community opportunities are available, THEN more patients will be referred , BECAUSE key stakeholders are more likely to engage.
2. IF key stakeholders (PWMS and HCPs) can help shape opportunities, THEN this will increase motivation to engage (utilise insight and evidence).

External Factors:

1. NHS staff turnover / change could result in disengagement. NHS work demand
2. NHS work demand
3. Staff turnover in the fitness industry

Key drivers for success:

1. Buy in from key stakeholders (HCPs, leisure providers, exercise professionals, PWMS
2. Improving communication between secondary, tertiary and community care

Factors that can impact success:

1. NHS staff turnover / change could result in disengagement. NHS work demand
2. NHS work demand
3. Staff turnover in the fitness industry

9.3 Key findings

9.3.1 Exploring the limitations of the physical activity guidelines

Chapter 2 discussed three main limitations of the PAGs for PWMS; 1) the lack of inclusivity in the guidelines, 2) the limited exercise prescription details, and 3) the absence of information on how to apply the guidelines in the community.

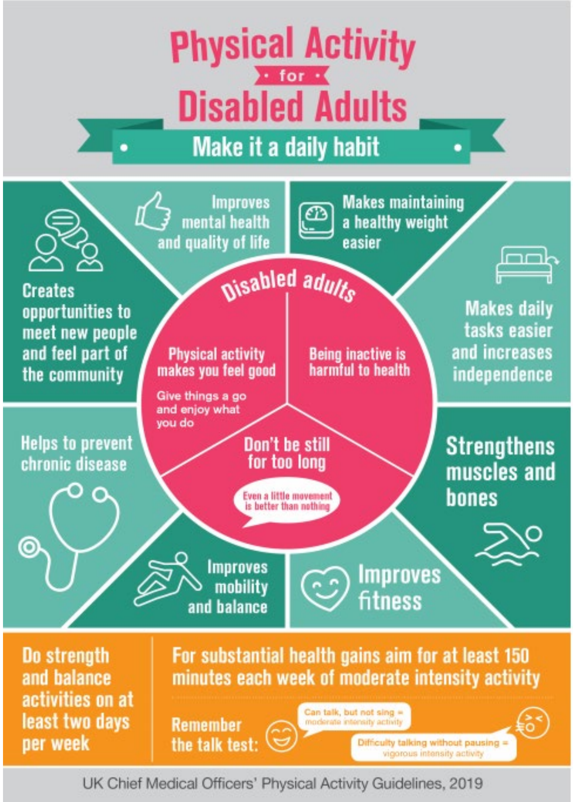
9.3.1.1 People with severe MS have additional support needs

Chapter 3 focused on perceptions of an ideal exercise intervention for people with high MS disability. The study targeted questions that elicited information regarding the effects of living with MS, experiences of exercise, and expectations of participating in exercise. Research suggests that disability status should direct efforts to develop appropriate physical activity interventions [471]. This was supported by findings in chapter 6, where PWMS and HCPs suggested stratifying exercise sessions by disability levels. Participants discussed two sessions per week of home-based activity led by a physiotherapist. However, studies like these will be resource-intensive and logistically challenging, potentially making them unaffordable and impractical for implementation (and at scale)[472]. As discussed in chapter 3, Silveira and colleagues[190] published a qualitative study to design an exercise programme for PWMS who use a wheelchair. The study results compare well with the findings from chapter 3. For example, the mode (aerobic and strength), frequency (2 days per week), and duration (30+ minutes) were the same in both studies. Additionally, both studies had the same opinions on exercising at home to "avoid the hassle of going into the community" [190]. However, participants in the study by Silveira and colleagues [190] expressed an interest in group-based exercise, although some suggested it be online.

The novelty of the study discussed in this thesis is that it explored what they would hope to achieve from participating in an exercise intervention and why. This is evident by the outcomes that PWMS wanted from participating in an exercise study. Participants emphasised that their main goal was maintaining or regaining their functional ability and avoiding using walking aids or a wheelchair. The overarching aim of this study was to identify perceptions of exercise from people with high MS disability as they are not included in the PAGs. The goal was to explore the concept of an exercise intervention that would likely be acceptable to this population. Chapter 3 provided the foundation for designing an exercise intervention for people with moderate to severe MS (Figure 3). The next steps for this area of research are to use this foundation and incorporate theoretical constructs that can underpin the preferences, hopes, and fears of participating in an exercise intervention.

In 2019, the Chief Medical Office published PAGs for disabled adults [473]. Figure 15 shows the infographic for the PAGs for disabled adults. The infographic provides limited advice on the frequency, intensity, or type of exercise. Also, the guidelines recommend that individuals complete at least 150 minutes of moderate-intensity activity per week, which is considerably more than the PAGs for people with mild-moderate MS [25]. However, the guidelines do state that ‘doing some physical activity is better than doing none [473]. However, the aim should be to develop specific PAGs that provide people with high-disability MS with specific recommendations for exercise.

Figure 15: Physical activity guidelines for disabled adults



9.3.1.2 High-intensity interval training is safe and feasible but lacks long-term appeal

Chapter 4 explored the feasibility of PWMS exercising at a high intensity. HIIT has become an area to explore for this population[229]. HIIT is a mode of exercise that has grown in its application, including with clinical populations[219]. Data from chapter 4 indicated that HIIT is a feasible intervention for people with low MS-related disability, which aligns with previous HIIT research in this population [229]. However, the novel findings from chapter 4 are the participant’s perceptions of the intervention. The participants discussed how they experienced some worsening symptoms during the sessions. So, whilst this study suggests that HIIT is a safe form of exercise for PWMS, questions remain regarding the long-term appeal in PWMS. This is supported by a systematic review that found that when unsupervised individuals do not adhere to the intensity prescribed [474]. Nevertheless, if PWMS can and want to exercise at a higher intensity, they should be encouraged to do so. Future PAGs should guide PWMS on exercising at various intensities, broadening their exercise options.

The PAGs lack detail in the recommended exercise prescription. The PAGs[25] recommends 30 minutes of moderate-intensity aerobic exercise (2 days per week) and strength training for major muscle groups (2 days per week). The PAGs do not provide details on progressing the aerobic or strength training programmes. Additionally, the PAGs for PWMS do not provide recommendations for vigorous activity. The guidelines developed by WHO in 2020 recommend that the general population, adults with chronic conditions (such as cancer, hypertension, and type 2 diabetes), and adults living with a disability (such as multiple sclerosis, Parkinson's, and spinal cord injury) undertake at least 75 to 150 minutes of vigorous-intensity exercise per week [475]. There is a sizeable discrepancy between the MS-specific guidelines and the more general PAGs.

9.3.1.3 Use of the guidelines in the community

A third limitation in the MS-specific PAGs discussed in this thesis is the absence of strategies for applying the guidelines in the community. Chapter 5 presented a scoping review that explored the evidence of community-based exercise interventions for PWMS. The study investigated the characteristics of community-based interventions, such as whether PAGs were applied. Six of the seventeen interventions included in the review based their exercise prescription on established guidelines [158,309,312,314,476,477]. Four studies [158,312,314,316] used guidelines explicitly developed for PWMS, with the guidelines by Latimer-Cheung[25] and colleagues being the most frequently cited (n=3) [158,314,316].

These novel results suggest that the guidelines are being developed but not communicated or applied with PWMS in the community. Despite evidence for the benefits of exercise and the development of exercise guidelines, PWMS are less active than the general population[155]. Given the evidence for the benefits of exercise for PWMS, programmes need to support this population to be more active.

Since completing the research in this thesis, Canning and colleagues have published research testing the effectiveness of the PAGs for PWMS [148]. The study involves PWMS attending a community-based exercise programme based on the PAGs. The results found that adhering to the PAGs at least 75% of the time over 16 weeks significantly improved aerobic capacity, strength, fatigue symptoms, mobility, and QOL [148].

9.3.2 Developing community-based exercise interventions

9.3.2.1 Barriers to exercising in the community

Chapter 6 highlighted several key issues to be addressed in helping PWMS access exercise opportunities in the community, such as the impact of the condition, fear of making their condition worse, and lack of trust in exercise instructors. In chapter 6, PWMS discussed physical effects such as poor balance, high levels of fatigue, and poor bladder control as some of the physical effects of their MS, as well as psychological issues due to their condition, such as fear. Additionally, PWMS and HCPs indicated that they did not trust the skill and knowledge levels of exercise professionals in the fitness industry. The importance of quality instructors is supported by previous qualitative research [329]. Physiotherapists were reported as the most desirable option. However, this would not enhance the availability of exercise support in the community. The challenge is to develop a better clinical care model in which health professionals and exercise specialists work more closely to provide medically directed exercise programmes appropriate for everyone[358]. Physiotherapists working in partnership with community physical activity providers are one way to develop the confidence of HCPs and PWMS in community-based exercise [329]. Additionally, HCPs require education on the knowledge and expertise of exercise professionals to reassure them of their competence.

Participants with MS felt that the social side of exercise was vital, consistent with previous research [192,328,329]. Once diagnosed, PWMS can feel isolated; providing them with an opportunity to get out of the house and meet other people in a friendly and supportive environment was desired. Nevertheless, the group dynamics of an exercise class would need to be carefully managed. Many PWMS felt anxious that being in a group with people with higher levels of impairment would make them feel dejected because of the progressive nature of the condition, so a stratified approach to an exercise group would need to be applied. This notion was supported by HCPs, who felt that a group would be unmanageable without stratification. As discussed throughout this thesis, the PAGs are for people with mild to moderate MS, and data from chapter 3 confirms that people with high MS disability have different needs (exercising at home to avoid travel) and goals for being active (increasing or maintaining independence). Data from chapter 5 suggests that community-based interventions are primarily aimed at minimal disability. One study[477] recruited people who are moderately affected by MS (EDSS 6.0 ±0.6) with positive results such as improved activity levels, balance, and strength.

9.3.2.2 *Physical activity is not a priority for HCPs*

Previous research has highlighted that HCPs are crucial in changing the behaviours of people with chronic conditions [379]. PWMS identify HCPs as the most credible source for physical activity information [364]. However, previous research has identified how PWMS receive minimal or conflicting advice on exercise from HCPs [478]. In Chapter 6, health professionals discussed the challenges of promoting exercise for PWMS and how it is not a priority. This is supported by findings from chapter 8, where only two patients were referred to the community-based intervention by an HCP (physiotherapist). However, as discussed previously, expecting NHS clinicians to refer to a community-based intervention without developing trust in the service was perhaps unrealistic. That being said, previous research has explored the priorities of neurologists for exercise promotion in PWMS care and provided suggestions for how the low importance might be addressed in practice [381]. The research identified several barriers regarding neurologists promoting exercise to PMWS. All neurologists in the study endorsed exercise as a critical component of patient care [381]. Although, lack of time during a patient's appointment was a barrier to discussing exercise with patients. A priority for neurologists was "What are the prescriptions/guidelines for exercise among persons with MS?" This suggests that neurologists are unfamiliar with the published guidelines for PWMS [381]. Previous research has found that HCP referral to an exercise program is twice as effective as providing written information about the PAGs to PWMS [364]. An option for future research is to provide training on the PAGs for HCPs. However, there is a clear need for developing specialised community-based exercise programs PWMS, and the next steps are to empower HCPs to start discussing exercise with their patients and developing links with local exercise opportunities.

9.3.2.3 *Using MRC and BCW to develop interventions*

Engagement with and maintaining exercise is challenging for those with long-term conditions such as MS [479]. Exercise recommendations alone are insufficient for behaviour change. Therefore, an intervention that aims to improve exercise participation must also employ techniques to facilitate engagement in exercise behaviour. Chapter 5 discussed how exercise self-efficacy, a construct of the social cognitive theory, is likely to support and improve the activity levels of PWMS [480]. Theory-driven interventions are more effective than interventions without theory as they outline the mechanisms of behaviour change [481].

