The Effects of a Dyadic Intervention on Physical Activity Levels and Patterns in Persons with Multiple Sclerosis and their Care-Partners: A Pilot Case Study

Zain Awadia

A thesis submitted in partial fulfillment of the requirements for the
Master's degree in Human Kinetics

School of Human Kinetics
Faculty of Health Sciences
University of Ottawa

Abstract

Physical activity is one approach that may help manage the symptoms experienced by persons with MS and the burden faced by their care-partners. This thesis examined: i) the efficacy of a physical activity intervention for increasing physical activity in dyads affected by moderate-to-severe MS; and (ii) the interdependence in physical activity in MS-care-partner dyads. A 12-week, randomized pilot feasibility trial was conducted in five (two intervention; three control) MS-care-partner dyads. Participants self-reported physical activity and wore an accelerometer for 7-days at baseline and 12-weeks (i.e., follow-up). A large effect of the intervention was observed on self-reported physical activity (*d*= 0.98) and time spent sedentary (*d*= -1.26). Most correlations in physical activity within dyads were moderate-to-strong at baseline (*rs* range= 0.33-0.72) and over time (*rs* range= 0.40-0.80). The results from this pilot case study lay the foundation for larger physical activity interventions in dyads affected by MS.

Preface

This thesis included collaboration between myself and other members of the research team. The primary study design was conceptualized by Dr. Afolasade Fakolade, Dr. Lara Pilutti, and Dr. Marcia Finlayson. The thesis research questions were developed by myself with contribution from Dr. Lara Pilutti. Participant recruitment was conducted by Ms. Myriam Venasse, intervention development and delivery were conducted by Ms. Odessa McKenna and Ms. Katherine Cardwell, and data collection and checking relative to this thesis were completed by myself and Ms. Christeen Ammari. Data analysis presented herein was conducted by myself. The writing and presentation of the introduction, literature review, methods, results, discussion, and conclusion were completed by myself, with oversight and revisions from my supervisor, Dr. Lara Pilutti.

Acknowledgements

I would like to acknowledge and give my most sincere thanks to my supervisor (Dr. Lara Pilutti) who made this work possible and provided with me with support over the course of my masters. Her dedication to her students is truly remarkable and I could not have imagined having a better mentor throughout this process. I would also like to thank my committee members (Dr. Sarah Fraser and Dr. Erin Cressman) for their guidance, suggestions, and flexibility with my project. Their expertise was invaluable to the success of my thesis.

My sincerest thanks also go out to my fellow lab mates at the Clinical Exercise Physiology Lab. Thank you all for the stimulating discussions, and for all the fun we had over the last number of years.

I would like to thank my parents, sister and girlfriend for all of their help and patience. Their encouragement, insightful comments, and constant questioning of my project made me the scholar I am today.

This thesis is dedicated to all the amazing participants that were involved in this project and the many others I have had the opportunity meeting as a researcher. I hope our research has made a positive change in your life.

Table of Contents

List of Tables

(in order referenced in text)

List of Figures

(in order referenced in text)

List of Appendices

Appendix 1. PAT-MS lesson plan.

Appendix 2. uOttawa REB Approval letter.

Abbreviations

ADL = activities of daily living

CI = confidence interval

CNS = central nervous system

EDSS = Expanded Disability Status Scale

GLTEQ = Godin Leisure-Time Exercise Questionnaire

ICC = intraclass correlation coefficient

IQR = interquartile range

LPA = light physical activity

METS = metabolic equivalents

MS = multiple sclerosis

MVPA = moderate-to-vigorous physical activity

OR = odds ratio

PAT-MS = Physical Activity Together for People with MS and their caregivers

PDDS = Patient-Determined Disease Steps

SAC-Q = Self-Administered Comorbidities Questionnaire

SCT = Social Cognitive Theory

SDT = Self-Determination Theory

ST = sedentary time

Chapter 1: General Introduction

1.1 Brief overview of multiple sclerosis

Multiple sclerosis (MS) is a chronic, progressive disease affecting the myelin sheath of the central nervous system (CNS).[1] Canada has one of the highest prevalence of MS in the world with an estimated 90,000 individuals living with MS.[2] MS is usually diagnosed between the ages of 20-40 however, age at onset and diagnosis can vary.[3] Common features of MS include a decline in mobility and cognitive function,[4,5] heightened fatigue,[6] and changes in mental and emotional function.[7,8] These impairments can negatively impact participation in everyday activities and significantly reduce the quality of life for persons living with MS.[3] Unfortunately, there is no curative treatment for MS, however, disease modifying therapies and other efforts to improve symptom management and quality of life have shown to be effective at reducing the impacts of the disease.[9,10]

1.2 Disease progression and MS care-partners

As the disease course progresses, individuals with MS encounter new or worsening symptoms and an accumulation of disability which can significantly limit their independence in everyday life.[3,11] Indeed, nearly all people with MS (93%) report experiencing some mobility impairment within 10 years of disease onset and 50% report requiring an assistive device within 15 years of onset.[12,13] Given the progressive nature of the disease, individuals with MS often require a “care-partner” that can provide support for their everyday activities.[14] Recent studies report that family and friend caregivers provide up to 80% of the total care received by a person with MS.[15]

1.3 MS care-partner well-being

Providing support for a person living with MS has shown to have negative effects on the mental and physical health of care-partners.[16,17] For instance, care-partners of persons with MS are more likely to report lower health-related quality of life and higher rates of anxiety and depression than non-carers.[18] General care-partner research indicates that chronic disease care-partners are also at an elevated risk of developing chronic illnesses, such as depression and heart disease, and their mortality rate is increased by 63% compared to non-carers.[19] Care-partners will often experience strain caused by the physical, emotional, social, and financial demands of the caregiving role.[14,16]

1.4 Physical activity as a health-promoting behaviour for persons with MS and care-partners

Physical activity may, in part, mitigate the disabling symptoms associated with MS, and the strain experienced by an MS care-partner.[20,21] Several studies have demonstrated that engaging in exercise can yield improvements in functional ability, cardiorespiratory fitness, fatigue, symptoms of depression and anxiety, and quality of life for persons with MS.[22–27] However, most of these studies have not included individuals with moderate-to-severe MS. While the study of physical activity in MS care-partners has been limited, general caregiver research has indicated that regular participation in physical activity can help reduce caregiver stress and improve the quality of life of care-partners providing support to individuals with Alzheimer