A strength of the intervention developed in this thesis is its systematic development, achieved through a robust systematic process underpinned by behaviour change theory using the BCW [349] and MRC guidance[393]. Although previous exercise interventions for PWMS have been developed using theory, such as the social cognitive theory [263], these interventions often do not detail the intervention development process [294]. Hoddinott defined intervention development studies as *"A study that describes the rationale, decision-making processes, methods and findings which occur between the idea or inception of an intervention until it is ready for formal feasibility, pilot or efficacy testing prior to a full trial or evaluation"* [482]. Development frameworks such as BCW and MRC guidance have been developed to tackle issues such as interventions designed without using theory[59] or methodological rigour[482]. However, frameworks also have problems, as discussed in chapter 7, such as the time required to develop an intervention and the standardised approach impairing the creativity of behaviour change science [419]. Nevertheless, this thesis provides an excellent example of developing a complex community-based intervention and highlights the complexities of the process.

Previous research in exercise for PWMS has recommended using the social cognitive theory [200]. The studies conducted in this research programme identified 13 BCTs to support the delivery of a community-based exercise intervention. Due to the complexity of the behaviour, the intervention required a theoretical framework that considered multiple intervention options[483]. Therefore, constructs from more than one theory were used to underpin the intervention rather than a single psychological theory. The advantage of the BCW is the incorporation of a broader range of theories. The TDF bridged the gap between what needed to change and identifying the appropriate theory [408].

Additionally, using the BCT taxonomy when developing the intervention allowed for selecting evidence-based techniques most likely to succeed. The 13 BCTs chosen in the intervention draw from constructs of behaviour change theories such as social cognitive theory [263], Theory of Planned Behaviour [203], Health Belief Model [429], and Self Determination Theory [204]. This thesis demonstrates that using the MRC guidance combined with the BCW theoretical framework can provide a comprehensive, structured method for developing and evaluating behaviour change interventions in PWMS.

9.3.3 Community-based intervention enhances constructs of COM-B

Participants in the proof-of-concept study (Chapter 8) suggested that the intervention format, content, and processes were acceptable, backed by the high attendance and low attrition rates. Additionally, the participant experiences explored in the evaluation were positive. However, these findings must be considered cautiously due to the small sample size (n=9 completing the intervention, n=1 withdrew due to travel issues). Figure 13 in chapter 8 highlights the evaluation results framed in the COM-B constructs. More work is needed to increase the evidence of community-based exercise interventions to encourage health professional engagement in community-based referral programmes. Creating well-defined referral criteria and a simple referral process will help bridge the gap between health professionals and community-based referral programmes. Additionally, future community programmes should consider working more closely with local physical activity providers, increasing the knowledge and skills of fitness professionals, and providing PWMS with practical support to help physical activity be part of their everyday lives.

The research in community-based exercise for PWMS is growing. Combined with the access to exercise professionals with knowledge and skills for working with PWMS, the opportunities for access to exercise opportunities will increase. However, inequalities in access will remain for those of lower socio-economic status and those with higher disability. Nonetheless, exercise participation can be improved if all HCPs encourage and promote physical activity recommendations to their patients as soon as possible and as often as possible.

9.4 Implications

The logic model (Figure 14) presented above shows the work required to support PWMS to be active. The following sections discuss the implications for the physical activity guidelines, research, and community/practice.

9.4.1 Implication for the physical activity guidelines

Ongoing and future studies will continue to extend the knowledge and evidence of exercise for PWMS. The PAGs must be updated to incorporate the advancing evidence. The guidelines explored in this thesis were developed in 2013 and must be updated. The research discussed in this thesis highlights numerous areas that updated guidelines should consider and opportunities for the guidelines to impact more PWMS. These are presented below:

- There is a need for specific PAGs for PWMS currently excluded from the PAGs. These include young (under 18) PWMS, older (over 65) PWMS, and people with higher disability MS.
- Data from Chapter 6 highlighted that HCPs understand the benefits of exercise for PWMS but do not see it as a priority. Future PAGs should provide implementation strategies to ensure the intended users benefit. Examples include the development of resources to raise awareness of the PAGs with PWMS, HCPs, and leisure providers.
- Tailoring exercise is vital for PWMS, and future PAGs should guide how to tailor the recommendations to the individual. For example, aiming to cumulate 60

minutes of aerobic activity across the week rather than two 30-minute sessions per week.

9.4.2 Implications for research

This thesis has highlighted areas that require further investigation. These include further expansion of the PAGs, testing of the community-based intervention and exploring strategies for the long-term adoption of exercise in PWMS.

9.4.2.1 Expansion of the PAGs

- Chapter 3 showed that exercise behaviours in people with higher disability MS were impacted by numerous barriers, including fear and environmental factors, such as the ability to travel and access to exercise opportunities. Future research should explore supporting people with higher disability to move more to reduce sedentary time.
- The PAGs for the general population, people with cancer, and people with disabilities[127] all recommend vigorous-intensity exercise. Future research should look at the impact of vigorous activity on PWMS.
- Data from Chapter 8 suggested that PWMS rested for the remainder of the day after participating in the exercise class, potentially reducing daily physical activity. Future research should explore this potential response to bouts of exercise.

9.4.2.2 Further development of the intervention

- Further research is needed to establish the effectiveness of the community-based exercise intervention. The second phase of MRC guidance [58] is ‘feasibility and piloting’, which includes three stages 1) Testing procedures, 2) estimating recruitment and retention, and 3) determining sample size. The study does not need to be a scale model of the planned full-scale trial but should examine the critical uncertainties identified in the development phase [393]. During the feasibility and piloting phase, the evaluation should adopt several focus areas, for example, further investigation of the acceptability, implementation, and practicality of the intervention considering learnings from the proof-of-concept evaluation [393] (chapter 8). Examples of potential outcomes include treatment fidelity, resource requirements, factors affecting implementation, participant experiences, and effects on participants. The feasibility and piloting phase should also include identifying suitable methods for a future randomised controlled trial (RCT), including outcome measures, recruitment strategies, data analysis, and cost-effectiveness.

9.4.2.3 Strategies for long-term adoption of exercise in PWMS.

- Participants involved in the proof-of-concept study (chapter 8) stated that they wanted continued support beyond the completion of the intervention. Therefore, the intervention needs further development to increase participants' self-efficacy to self-manage their exercise behaviour. An option is to explore which additional BCTs are needed to elicit the required behaviour change, such as self-management.
- It is also possible that the design and delivery of the community-based intervention heightened participants' apprehension to exercise. Developing an intervention in patients' best interests could build further anxiety about exercise rather than cultivate independence and self-efficacy.
- Long-term follow-up of research outcomes should also be included in the future evaluation of the intervention. Long-term follow-up data is frequently unavailable in published literature, preventing an understanding of the long-term maintenance of exercise over time. These options should be explored in future development work to identify the most appropriate ones.

9.4.3 Implications for practice and community

The practical implications for real-world application were imperative in this research programme. The research findings in this thesis highlight that supporting all PWMS to exercise is complex. Developing PAGs is a good step in the right direction. However, developing an ecosystem that supports and encourages active behaviour in PWMS is crucial. Implications for practice and community include routine exercise promotion and access to community-based opportunities.

9.4.3.1 Promotion of exercise for PWMS

- For people with mild-to-moderate MS, physical activity is safe and worthwhile, resulting in PAGs being developed [25]. In Chapter 6, professionals and PWMS agreed that exercise benefits PWMS. Professionals discussed how exercise could help manage MS symptoms, improve quality of life, and reduce the risk of developing comorbidities. However, PWMS express apprehension and fear toward exercise. Chapter 6 reported how HCPs do not routinely discuss exercise with their patients. HCPs stated that exercise promotion is not a priority for health professionals in MS care. Research reports that medical students and doctors do not discuss physical activity with their patients [376]. Fear of offending or alienating patients, lack of knowledge and time are the three most common barriers to giving physical activity advice [376]. Discussing exercise with PWMS using the PAGs as a resource could help alleviate PWMS's fears about engaging in exercise.

9.4.3.2 Community-based exercise opportunities and support

- During the intervention development phase (chapter 7), one must consider how an intervention can be adapted and adopted within the community. The need to promote physical activity in individuals with chronic health conditions such as MS remains, so new community-based opportunities need to be provided. The target population for the developed community-based intervention was ambulatory PWMS, with or without a walking aid. This population was chosen due to the extensive evidence and the robust development of the PAG[25]. The findings in this thesis support previous reviews that recommend the need for more effort to promote physical activity in the MS community [484,485]. Several implications can be gathered from the findings in the thesis, including improvement of self-management support, giving advice on symptom management, and improving access to the intervention.
- Work is needed to increase the knowledge and competencies of all stakeholders (HCPs, PWMS, and leisure providers). Since the commencement of this research programme, a level four exercise qualification has been developed for working with neurological patients. The next step is to upskill exercise professionals, making access to exercise support in the community easier for PWMS. This will also present an opportunity to create links between HCPs and community leisure providers to provide ongoing support.

9.5 Thesis strengths and limitations

The strengths and limitations of the individual studies are discussed in the preceding chapters. This section considers the strengths and limitations of the thesis as a whole.

MS is a complex, variable, and progressive condition. A mixed methods approach was used to understand the priorities and experiences PWMS attributed to exercise and physical activity. The thesis included one scoping review, three qualitative projects, theory mapping, and one proof-of-concept study. A strength of this approach is the flexibility it allows for the topic to be explored from different perspectives, allowing a richer understanding not provided using one method [30]. The combination of the extensive patient experiences and preferences (chapters 3, 4, 6, and 8), thoughts of HCPs (chapter 6), review of the evidence (chapters 2 and 5), and the theoretical underpinning (chapter 7) were strengths of the intervention development. However, the small sample size of the HIIT intervention (chapter 4) and the proof-of-concept study (chapter 8) means the quantitative results were only exploratory and question whether the findings represent the MS population. This highlights a fundamental limitation and an area for future research: the effect of the developed intervention (chapter 8) is yet to be tested. However, findings from the evaluation can feed into future iterations of the intervention, where effectiveness can be measured.

9.6 Personal reflections

In Chapter 1, I discussed the importance of reflexivity as a component of research, particularly within qualitative research. This section presents a brief reflexive account of my experiences of undertaking this research, what I have learnt from the process and how it has developed me as a researcher. The section will discuss my reflections on the methodologies used in the thesis, the data collection, and the data analysis.

9.6.1 Reflections on the methodology

While reading extensively about research paradigms, I realised that my philosophical position is not in any particular theory. I am interested in how best to address the research problem and apply the research methods at my disposal. The word pragmatism is originally derived from the Greek word "pragma," which means action and is the central concept of pragmatism [486]. As a research paradigm, pragmatism aims to solve practical problems in the real world [486]. It emerged as a method of inquiry for more practical-minded researchers [486]. I am a researcher who aims to explore the application of research in the real world, and this is the path I expect my academic career to follow.

In this thesis (chapter 7), I combined the MRC guidance and the BCW to develop an intervention using data from the scoping review (chapter 5) and other projects within the PhD. The BCW has been developed from a comprehensive synthesis of behavioural change frameworks and promotes the integration of theoretical constructs to help researchers and HCPs select and design interventions that more effectively target and change behaviours [430]. I felt that using a tool such as this would progress our understanding and facilitate the translation of research into practice. However, using the BCW wheel was challenging and required me to constantly consider the reasons for my decisions from the context of the research data. A significant challenge came when choosing the behaviour change techniques (BCTs) for each intervention function. The BCTTv1 includes 93 techniques, and I became concerned with selecting the right ones for the interventions. Questions I asked myself included are these the right choices for PWMS? Will they work in practice (the community)? Are my opinions influencing the choices as well as the data? At this point in my PhD, I realised that I required training to ensure I was able to select the correct BCTs. The BCTTv1 provides online training to code and select BCTs. Using these online modules to practice selecting the relevant techniques combined with my critical reflections allowed me to be confident with the final selections. Consequently, when using a technique such as the BCW, it is crucial to understand the experience and training level of the researcher leading the process.

Throughout the research, I was the lead researcher. However, for the delivery of the community-based intervention (chapter 8), I took a back seat and allowed the project to develop organically. I chose this way of delivery to make the research as real-world as possible, which included not engaging in the recruitment or delivery of the programme. I learned a lot as a pragmatic researcher from this process, as it allowed me to reflect on the project in action. An example is the lack of referral to the programme from the HCPs. In chapter 6, HCPs highly supported a community-based intervention but stressed that recommending exercise to patients is not a priority. I found the lack of referrals from HCPs disappointing, and this is an area of research I would like to explore in the future. However, in hindsight, it was unrealistic to expect NHS clinicians to refer to a community-based intervention without evidence. It would have been more realistic to ask NHS clinicians to support recruitment to a specified research study rather than a referral.

9.6.2 Reflections on data collection and analysis

This thesis's most prominent means of data collection was through semi-structured interviews. A large amount of participant input has strengthened this thesis and reinforced my belief that understanding participants' perspectives is crucial to research. Working with the participants during each study was a particular highlight of the research and provided me with real-world context. Conversing with PWMS with various levels of disability and HCPs highlighted the complexity of the issues of exercise behaviour in PWMS, which was critical in understanding the participant’s perspectives and priorities. Although I believe in everyone being physically active, working with PWMS reminds me that an individual’s capabilities, opportunities, and motivation are different. I feel this is important for developing future research to increase exercise participation in this population. I remember one participant (chapter 8) discussing how having MS removed all spontaneity from life "You have got to think ahead at all times. Even having a shower, you have to organise it". Moments like this helped me to realise how complex behaviour change can be and how it will be different for everyone. Due to this appreciation of the differences between people, I felt that a qualitative focussed mixed-methods approach (discussed in chapter 1) was justified. This approach allowed me to collect rich participant data and learn from their experiences.

However, I was always aware that I was a researcher, asking questions and probing about their experiences of the condition to which I could not relate. Nevertheless, I feel that perhaps the participants found it acceptable to work with a researcher who understands MS but has no lived experience with the condition. During this process, I was also aware that everyone's lived experience of MS differs. Conducting the interviews allowed me to develop listening, reflecting, compassion, and empathy skills to build a rapport with all participants.

I have strived to reflect on my background and acknowledge my personal and professional biases, mainly when conducting and analysing qualitative research. I have learned that preventing my experiences from guiding the PhD throughout the research process is essential. The support of my supervisors and academic colleagues reminded me to remove myself from the research, thus ensuring the study was as unbiased as possible. Nevertheless, my previous experiences gave me a deeper insight during qualitative interviews and allowed me to better understand and empathise with the participants.

I chose framework analysis as the form of qualitative analysis for each study because of its systematic and transparent approach. As discussed in chapter 1, framework analysis is not aligned with a particular epistemological, philosophical, or theoretical approach[49]. I feel the framework analysis was justified due to the nature of the studies. For example, in chapter 6, the study aimed to learn the critical constructs required for a community-based exercise intervention. The analysis for this required an inductive and deductive approach to the analysis as I sought to explore their thoughts and experiences of living with MS and the preconceived themes of developing the intervention. I found that the development of matrices allowed me to intuitively reduce and compare large amounts of data.

9.6.3 Reflections on myself as a researcher

My academic career has not followed the typical degree, master's degree (MSc), and PhD approach. My education and study have primarily been completed whilst in employment. After completing my MSc, I began work as a research assistant on a large RCT with PWMS [192,390,487]. Therefore, at the start of the PhD research programme, I had a solid knowledge of multiple sclerosis and its management. I have always had a keen interest in physical activity, exercise, and behaviour change in clinical populations following my previous career in the fitness industry. Since my time as a research assistant, I have progressed to a research fellow and now a senior research fellow. As a full-time academic, I have completed my PhD part-time (and raised a young family) since 2017. Conducting the research and writing this thesis has been incredibly challenging yet rewarding. Over the last five years, my knowledge and ability as a researcher have changed considerably, and I hope this is demonstrated in the thesis.

An interesting development was altering my philosophical position as my research progressed. Braun and Clarke [488] define a ‘small q’/’Big Q’ distinction in qualitative research. ‘Small q’ is described as a positivist-orientated approach to coding reliability approaches, whilst ‘Big Q’ is defined as an organic and flexible approach. At the start of my PhD journey, my approach to qualitative research was very much ‘small q’. I was concerned with the reliability of the data I was collecting because I believed that for it to be reliable, the coding should be replicable [489]. My coding decisions should be the same if a second researcher analyses the data.

However, I began to become aware of the subjectivity of qualitative research. My subjectivities not only shaped how the research was designed, data was collected, and results were analysed but also how they were presented and discussed [490]. For example, qualitative researchers often incorporate quotes into the findings to ground their interpretations in participants' voices, an approach encouraged to show rigour [490]. Furthermore, I became aware that the data does not strictly mirror the voices of participants; instead, it reflects the voices of participants as I have interpreted them [490].

As I progressed through the research programme, my perspective shifted along a big Q/ small q continuum towards a more organic and reflexive researcher. I moved away from terms such as ‘data saturation’ (used in chapter 3) and themes ‘emerging’ from the data (used in chapters 1 and 3).

Data saturation is when no new information, codes or themes are yielded from data (Braun and Clarke). Data saturation raises the philosophical question of whether theories, data or themes can ever be genuinely saturated [491]. Rather than data saturation, the sample sizes for the studies discussed in this thesis were pragmatic and shaped by the limited time and resources available. Braun and Clarke suggest that data saturation is often deployed as a post-hoc rationale or acceptable rhetorical justification for a more pragmatically determined sample size [488].

Themes emerging from the data suggest that the researcher’s role is to unearth the truth buried in the data, allowing it to emerge without becoming biased by the researcher's subjectivity [491], which means that any research would find the same themes within the data. This language of thematic emergence preserves an appearance of objectivity, removing the researcher's subjectivity from the research process [491]. However, the idea that a researcher can set aside their own background knowledge, experience, and theoretical leanings whilst conducting the research and be a passive, objective observer seems outdated and implausible [492]

Through my studies, I learned that becoming a qualitative researcher occurs through intentional, directed effort and informal, implicit learning [491]. As my understanding progressed and my philosophical position altered, I became more reflexive about the research process. To ensure rigour, I acknowledged my beliefs, values and subjective perceptions and how they shaped my analysis and, ultimately, the results and conclusions.

The purpose of a PhD is to prepare an individual for becoming an independent researcher. A particular area I developed as a researcher was the ability to manage projects. Research project management requires the researcher to make decisions to ensure the project progresses. Project management also involves the management of numerous stakeholders, such as HCPs, patients, funders, and collaborators. Sometimes I found I was making concessions on the quality of research methods due to time or resources to deliver the project.

An example is a need for qualified instructors to deliver the community intervention when no qualification existed for exercise professionals to work with PWMS. However, I felt the PhD process has taught me to be confident to make pragmatic decisions for the delivery and ensure robust science. Completing the research in this PhD has undoubtedly set me on the road to becoming an independent researcher. It has enabled me to develop professionally, as a researcher, and personally. It has improved my understanding of the scientific process, and I hope the experience stands me in good stead for continuing to progress as an academic. However, there is still so much to learn.

10 References

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11 Appendices

11.1 Appendix A: Participant Information Sheet

Developing exercise interventions for people with moderate to severe multiple sclerosis.

Version 1

Introduction

Living with multiple sclerosis (MS) can be a difficult experience both physically and psychologically. Exercise is increasingly becoming accepted beneficial for the health and wellbeing of people with multiple sclerosis. Whereas the benefits of exercise have been established in people with mild to moderate degrees of disability due to MS, little is known about the benefits of exercise in people with a higher degree of disability from MS.

To provide you with all the key information for the study, we have pulled together a list of questions and answers. We hope this will allow you to make an informed decision about whether to be involved in this project.

Frequently asked questions

Q. What is the main purpose of the study?

A. The main aim of this study is to find out what types of physical activity people with severe MS would find feasible. We would like to determine what would be their preferable types of exercise and what they would like to achieve from an exercise programme. We would also like to explore ways of limiting periods of inactivity in people with MS.

Q. Why has my doctor told me about this study?

A. You have been selected as a suitable patient from your medical history, and because you are receiving treatment for your multiple sclerosis.

Q. What will I have to do?

A. If you have advised your neurologist that you are interested in taking part in the study you will be contacted by a researcher. The researcher will contact you to discuss the information in this document and you will have an opportunity to ask any questions you might have. You will then be sent a consent form to complete, and a freepost return envelope. Once the research team has received the consent form you will then be contacted by telephone for an interview.

Interview

The interview will last a maximum of 45 minutes and will be an informal discussion of you experiences and opinions of exercise.

Q. How long will the study last?

A. Your involvement in the study will finish once we have completed the telephone interview.

Q. Will there be any effect on my follow-up treatment?

A. No, your participation in this study will not affect your follow up treatment in any way.

Q. What are the potential benefits of taking part in this study?

A. Previous research suggests that exercise can have a positive impact on your physical and mental wellbeing. Very little research has been done with people with more severe MS. By gaining the opinions of people with the condition we can begin to design exercise research interventions for people with more severe MS.

Q. What are the potential disadvantages and risks of taking part?
A. The potential risks of taking part in this study are minimal, although the interviews may discuss subjects of a sensitive nature. If you feel distressed during the interview, the interview will be stopped and the researcher who will be able to counsel you.

Q. If I decide to take part will my GP be informed?
A. With your consent, we will write and inform your doctor that you are taking part in this study.

Q. Do I have to take part?
A. No. It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to complete a consent form.

Q. What if I do not wish to take part?
A. Your participation is completely voluntary. If you decide not to take part, this will not affect the standard of care you receive from the hospital or any health professional.

Q. What if I change my mind during the study?
A. You are free to withdraw at any time without it affecting your future treatment.

Q. What will happen to the information from the study?
A. The information from the study will be used anonymously to help design a larger scale exercise trial for people with multiple sclerosis, with results and some quotes published in academic journals. The overall conclusions from the study will be made available to you; however, it will not be possible to produce an individualised report.

Q. Will the information obtained in the study be confidential?
A. Yes, the confidentiality of our study participants and their data is of utmost importance. All data from the study is anonymised. This means you will be allocated a number during the study, and this will be used to store data. In addition, we need to obtain your permission to allow the research team access to your medical records, and to information collected during the study. This is one of the clauses, which you will sign in agreement on the consent form.

Our procedures for handling, processing, storage, and destruction of data are compliant with the Data Protection Act 1998.

Q. Who is organising the research?
A. The study is organised by the Centre for Sport and Exercise Science, Sheffield Hallam University in collaboration with the Academic department of Neurology at the Sheffield Teaching Hospitals NHS Foundation Trust.

Q. Who has reviewed the study?
A. The South Yorkshire Research Ethics Committee has reviewed the study.

Q. What if I have further questions?
A. If you have any questions with regards to this study you may phone:

Name: Professor Basil Sharrack (Consultant Neurologist) Tel: 0114 2719303
Name: Mr Liam Humphreys (Study researcher) Tel: 0114 2255645

Q. What if I wish to complain about the way this study has been conducted?
A. if you have any cause for complaint about any aspect of the way in which you have been approached or treated during the course of this study, the normal National Health Service complaints mechanisms are available to you and are not compromised in any way because you have taken part in a research study. The normal complaints procedure applies, and you should contact the following person:
Name: David Throssell (Medical Director) Tel: 0114 2711900

You can also voice your complaint to any individual of the research team:
Name: Professor Basil Sharrack (Consultant Neurologist) Tel: 01142719303
Name: Mrs Anouska Carter (Project Co-ordinator) Tel: 0114 2255633
Name: Liam Humphreys (Study researcher) Tel: 0114 2255645

Sheffield Hallam University has the following policies in place for the legal liability of the university; (a) Professional indemnity (£10 million); and (b) Public liability (£20 million).

Thank you for taking the time to consider participating in this study.

11.2 Appendix B: Chapter 3 interview schedule

MS and Exercise for people with mod-severe MS: Telephone Interview Guidelines

Thank you for agreeing to take part in this interview, your time is much appreciated. My name is XXXX, I am researching how people with more severe MS feel about exercise. We hope that this will help to guide further research into exercise for people with more severe MS.

I will be recording the whole interview, which should take no longer than 45 minutes. If at any point you want to end the interview, please just say. Also, if there are any questions you do not understand just let me know and I will try my best to rephrase them.

General Background: daily living

It will be helpful to understand the nature of your MS, so could you please tell me a little about how MS has affected you?

- What symptoms do you have?
    - Weakness?
    - Stiffness, spasms or spasticity?
    - Problems with balance or coordination?
- What are the key limitations that you have in terms of daily activities?
- How important is exercise to you?
- Do you feel exercise will help your MS?
- Do you use any aids or orthotics to help you to be more active?
    - AFO
    - walking aids
    - FES

Exercise Background: Building a rationale for an exercise intervention

Understanding of sedentary behaviour

***Sedentary behaviour* refers to any waking activity that occurs whilst sitting or reclining posture** that involves very little movement and hence requires very low energy expenditure. Common sedentary behaviours include TV viewing, video game playing, computer use (collective termed “screen time”), driving automobiles, and reading. Being less sedentary regardless of your levels of physical activity can have health benefits.

- Can you give examples of when you might be sedentary?
- Are you happy with your level of sedentary behaviour?
- Is this something that you would like to change?

Understanding Physical Activity and Exercise

We would like to get an impression of how you feel about Physical Activity and Exercise.

Physical activity is any body movement that works your muscles and requires more energy than resting. Physical activity generally refers to movement that enhances health. ***Exercise*** is a type of physical activity that's planned and structured.

- Currently do you feel that you do any physical activity?
- Are you aware of any exercise recommendations for Mod-severe MS?
    - Have your doctors or therapists talked to you about exercise?
    - Do you have any thoughts about what type of exercise might be appropriate?
    - Do you have any thoughts about why exercise might help?

Experience of exercise

Can you now tell us a little about your experiences of exercise. We would like to know about what sort of activities and exercise you enjoyed before you developed MS and also more recently.

- What sort of exercise did you enjoy doing before you developed MS?
- What sort of exercise have you done since you developed MS?
- What types of exercise have worked well for you?
- What has motivated you to exercise in the past?
- What opportunities have helped you in the past?
- Do you have exercise equipment that you use?
- What hasn't worked for you?
    - Have you felt worse as a result of exercising?
    - Have you types of exercise would you not consider?
    - In the past, what are the main things that have stopped you from exercising?

Challenges to making it happen /barriers to exercise/reduction in sedentary behaviour

- What do you feel are the barriers that prevent you from exercising more?
    - Which MS symptoms make exercise challenging for you?
        - Fatigue
        - Balance & walking
        - Muscle spasms & stiffness
        - Bladder & bowel problems
        - Low mood, anxiety & depression
        - Muscle weaknesses
    - Which is the most important to you?
    - Might it be difficult to fit exercise alongside other commitments?
    - Do you struggle to know what sort of exercise you might do?

Exercises that might be helpful

There are a number of possible approaches to exercise that have been found to be helpful for others. I would like us to go through a few of these together but if there are other approaches that you are aware of, it would be very helpful if you could share these with me.

Some people find it helpful to exercise in a gym environment where there is equipment that they can use despite not being very mobile, such as an exercise bikes (arm or leg).

- How would you feel about exercising in a gym environment?
- Would it be important to you that you were exercising with other people with a similar level of ability to yourself or would you be comfortable exercising with anyone?
- Would it be practical for you to have gym equipment at home?

Some exercise equipment is designed to be used specifically for people with limited movement. For example, the machines help you move parts of your body that you might not be able to move easily yourself.

- How would you feel about using this type of exercise machine?
- These machines would only be available in centres created for this purpose; if there was one local to you, do you think you might use it?
- Would you have someone who might be able to help you?
- Do you think you might go with friends or by yourself?

Some people with more limited movement prefer to exercise in their home environment.

- Would you be motivated to do this?
- Would you be more comfortable exercising at home by yourself?

- Do you prefer the company of others when you exercise?
- Do you prefer to exercise to music?
- Have you ever tried exercise videos? If so, which and did you find these helpful?
- Have you access to a Wii game or Wii Fit game? Have you tried using this and if so, how did you get on with this?

Some people enjoy group activities and team sports (seated sports such as ping pong, adapted cycles available for hire in the Peak District). Is this something that you might find attractive?

- How important is it to you to exercise outdoors?
- Are competitive activities attractive to you?
- How important is it to you to do activities with your family and friends?

Would you be prepared to travel to exercise with others or use exercise facilities?

- How long might you be willing to travel for?
- How would you travel - car, community transport? public transport?

Some people benefit from an individual to work with them, for example, an exercise professional or a therapist to assist with exercise, to monitor progress and activity levels and to give encouragement.

- Do you think this would help you?
- If so, do you think support from a distance would be enough, such as over the telephone or online or would you need to see someone in person?

Do you have any other ideas for activities that you may be able to do given the right support?

- How might you simply be more active in your day-to-day activities?

Expectations

Could you tell us a little about your expectations of exercise?

- If you were to do more exercise, what do you expect the impact of that might be?
- How do you think your body might respond to exercise?
- What do you think the benefits might be?
- What do you think the difficulties might be?

Research Design and Feasibility

If you were to take part in an exercise programme…

- What would you like to see included?
- Who would you like to see running the sessions? i.e. exercise specialist, physiotherapist, gym instructor
- Would you prefer to exercise on your own or in a group?

Having thought about the types of things you might do, we should consider what might be achievable.

- Do you have any thoughts about what might be achievable for you?
  - How many times a week could you engage with exercise?
  - How could you increase your activity levels?
  - How long do you think you may be able to exercise for?
  - How would you expect the exercise to feel?

Incentives and social influences

What incentives would make exercise happen for you? What sort of support might you need?

- Exercise advice?
- Getting together with others with similar interests?
- Support from those around you, partner, friends or family?
- Help with transport?

What do you think those around you (your family and friends) would feel about you trying to exercise?

- Would they be supportive?

11.3 Appendix C: Example from the coding framework

Participant	Effects of MS	Fear	Location
P3: Female; 44; SPMS; EDSS 6.5	Um, if I don’t fall twice a day, it’s, it’s, it’s a good day! It would be embarrassing, because obviously I went to the gym when I was fine, and going and seeing everybody that’s all healthy and skinny and working, running on a treadmill might be	I don’t want to aggravate my leg pains I don’t want MS to take over my life! It’s, it’s something I kind of worry about, but I don’t know, I wouldn’t know, I don’t know which way to handle it. I don’t know if it is like exercising, the more you do it the easier it’ll get, or if it’s going to be one day it’ll be easy-ish, the next day it’ll be a no-go, do you know what I mean? because there’s always the worry that you’re going to hurt, hurt yourself more. I don’t know how much it would knock you out really.	Doing things in the, yeah, doing things in the comfort of your own home is a lot nicer than going to maybe, say, another hospital or anything like that, because you go to that many. I mean, I’m under three; there’s the Northern General, the Hallamshire and Chesterfield.

P4: Female; 42 RRMS; EDSS 6.0	I have problems with, with, um, walking Pain and fatigue. probably the pain and the fatigue which is preventing me from doing things,	but the problem is if I was to go and utilise the limited, you know, the limited energy that I have doing, you know, going to do some kind of activities, I would, I would be struggling. But then I think I would be struggling anyway. When I go to the physios they only give me a limited amount of stuff to do, you know like. but the problem is if I was to go and utilise the limited, you know, the limited energy that I have doing	Oh no, (in the home) that would be great, yeah. I mean that would be, um, that would be a good, really good option for me, in my situation that, that I am, find myself in at, at the moment, yeah.
P5: Female; 48; RRMS; EDSS 6.5	I can join a gym but it's the embarrassment of showing my inadequacies to other people.	in my head I want to do all sorts of things, but realistically my body doesn't let me, you know do, do things	well in my own home I wouldn't want to go there with people who really fit and making me look stupid.

11.4 Appendix D: PDDS: Patient-determined Disease Steps

Please read the choices listed below and choose the one that best describes your own situation.

This scale focuses mainly on how well you walk. You might not find a description that reflects your condition exactly, but please mark the one category that describes your situation the closest.

0 – normal

I may have some mild symptoms, mostly sensory due to MS but they do not limit my activity. If I do have an attack, I return to normal when the attack has passed.

1 – mild disability

I have some noticeable symptoms from my MS, but they are minor and have only a small effect on my lifestyle.

2 – moderate disability

I don't have any limitations in my walking ability. However, I do have significant problems due to MS that limit daily activities in other ways.

3 – gait disability

MS does interfere with my activities, especially my walking. I can work a full day, but athletic or physically demanding activities are more difficult than they used to be. I usually don't need a cane or other assistance to walk, but I might need some assistance during an attack.

4 – early cane

I use a cane or a single crutch or some other form of support (such as touching a wall or leaning on someone's arm) for walking all the time or part of the time, especially when walking outside. I think I can walk 25 feet in 20 seconds without a cane or crutch. I always need some assistance (cane or crutch) if I want to walk as far as 3 blocks.

5 – late cane

To be able to walk 25 feet, I have to have a cane, crutch or someone to hold onto. I can get around the house or other buildings by holding onto furniture or touching the walls for support. I may use a scooter or wheelchair if I want to go greater distances.

6 – bilateral support

To be able to walk as far as 25 feet I must have 2 canes or crutches or a walker. I may use a scooter or wheelchair for longer distances.

7 – wheelchair / scooter

My main form of mobility is a wheelchair. I may be able to stand and/or take one or two steps, but I can't walk 25 feet, even with crutches or a walker.

8 – bedridden

Unable to sit in a wheelchair for more than one hour.

11.5 Appendix E: Permission to contact form

Study title: High intensity Interval Training for People with Mild Multiple Sclerosis: A Feasibility Study

Study Aim: The aim of the proposed study is to assess whether high intensity interval training is a safe, enjoyable and effective exercise option for people with mild multiple sclerosis.

Chief Investigator: Professor Basil Sharrack, Consultant Neurologist

Yes, you can phone me to discuss my interest in this project once I have had time to consider the information given to me	☐
The phone call is to discuss if I am interested in participating in the research project.	☐
The phone call does **not** mean I agree to be in the project.	☐
I understand that I can change my mind at any time.	☐
I understand that my contact details are confidential. They will only be used to tell me about this research project that is currently being done at Sheffield Hallam University.	☐
I wish to be phoned by the project researcher Liam Humphreys to discuss the project.	☐

I can be phoned at this phone number/numbers

____

The best days and times to phone me are

Signed____

Date____

11.6 Appendix F: Session feedback form (adverse event)

High intensity Interval Training for People with Mild Multiple Sclerosis: A Feasibility Study

Participant number:

Session number:

Participant comments:

Has the participant had any Adverse Events during this session? ☐**Yes** ☐ **No** ***(If yes, please list all Adverse Events below)***

Severity	**Action Taken Regarding Study Intervention**	**Outcome of AE**	**Expected**	**Serious**
1 = Mild 2 = Moderate 3 = Severe	1 = None 2 = Discontinued session 3 = Discontinued from study	1 = Resolved, No Sequel 2 = AE still present- no treatment 3 = AE still present-being treated 4 = Residual effects present-not treated	1 = Yes 2 = No	1 = Yes 2 = No (If yes, complete SAE form)

Adverse Event	Start Date	Stop Date	Severity	Relationship to Study Treatment	Action Taken	Outcome of AE	Expected?	Serious Adverse Event?	Initials
1.									
2.									
3.									

11.7 Appendix G: Example of the coding framework

	Feelings before the trial				Negative impact of the trial	
	B : Apprehension or fear	L : Peer support	O : Why signed up	I : Motivation	A : Adverse event	K : Negatives of HIIT
P1: Female, 28; MS	Um, I'd probably be in a lot of pain. I thought I was going to be, um, I thought I was going to be really bored, um. Um, I was anticipating the pain in my knees. I wasn't like, yeah, I was, I suppose, really, apprehensive. But I didn't go in to it with a negative mindset anyway.	Some of them thought it was really good. You know are you going to keep it up and some of them were like, oh God, I don't know how you do that (laughs). And a couple of my friends have got bikes and they were just like, you need to go spinning, like, spinning's, like awful (laughs). When they go out, those actually go out on bikes in real life, and they are like actual cyclists, and they say you should come with us, trying to get me to go and all that, oh (laughs), clinical trials.	Um, it's, one research, I like research. Just get involved; otherwise, nobody will ever know anything. Um, it didn't sound like a horrible, yeah, I thought it was pretty good actually. It's a good opportunity. It's not like you are pumping yourself full of drugs, like, the other one, you know. It's not drugs, it's something completely natural.	Um, this is where I have trouble because I always refuse to believe it's my MS that's making me tired. There's always of other stuff, um, but, because I don't really know what, I struggle. It's like you say, you struggle to differentiate between whether you're tired or not. I just have to kind of compare myself to the people I'm working with, and at the minute they're tired as well. Um, I think mainly it's to do with stress,	Um, sometimes I felt sick. A couple of times I went deaf (laughs). That was the only thing that worried me really because that's a symptom that I got when I first, um, I just went blind.	That was it. It was just like my legs went numb (laughs). You know when you stop like, stop exercising, you feel a little bit sick (laughs) can't walk properly.

P02: Female ; 27	I fully expected to feel awful and tired and achy and that I'd hate it, and to be perfectly honest, I didn't think I'd be able to do it, because I have so little, sort of, I don't feel like I can push myself sometimes with a lot of simple things, and I try not to use it as a crutch, but I always think oh what if I hurt myself, or what if I, you know, do myself some damage and it takes me ages to feel better Am I going to end up like, you know, in a total pickle?	And my mum and dad are quite protective. So they kept saying oh don't overdo it, you'll end up hurting yourself. Yeah, and with my mum having, um, sort of mobility issues as well, um, she'd kind of got the view of, she used to go and do physio, and she always felt worse after the physio. So I think she'd got a sort of predetermined opinion that I was going to be similar to her. That I was going to do something intense and feel terrible and take ages to get over it and kind of not reap any benefit. But obviously it's gone the other, which is nice.	Well, I, it's one of those things. I think you always put your trust in the people who are supposed to know more than you. So if he [neurologist] told me, it's kind of, if he said jump, I'm going to say how high, because he's telling me something for my own sort of benefit. So if he recommended it, I think regardless of my personal view on something I think I'd probably, you know, give it a crack. Um, especially with him saying it was to do with research. I thought well if it is going to benefit me, it'll benefit others. So even if I'm terrible at it, may as well give it a shot .	No, I kept expecting to kind of, I flake out of things really easily if I don't think I can do them, but with what I said to you I kind of saw it as more of a, I put my feelings second and thought I've got to do this because it's your research. So that kind of staved off the I can't do this, or I don't want to do this, I treated it more like an appointment that I had to do. And I think doing that made it more of a, I don't know, that made me enjoy it more because it wasn't a hassle, it was just something I was doing. .	First couple of sessions, quite tired. I think the first couple I possibly went home and vegged, um, because I wasn't used to doing anything that wasn't sitting down after work or just going to the gym for an hour. But, as it progressed, I think maybe like the second week, I started, you know, going home, taking the dog for a walk afterwards, to kind of keep on that high. I literally had a sore bum for the first couple of weeks … .	Um, yeah, first week I thought oh God what have I let myself into. Um, not particularly, just because I'm, I tend to get quite tired, so I wasn't particularly worried that it was anything detrimental. I just kind of thought oh, you know, I'm doing more strenuous activity so it's going to be a longer recovery time.

P03: Female ; 50	I thought I might be ti- a bit tired, um, I thought I might ache a lot more. Um, but I didn't have any, I didn't have any worries or concerns about it. . So that, that was the only time I was a little bit concerned. And I was thinking oh no, you know, kind of maybe, um, maybe I'm not up to this.	I wanted to get back into the habit. Um, and they thought it was great but, you know, I was going to, um, you know, get this opportunity to. But, a lot, like I say a lot of people don't know I've got MS because I don't really, the few, the friends that I do know that I don't see very often their first question is and how's your MS?	I think I just, I just, well I think I just wanted to get fit again to be quite honest. I m-, I'd, I'd started swimming, um, and I just, yeah, I had, like I say it was a six week course. I had the six week summer holidays in front of me. I think I might have thought twice had, had it not had the six week holidays in front of me. Um, just because, I, I hit, I hit such busy times coming down to, to where you are. So it just worked really well, that, you know, the holidays were on the horizon and it, and, you know, kind of that fitted in with you all right.	Yeah I think, I think I just enjoyed, um, I think there is something about, kind of something kicks in doesn't it when you're kind of, your heart's racing. Or when, when I have to say when I get, when I get the beeps coming on I think, oh no, not the beep - very funny! But in general, you know, there is something about pushing yourself. Um, I've never been competitive with other people but I do, I, I am quite competitive with myself, do you know what I mean.	A couple, of times I felt kind of not pulling up, possibly not, from the, the, straight after but, a kind of towards a day later, um, a bit stiff. But in general, you know, , I don't whether I'm pushing myself I feel a bit, a bit tired afterwards, you know, kind of you know, kind of after you got off the bike, you know, kind of I'd, I'd go to the car and I'd kind of drive home and think oh I just want to sit down and have a cup of tea.	I I do wish bicycle seats were more comfy.

P04: Female ; 37		Husband was supportive and keen for me to do it and I thought I would enjoy it my friends were concerned. Saying you know are you okay and all that kind of thing. How did it go. Some of them thought it was quite funny cause they just thought it was there idea of hideous. My parents were uneasy about it and thought I should taking it easy and weren't convinced it was a good idea. . .	I used to do this but haven't done recently so why not give it a go. It might be good to also really give reasons for other people. But you know it's kind of a good feeling to feel like you may have contributed in some way to something at the time to do it. So there there's not a good reasons not to quite interested in things so interested in this experience but in here you do the VO2 monitoring and all that business. .	It gave me a bit of confidence to do things like go good jogging from one of the mums from school who previously thought to I'm not fit enough for etc. and I just thought well I didn't do it and it was fine. .	Well this is quite embarrassing because of skin trauma to the point that there was bleeding. . I get very tight up my left side at any way. It's just the side that's more effected. Hamstrings on the left hand right happens just through jogging and working and things. But I suspect it was possibly a little more pronounced with cycling. I actually had some massages because it was quite painful but that isn't unusual to have happened anyway and the person who did the massage said that she thought it was particularly tight. .I found the bike very uncomfortable.	It started to get tedious towards the end. if it had carried on any longer I that would have wanted to vary it My optimum number was 8. 6 seemed pretty quick. . It as hard as you make it isn't it but six didn't seem to hard and I could literally go flat out right from the first one. 8 felt Like a challenge and 10 I wasn't given everything at the beginning.

11.8 Appendix H: Healthcare professionals interview schedule

Version 3

Demographics

- What is your current role and job title?
- Who is your employer?
- Where does your service / role operate? (i.e. Sheffield, S.Yorks, Rotherham)

Your views on exercise for people with MS

- What are your views regarding physical activity (PA) /exercise for MS patients?
- Tell me about your current delivery of PA advice
  - On a scale 1 - 10 how confident are you in giving PA advice?
  - What are your thoughts on training of staff?
    - Would you be interested in receiving brief training?

- What are your thoughts on the current physical activity opportunities available to your patients?
  - Do you know of any examples of good practice?

- What are your views about having a specific MS and exercise rehabilitation service in Sheffield and Rotherham?

Community physical activity service

- If you had lots of money and could design a service tomorrow what would it look like?
  - Who would be involved?
    - Who should run the service?
  - Where?
  - What? modes of exercise
  - how would people access the service (i.e. through GP exercise referral scheme, from hospital i.e. treating clinicians, AHP's, community referrals, or self-referral)
    - Who needs to be involved in referral?
  - What would be the main aim of the service?
    - Symptom management?
    - General wellbeing?

- Do you see any potential challenges or barriers to the successful integration of such a service within your organisation?
    - How would you overcome them?

Outcomes of exercise for people with MS

- What benefits would you like to see your patients receive from the service?
- Do we need to collect health outcome data alongside exercise participation?
    - What are the most important outcomes to be measured?

- What do you feel would be the key performance indicators for such a service?

11.9 Appendix I: People with MS interview schedule

Version 4

General Background

It will be helpful to understand the nature of your MS, so could you please tell me a little about how MS has affected you?

- What symptoms do you have?
    - Weakness?
    - Stiffness, spasms or spasticity?
    - Problems with balance or coordination?
- What are the key limitations that you have in terms of daily activities?
- How important is physical activity to you?
- Do you feel physical activity will help your MS?
    - In what way?
- Do you use any aids or orthotics to help you to be more active?
    - AFO
    - walking aids
    - FES

Experience of physical activity

- Tell me about your experiences of physical activity before you developed MS? How has this changed pre/post MS?
- tell me about your movement’s day to day?
- tell me about your positive experiences of physical activity?
- Currently do you feel that you do any physical activity?
    - Did you PA levels fall following diagnosis?
    - What sort of physical activity have you done since you developed MS?
- Tell me about times when you have found it difficult?
    - What hasn't worked for you?
    - Have you felt worse as a result of exercising?
    - Have you types of physical activity would you not consider?
- What do you think are the main barriers to exercising for someone living with MS?
    - How can we overcome them?
- How can we help people MS to be more active and stay active?
- What are the important questions you need answering if you are thinking about physical activity

Physical activity advice

- Were you given any advice about exercise from your clinical team regarding physical activity?
    - When was this advice given?
    - Was the advice useful?
    - Did your clinical team encourage / endorse /advocate physical activity for helping with rehabilitation or recovery?
    - Who gave the advice? doctor, GP, surgeon, oncologist, nurse, physio, fitness instructor, other?
    - Who do you feel is the right person to give advice?
- What has been your experience, if any, of accessing physical activity support for someone living with MS in the community?
    - Are you aware of any services?
    - Have you tried to access them?
    - Do you feel as though you have been well-supported, and your needs understood?

Physical activity and MS Rehabilitation Service

- If you could design a service to support PWMS to move more and be active, what would that look like?
- What type of service would you like to see?
    - What would it include?
        - What type of activities/ exercise?
    - Is it group based or individual?
    - How long would it last?
    - Would it be free? Would you be willing to pay towards the cost?
    - Where should it be offered? Who should deliver it?
    - Who would be eligible to take part?
    - Is it important that the service is just for PWMS? Would you be happy to exercise with others who have different clinical conditions or none at all?

Important outcomes

- If you are physically active do you think it's important to measure progress?
    - What should be measured?
        - Fatigue?
        - Strength?
        - Fitness?
        - Other?

11.10 Appendix J: Example of healthcare professional coding framework

Participant	Exercise is beneficial	Talking about exercise	Not a priority	Effects of condition
HP2: Female; 41 Neuro-physiotherapist	Finding solutions to taking part in exercise is really important for the MS population. I think just for management of the primary symptoms you know so particularly motor control, strength, sensory, and proprioceptive awareness exercise I think is really positive for all those.	It is about keeping people active and finding something that they're going to stick with	As an NHS physio, I don't think I ever spoke to individuals about exercise, about whether or not they went to a gym or not, or if they'd like to. We very much focused upon a more kind of medical approach to physio	The onset of MS is usually in young adulthood and people see that their peers are still active. I think what we're seeing at the minute, particularly amongst certain demographics is that there's a wave of exercise and physical activity that is kind of popular thing to do.
HP3: Female; 51; Neuro-physiotherapist	To gain better movement and better life quality exercise is part of it.	I do almost always refer people to a physio even if they've not got any particular problems, just to talk about sort of like suitable exercises and things like that. So, we do tend to always refer and to neuro-physios, in the local area.		Even if they look well, they might have balance issues and things. Also, the whole hour is sometimes a lot for someone to do which most classes are. If they get really bad fatigue trying to do that, whole hour can be difficult.

HP4: Female; 26; rehabilitation specialist		What they need is advice on exercise and advice on just getting out and keeping that up and knowing there is a support system.		People have reported in the past feeling intimidated exercising in a normal class because of their condition.
HP5: Female; 28; neuro-physiotherapist	Very many of the common symptoms that affect patients with MS such as limb weakness, Spasticity, , low mood, and MS fatigue, exercise plays an important part in improving that for patients.	I would say every consultation I am talking to patients about exercise.	MS patients are a group that don’t necessarily access support. They can keep themselves quite isolated. For a number of reasons, some people don't like seeing other PWMS, some don't like talking about their diagnosis.	MS fatigue I think is one of the biggest blockers

11.11 Appendix K: An example of PWMS coding framework

ID	Trained	Physio	Goals	Duration of session	Cost	Location	Social	Stratified
P8: Female; 30; PDDS 1	I'm thinking like a physio, an instructor that kind of knows a bit about the anatomy and sort of body. And I think it's quite important especially with PWMS that you know a little bit about what you're doing			45 minutes would be enough.	I would be willing to pay something. Something, not a gym membership though. I'm not talking like, you know, 35 quid a month. It would have to be, you know, like a class, maybe if there was a class and it could cover the cost of a venue and, you know, something for the instructor than yeah.	I'd like to see a bit more, um, obviously having, having to go out the house to, you know, it has to be local. It has to be easy, it has to be accessible, because one, you know, I know since I've lost my driving licence it was a lot harder to motivate myself to get to, you know,	I'm quite sociable so it's nice to go to a group. Like going to the gym on my own is always a little bit daunting and a bit boring.	I think the benefit of having the level, levels of MS in the same group would be, you know, you've got more people who are similar and it's a bit more encouraging, I think. Um, if people have got depression or, you know, they're really, I don't know, I can't think of another word for jealous but, you know, they wish they were like somebody else or, you know, it could probably make someone feel a little bit bad.

P9: Male; 59; PDDS 5	Does it have to be a neurophysio? I think it has to be somebody who you really trust.	Do try to get the advice of a proper neuro, neurophysiotherapist in order to work out what’s the right exercise for you, and then hopefully you will get the physical benefit and hopefully you will get the BDNF, disease modifying treatment, effective neuro exercise.	how fast can I open the pages of a book, do I find that difficult? How fast can I take my coins out of my wallet, because I found that difficult, and those sort of things that matter, can I carry a cup of tea and a bowl of cereal across the room to have my breakfast, that sort of measurement I think is very useful.		Would all exercise be, would exercise be free? Should it be funded through the state? No, I don’t think it should be funded completely. give people a free starter, free four weeks,		Getting people together and the sociable part of exercise is vital and. And people with neurodegenerative diseases will have problems with social, socialising and introducing new ways of socialising for them. And that’s great.	The client in different levels of severity. And I would see that if we take the example, we had of recently diagnosed, not bad, moderate disabilities to severe, I would want any of those people to refer themselves into an exercise scheme. But it doesn’t have to be at the gym only

	if in my early stages of MS, um, I had gone to a gym and had, there'd been fitness instructors there who had done rehab of neurological diseases and neurodegenerative, generative diseases, um, I would think great that I can, I would listen to that sort of person.	I think you've got to somehow gain the confidence of the patient. And when I come here, the neurophysios give a lot of advice on physiotherapy-type things. They don't push particularly at the aerobic exercise BDNF story.			But if you put some money in yourself, um, they commit more.			I don't think referral has to be stratified too much. I just tend to think of those categories. But ultimately the same thing is people need to get in. I think group exercise to be pragmatic is good for people.

11.12 Appendix L: BCW worksheet 1 - Define the problem in behavioural terms

What behaviour?	People with multiple sclerosis meeting the recommended levels of physical activity.
Where does the behaviour occur?	In the community (home or fitness facility) Not in a hospital
Who is involved in performing the behaviour?	PWMS, physiotherapists, fitness instructors, health professionals

11.13 Appendix M: Worksheet 2 - Define the problem in behavioural terms

Task 1: Generate a 'long list' of candidate target behaviours that could bring the desired outcome

Intervention aim: Provide PWMS with a theory-based community exercise intervention to help them be more active.

Intervention designer response

Providing physical activity opportunities:

- Home-based
- Internet-based
- Self-directed exercise
- Leisure/community facility

Reduction in the barriers for PWMS engaging in exercise

- Education on the effects of exercise for PWMS
- Communication of physical activity recommendations for PWMS
- Develop peer support groups
- Access to knowledgeable appropriately trained instructors
- Health professionals promote/endorse exercise
- Access to physiotherapy

Task 2: Prioritise the behaviours

Potential target behaviours	**Impact of behaviour change** (unacceptable, unpromising but worth considering, promising, very promising)	**Likelihood of changing behaviour** (unacceptable, unpromising but worth considering, promising, very promising)	**Spill over score** (unacceptable, unpromising but worth considering, promising, very promising)	**Measurement score** (unacceptable, unpromising but worth considering, promising, very promising)
Providing home-based PA opportunities	Promising	promising	Unpromising	Unpromising
Internet-based	Promising	promising	promising	promising
Self-directed exercise	Unpromising	Unpromising	Unpromising	Unpromising
Leisure/community facility	Promising	Promising	Promising	Promising
Education on the effects of exercise for PWMS	Promising	Unpromising	Unpromising	Unpromising
Communication of physical activity recommendations for PWMS	Unpromising	Unpromising	Unpromising	Unpromising
Develop peer support groups	Promising	Promising	Promising	Unpromising
Access to knowledgeable appropriately trained instructors	Promising	Promising	Promising	Promising
Health professionals promote/endorse exercise	Promising	Promising	Promising	Promising
Record selected target behaviour here:	• Exercise in a leisure/ community facility, • access to knowledgeable appropriately trained instructors and physios • Peer support			

11.14 Appendix N: Worksheet 3 – Specify the target behaviour

Target behaviour	Increase physical activity levels of PWMS in the community
Who needs to perform the behaviour?	People with low-to-moderate MS related disability
What do they need to do differently to achieve the desired change?	Attend a community-based exercise intervention for 12 weeks
When do they need to do it?	Community-based intervention will be one day per week Self-managed physical activity will can be done whenever they can
Where do they need to do it?	Community/leisure facility Home Local area
How often do they need to do it?	Adults (aged 18-64 years) with MS: 30 minutes of moderate intensity exercise 2 times per week Strength training exercise for major muscle groups 2 times per week
With whom do they need to do it?	Can be done by themselves if individual is confident With friends and family With a fitness instructor In a group

11.15 Appendix O: Worksheet 7 – policy categories

Intervention function	Policy categories	Does the policy category meet the APEASE criteria?
Education	Communication/marketing	Yes
	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Regulation	N/A
	Legislation	N/A
	Service Provision	Yes
Persuasion	Communication/marketing	Yes
	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Regulation	N/A
	Legislation	N/A
	Service provision	Yes
Incentivisation	Communication/marketing	Yes

	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Fiscal measures	N/A
	Regulation	N/A
	Legislation	N/A
	Service Provision	Yes
Training	Communication/marketing	Yes
	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Fiscal measures	N/A
	Regulation	N/A
	Legislation	N/A
	Service Provision	Yes

Environmental restructuring	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Fiscal measures	N/A
	Regulation	N/A
	Legislation	N/A
	Environmental/ social planning	Yes
Modelling	Communication/marketing	Yes
	Service provision	Yes
Enablement	Guidelines	Guidelines around physical activity already exist and will form the prescription
	Fiscal measures	N/A
	Regulation	N/A
	Legislation	N/A
	Environmental/social planning	Yes

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<tr><td colspan="3">Policy categories selected: Communication/marketing, service provision, environmental/social planning</td></tr>
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11.16 Appendix P: Worksheet 7 - Identifying Behaviour Change Techniques (APEASE criteria)

Intervention function	COM-B component	Frequently used BCTs	Does the BCT meet the APEASE criteria	Less frequently BCTs identified in qualitative analysis	Does the BCT meet the APEASE criteria
Education	Physical Capability Reflective motivation	Information about social and environmental	No	Self-monitoring of outcomes of the behaviour	No
		Information about health consequences	Yes		
		Feedback on behaviour	Yes		
		Feedback on outcome(s) of the behaviour	Yes		
		Prompts/cues	No		
		Self-monitoring of behaviour	Yes		

Persuasion	Automatic motivation Reflective motivation	**Credible source**	Yes	Verbal persuasion about capability	No
		Information about social environmental consequences	No		
		Information about health consequences	No		
		Feedback on behaviour	Yes		
		Feedback on outcome(s) of the behaviour	Yes		
Incentivisation	Automatic motivation Reflective motivation	**Feedback on behaviour**	Yes		
		Feedback on outcome(s) of the behaviour	Yes		
		Monitoring of behaviour by others without evidence of feedback	No		

		Self-monitoring of behaviour	Yes		
Training	Physical capability Psychological capability Physical opportunity Automatic motivation	**Demonstration of the behaviour**	Yes	Self-monitoring of outcomes of the behaviour	No
		Instruction on how to perform a behaviour	Yes		
		Feedback on the behaviour	Yes		
		Feedback on outcome(s) of behaviour	Yes		
		Self-monitoring of behaviour	Yes		
		Behavioural practice/rehearsal	Yes		
		Adding objects to the environment	Yes		

Environmental restructuring	Physical opportunity Social opportunity	Prompts/cues	No		
		Restructuring the physical environment	No		
Modelling	Social opportunity Automatic motivation	**Demonstration of the behaviour**	Yes		
Enablement	Physical capability Psychological capability Physical opportunity Social opportunity Automatic motivation	Social support (unspecified)	No	**Social support (emotional)**	Yes
		Social support (practical)	No	**Self-monitoring of outcomes of the behaviour**	Yes
		Goal setting (behaviour)	Yes		
		Goal setting (outcome)	Yes		

		Adding objects to the environment	No		
		Problem solving	No		
		Action planning	Yes		
		Self-monitoring of behaviour	Yes		
		Restructuring of the physical environment	No		
		Review behaviour goal(s)	Yes		
		Review outcome goal(s)	Yes		

11.17 Appendix Q: Worksheet 8 – Identify mode of delivery

Mode of delivery				Does the mode of delivery meet the APEASE criteria?
Face-to-face	Individual			No
	Group			Yes
Distance	Population Level	Broadcast media	TV	
			Radio	
		Outdoor media	Billboard	
			Poster	
		Print media	Newspaper	
			Leaflet	
		Digital media	Internet	
			Mobile phone app	
	Individually-level	Phone	Phone helpline	
			Mobile phone test	
		Individually accessed computer programme		

11.18 Appendix R: BCT used in each session

	BCT (taxonomy code, Michie et al, 2013)	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9	Session 10
1	Information about health consequences (5.1)	▨	▨						▨		▨
2	Feedback on behaviour (2.2)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
3	Feedback on outcome(s) of the behaviour (2.7)			▨			▨				▨
4	Self-monitoring of behaviour (2.4)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
5	Credible source (9.1)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
6	Demonstration of the behaviour (6.1)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
7	Instruction on how to perform a behaviour (4.1)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
8	Behavioural practice/rehearsal (8.1)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
9	Adding objects to the environment (12.5)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
10	Goal setting (behaviour) (1.1)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
11	Action planning (1.4)		▨	▨	▨	▨	▨	▨	▨	▨	▨

12	Review behaviour goal(s) (1.5)			▨							▨
13	Social support (emotional) (3.3)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

11.19 Appendix S: Instructor MS awareness raising booklet

Introduction

Multiple sclerosis (MS) is a complex condition and has many consequences, such as impaired muscle strength, mood, fatigue, and mobility. Exercise has been shown to be a safe and effective treatment strategy for people with MS (PWMS). Despite the suggested benefits of exercise, PWMS are often reported to be less physically active than the general population, with symptoms being linked to physical activity levels and partially accounted for by low exercise self-efficacy (situation-specific self-confidence). This low physical activity can lead to secondary complications such as obesity, cardiovascular disease and osteoporosis.

Historically PWMS have been advised to avoid exercise to conserve energy and prevent increases in body temperature that could worsen symptoms (Uhthoffs syndrome) (Petajan and White, 1999). Early research focused on rehabilitation-based physiotherapy treatments (Oligati and Prampero, 1986) and water-based exercise (Gehlsen et al., 1984); these studies generally had small sample sizes and lacked the robust de- sign of a randomised-control trial (RCT). Research in the area has since gained momentum, with the Cochrane review on 'Exercise therapy for Multiple Sclerosis' (Rietburg, 2005) recognising nine RCT's of high technical quality, concluding that exercise is efficacious for improved outcomes in MS. However, it was recognised that further research of high technical quality is required. Further reviews by Heesen et al., (2006), Dalgas et al., (2008), Motl and Pilutti (2012), La- timer-Cheung et al., (2013) and Sá (2013) supported these findings and concluded that supervised exercise (aerobic and or strength) training is beneficial for people with mild-to-moderate MS. Moreover, a recent review on exercise safety for PWMS suggested that exercise causes no increase in re- lapse rate or the number of exercise-related adverse events reported in PWMS (Pilutti et al., 2014), indicating it is both a safe and effective treatment strategy for this patient group.

Current evidence suggests that exercise may do more than improve function and better manage symptoms in MS, but may slow down the disease pro- cess, with some evidence to indicate a possible disease-modifying effect. This indicates that guidance for long-term prescription is required (Dalgas and Stenager, 2012).

Depending on the nature and level of impairment associated with the dis- ease, PWMS may experience a variety of symptoms that may directly affect their responses to exercise.

These symptoms include:

- Spasticity
- Incoordination

- Impaired balance
- Fatigue
- Muscle weakness, paresis (partial paralysis), and weakness
- Sensory loss and numbness
- Cardiovascular dysautonomia (problems with cardio acceleration and reduction in blood pressure response)
- Tremors
- Heat sensitivity

Review of the Literature

BRIEF OVERVIEW OF THE RESEARCH

It is now generally accepted that exercise and physical activity is safe and beneficial for people with mild-to-moderate multiple sclerosis. Research suggests that exercise therapy is safe (Sa, 2014) and there is no evidence that exercise increases relapse rates (Pilutti et al, 2014).

The majority of physical activity research is in people with mild-to-moderate MS research is limited in people with moderate-to-severe MS (Langeskov-Christensen et al, 2015). Research is required that investigates the feasibility and safety of exercise in people with higher impairment levels.

Evidence indicates that significant physiological deconditioning occurs in persons with MS, particularly due to disability progression (Motl et al 2013). PWMS can find themselves in a cyclical situation; their condition leads to physiological deconditioning, which leads to physical inactivity, which results in further physiological deconditioning.

MS has a wide range of effects on a person's health. Compared to healthy people MS patients have reduced aerobic capacity, decreased muscle strength, reduced muscle endurance, impaired balance, impaired motor control and high levels of fatigue (Doring et al, 2012). Due to this range of debilitating effects of MS physical activity research interventions consider outcomes beyond standard indicators of fitness. Physical activity and exercise interventions for PWMS tend to consider the impact of physical activity on multiple outcomes. There is evidence that physical activity has positive effects on health-related quality of life, physical function, fatigue, aerobic fitness, and mental health. The results from the literature show promise for the use of physical activity in PWMS.

Latimer-Cheung and colleagues (2013) provided exercise prescription recommendations for PWMS. The guidelines are set for people between 18-65 years of age and mild to moderate disability. The main recommendations are for individuals to complete at least 30 minutes of moderate intensity aerobic activity 2 times per week and strength training exercise for major muscle groups 2 times per week. The guidelines offered by Latimore-Cheung and colleagues (2013) are vague and offer very little advancement on previous recommendations offered by Rietberg and colleagues (2004). Rietberg and Colleagues (2004) recommended that future research should use a core set of outcome measures; more research was needed for people with higher disability, and older ages. These recommendations are still relevant for the research today as there seems to have been no further development in these areas.

Future research:

- Include behavioural strategies to promote long-term exercise and physical activity adherence.
- Clearly embed a treatment fidelity framework for randomised and quasi experimental studies in order to ensure consistency and replicability; design, interventionist training, intervention delivery, receipt by the participant, enactment by the participant.
- Explore the benefits of exercise and physical activity interventions in people with more severe MS and those with different types of MS.
- Determine the optimum dose of exercise for PWMS in relation to important symptoms such as fatigue.
- Bespoke tailored interventions based on severity of MS, type of MS and individual symptoms.
- Training and competence assessment of service deliverers to ensure consistency of delivery.
- Consistency of outcome measures used to allow for comparison across studies.
- Design, implement, and evaluate community based physical activity opportunities for PWMS.

The MS Patient

HOW A PERSON IS AFFECTED BY MS

Physiological profile of MS patients

MS patients, especially with more severe impairments, may exhibit some differences in their physiological characteristics in comparison to healthy age-matched people in terms of cardiovascular and muscle physiology. Decreased aerobic capacity and cardiorespiratory fitness, in expression of VO2 max or maximal oxygen consumption, among MS patients has been about 30% lower than the healthy controls. Respiratory dysfunction due to respiratory muscle weakness and external causes like muscle defect and tiredness are contributing factors in reducing aerobic fitness. Other cardiac factors such as resting heart rate and resting blood pressure are noted to be increased in multiple sclerosis because of impairments in the autonomic control of cardiovascular function that has been estimated about 7% to 60% among MS patients. Also, decreased muscle force calculated by isokinetic and isometric muscle contractions and endurance, muscle mass in total body and increased muscle atrophy are seen in MS patients. It must be shown that muscle strength defect appears particularly clear in the lower extremities in comparison to the upper extremities. Flexibility is another physiological characteristic that has diminished in MS patients specially in those with spasticity. About 80% of MS patients feel high temperature intolerance that may be correlated with temporary exacerbation of clinical manifestations of the MS. This is an important concern about MS and exercise. Physical activity is beneficial and important for PWMS, but it should not cause overheating symptoms.

Secondary Disuse

PWMS who suffer from loss of muscle activation and control often experience difficulty participating in both activities of daily living and leisure activities. This can lead to a gradual decrease in physical activity. It has been shown that in PWMS, physical limitations are positively correlated with physiological changes. These limitations have been shown to be similar to those that occur in healthy people who have experienced prolonged physical inactivity.

Examples of such changes include:

Reduced muscle force as a consequence of:

- Changes in metabolic levels

- Failure of the excitation–contraction coupling mechanism
- Reduced muscle fibre size and number.
- Reduced cardiorespiratory fitness as a consequence of:
- Lower VO2 maximum (maximum capacity to transport and utilise oxygen during exercise)
- Higher overall oxygen consumption per activity
- Earlier achievement of the anaerobic threshold.

Traditionally, PWMS have sought advice on exercise or rehabilitation once they have developed functional movement difficulties. However, recent evidence highlights the benefits of exercise as an early intervention, even before clinical symptoms of MS are observed. It has been shown that people with a recent diagnosis of MS, who have no observable physical disability (Expanded Disability Status Scale [EDSS] score of between 0–2) already have kinematic, kinetic, balance, and muscle activation changes. This sub-group of people are the most likely to experience brain adaptations as neuroplasticity and increased central activation is more effective in people with fewer lesions. Furthermore, higher exercise levels have been shown to relate to slower accumulation of functional limitations, and improved quality of life over time in PWMS. It is important to encourage PWMS to start a regular exercise program early in the disease course. Targeting identified deficits can maximise their physical abilities through neuroplastic adaptations. It is important to note that in PWMS, respiratory muscle strength may also be impaired due to either the disease process or disuse influences. The weakness in respiratory muscles is correlated with higher levels of inactivity and disability. A study involving severely disabled PWMS reported that respiratory muscle weakness correlated with significant reduction in quality of life and exercise participation (as a consequence of a reduced forced vital capacity, inspiratory and expiratory maximal pressures and secretion clearance).

Exercise Training

The highest level of evidence for the benefits of exercise training (strength and cardiovascular) in PWMS shows that exercise can improve:

- Muscle force production
- Improved walking speed and endurance
- Improved self-efficacy
- Improved gait kinematics
- Improved immune system function

- Improved respiratory muscle strength
- Reduced fatigue
- Reduced physical and social disability
- Reduced symptoms of coronary artery disease.

Some PWMS have reported that exercise preceded an MS exacerbation, but no studies have been able to identify exercise as the cause of exacerbations. It should be noted that exercise can result in a temporary increase in existing symptoms or onset of new previously silent symptoms in PWMS. This is probably related to a heat-induced reduction in nerve conduction velocity. Such symptoms tend to resolve within thirty minutes of rest.

Strength training using functional weight bearing positions may provide greater improvements in functional measures than free- weights. It is important to use positions and equipment that are accessible and safe, and to consider an individual's mobility, balance, cognitive status, co-morbidities and any other existing MS symptoms. Thus, free-weights and resistance machines may be useful when functional training is not possible and when the person has significant focal weakness.

In PWMS weakness, poor endurance and functional impairment can be a result of loss of muscle activation or muscle control. This is due to the disease process of MS and/or secondary effects from prolonged disuse. The secondary effects of disuse can be prevented or reversed in PWMS. The earlier the interventions the better. Exercise does not make MS worse but may lead to a temporary worsening of existing symptoms or onset of new symptoms.

Strength training

- Progressive resistive strength training improves the strength of targeted muscles in PWMS.
- Allow full recovery between strength training sessions by alternating between strength and cardiorespiratory training on separate days completing a maximum of two-to-three strength training sessions per week.
- PWMS who experience fatigue will require a flexible approach to weight progression in their strength training program.

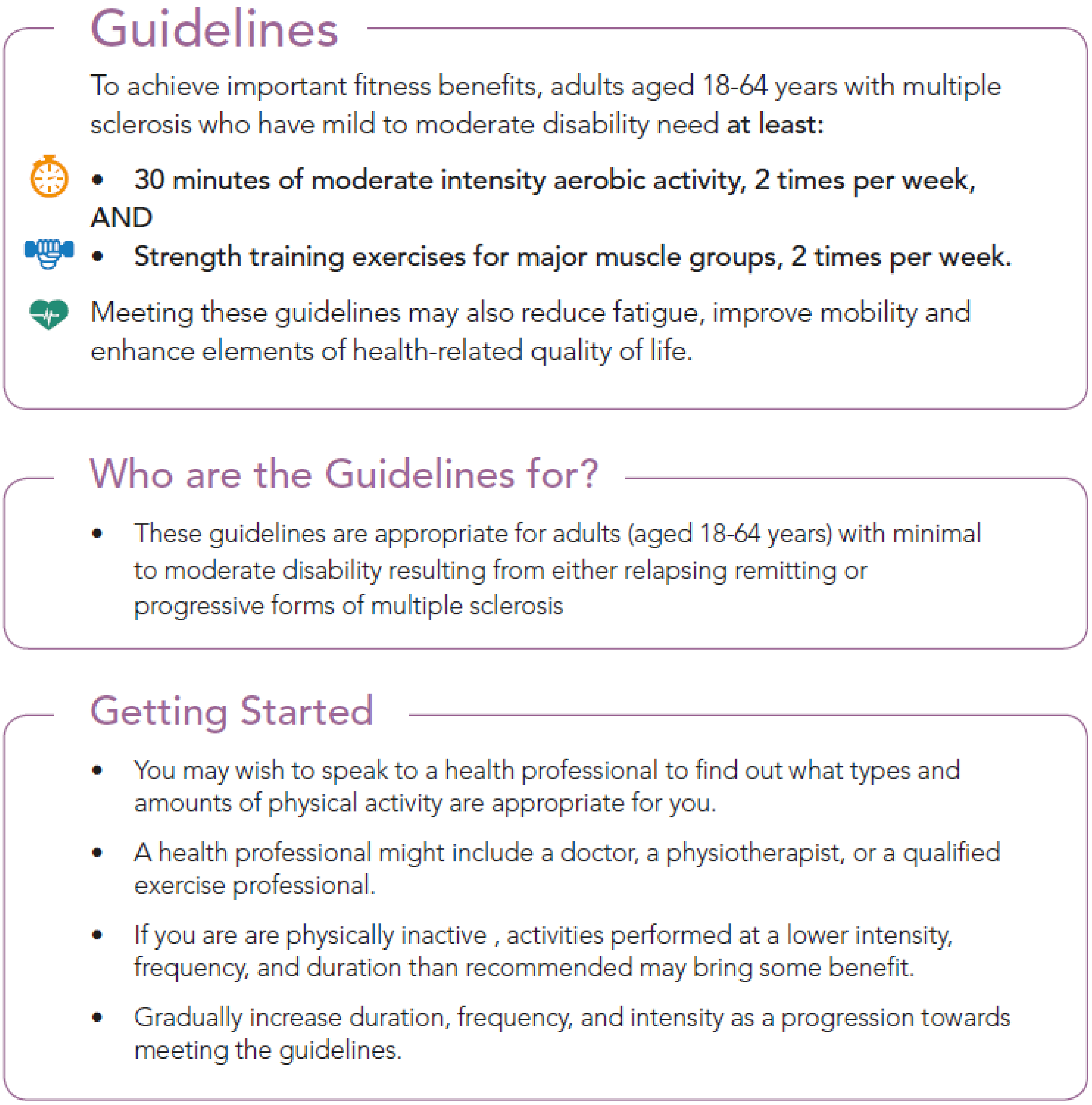
Cardiorespiratory training

- Endurance exercise can significantly improve poor cardiorespiratory functions and many other symptoms reported by PWMS.

- PWMS who have greater than two risk factors for cardiorespiratory disease should undergo formal testing. This will establish their working heart rate to achieve the desired percentage VO2 maximum.
- Starting an exercise program at a lower intensity, such as 50–60% THR or workload maximum, and exercising for shorter duration, may help to prevent undue fatigue and symptom aggravation.

Exercise Guidelines

Developed by Latimer-Cheung et al (2013)



Guidelines

To achieve important fitness benefits, adults aged 18-64 years with multiple sclerosis who have mild to moderate disability need **at least:**

- **30 minutes of moderate intensity aerobic activity, 2 times per week,**

AND

- **Strength training exercises for major muscle groups, 2 times per week.**

Meeting these guidelines may also reduce fatigue, improve mobility and enhance elements of health-related quality of life.

Who are the Guidelines for?

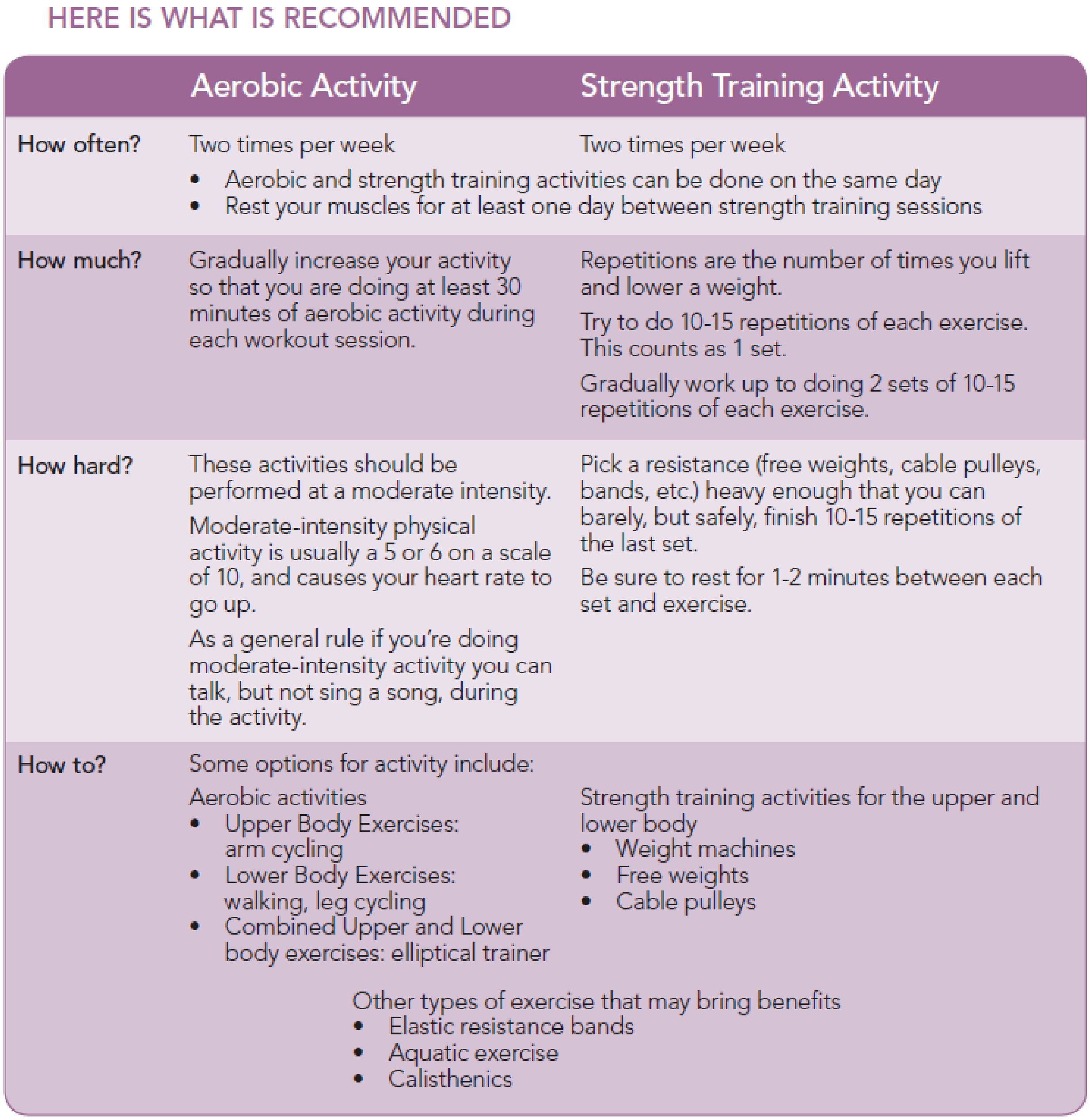
- These guidelines are appropriate for adults (aged 18-64 years) with minimal to moderate disability resulting from either relapsing remitting or progressive forms of multiple sclerosis

Getting Started

- You may wish to speak to a health professional to find out what types and amounts of physical activity are appropriate for you.
- A health professional might include a doctor, a physiotherapist, or a qualified exercise professional.
- If you are are physically inactive , activities performed at a lower intensity, frequency, and duration than recommended may bring some benefit.
- Gradually increase duration, frequency, and intensity as a progression towards meeting the guidelines.

Exercise Guidelines

Developed by Latimer-Cheung et al (2013)



HERE IS WHAT IS RECOMMENDED

<table>
<tr><th></th><th>Aerobic Activity</th><th>Strength Training Activity</th></tr>
<tr><td>How often?</td><td>Two times per week</td><td>Two times per week</td></tr>
<tr><td></td><td colspan="2">• Aerobic and strength training activities can be done on the same day
• Rest your muscles for at least one day between strength training sessions</td></tr>
<tr><td>How much?</td><td>Gradually increase your activity so that you are doing at least 30 minutes of aerobic activity during each workout session.</td><td>Repetitions are the number of times you lift and lower a weight.
Try to do 10-15 repetitions of each exercise. This counts as 1 set.
Gradually work up to doing 2 sets of 10-15 repetitions of each exercise.</td></tr>
<tr><td>How hard?</td><td>These activities should be performed at a moderate intensity.
Moderate-intensity physical activity is usually a 5 or 6 on a scale of 10, and causes your heart rate to go up.
As a general rule if you're doing moderate-intensity activity you can talk, but not sing a song, during the activity.</td><td>Pick a resistance (free weights, cable pulleys, bands, etc.) heavy enough that you can barely, but safely, finish 10-15 repetitions of the last set.
Be sure to rest for 1-2 minutes between each set and exercise.</td></tr>
<tr><td>How to?</td><td colspan="2">Some options for activity include:</td></tr>
<tr><td></td><td>Aerobic activities
• Upper Body Exercises: arm cycling
• Lower Body Exercises: walking, leg cycling
• Combined Upper and Lower body exercises: elliptical trainer</td><td>Strength training activities for the upper and lower body
• Weight machines
• Free weights
• Cable pulleys</td></tr>
<tr><td></td><td colspan="2">Other types of exercise that may bring benefits
• Elastic resistance bands
• Aquatic exercise
• Calisthenics</td></tr>
</table>

Special Considerations

MS patients are especially susceptible to exercise-related fatigue, heat intolerance, and falling. Furthermore, some problems such as spasticity, neurologic or cognitive deficits, and urinary incontinence may influence the exercise program. So, special measures should be considered in these cases.

Fatigue

There are some concerns about the potential effect of exercise on exacerbation of fatigue in MS patients. However, the existing evidence supports the fact that regular exercise training is linked with a small but important reduction in fatigue among persons with MS.

The table below identifies areas that need to be considered when exercising a person with MS.

Special Consideration	Precaution
Fatigue	Consider separate resistance and cardiovascular days
Spasticity	Foot or hand straps, limit use of free weights
Heat intolerance	Keep hydrated, keep room cool.
Cognitive issues	Provide written instruction, verbal cues. Start programmes with low resistance. Some may need additional supervision
Impaired coordination	Ensure all exercises are well balanced/stable.
Sensory loss/impaired balance	Use bands or straps instead of free weights, perform exercise in seated position if possible.
Daily variation in symptoms	Make daily modifications
Urinary incontinence	Make sure toilets are available
Symptom exacerbation	Discontinue exercise and refer to neuro-physiotherapist or consultant.

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11.20 Appendix T: Interview schedule - Evaluation of a community-based physical activity pathway for people with MS

Version 2

Experience of physical activity

- To start with, we are just going to go around the room and introduce ourselves.
- Tell me about your experiences of physical activity before you developed MS? How has this changed pre/post MS?
- What do you think are the main barriers to exercising for someone living with MS?
  - How can we overcome them?

Physical activity advice

- What has been your experience (before this programme) of accessing exercise support for someone living with MS in the community?
  - Are you aware of any services?
  - Have you tried to access them?

Experiences of the programme

- Why did you decide to take part in the programme?
- Can you tell me about any positive outcomes from attending the programme?
- Can you tell me about any problems you had from attending the programme?
  - Any lasting effects after the session?
- Do you have any thoughts about the leaders of the programme?
  - Did you have any apprehensions before the programme started?
- Tell me about how you felt about exercising in a group of people with multiple sclerosis?

- What did you think about the exercises used in the programme?
    - What about the equipment used?
- What were your thoughts on the location of the sessions?

Opinions and Future of the programme.

- What would you change about the programme to suit you better?
- Do you have any thoughts on how we could make the programme sustainable?
    - Would you be willing to pay?
        - What would you suggest as an amount?
- Would you recommend the programme to other PWMS?
- Do you see yourself continuing to exercise one the programme has finished?
    - What support would you need to continue being active?
    - What will stop you from being active?
- So, to sum up, if you had one thing to say about the programme, what would it be?

Any other comments?

11.21 Appendix U: Example from coding framework

	Thoughts on the design of the community-based intervention				
	Social	Content	Capability	Instructors	Referral
P1: Male; 66; PDDS 6		The good thing is he can tailor it so he can make it harder for you. Make it different for everyone's ability. So you not all doing the same thing.	Well, it was definitely better than coming in to use treadmills. Doing exercise this way I could feel how it was working and feel why I was doing it	The good thing is he can tailor it so he can make it harder for you. Make it different for everyone's ability. So you not all doing the same thing	My wife went to the doctors, and she heard about it said why don't we try it and give it a go. I will give anything a go
P2: Female; 55; PDDS 2	After that first meeting, I walked out of here, and I thought it's going to be good this. We had a laugh even at that session, and nobody knew each other, but everybody gelled. I thought, yeah this is going to be good. Yeah we all look daft together We all laugh at one another	If you want to make it harder you could but you didn't have to I preferred the fact it wasn't treadmill, bike You can stand on a treadmill or exercise bike as long as you want, but your not build any core strength just burning calories. We were doing more functional moving		[the instructor] is so good, he explains things well and he doesn't make you feel embarrassed or intimidated and that is half the battle.	It was all over Facebook.

P3: Female; 59; PDDS 5	It gave me the confidence to do a different type of exercise but knowing that there were people around that weren't going to criticise me Then I send her a text. After that first meeting, I walked out of here and I thought it's going to be good this. We had a laugh even at that session, and no body knew each other but everybody gelled. I thought yeah this is going to be good	There is different levels to each exercise. Some of us are not very stable so we have to sit down. I couldn't stand up for all those things we were doing today. I'd be on the floor. Well it was definitely better than coming in to use treadmills	I preferred the fact it wasn't treadmill or a bike. You can stand on a treadmill or exercise bike as long as you want, but you're not building any core strength, just burning calories. We were doing more functional moving	I say the instructor] has been brill	I saw it on the Facebook group

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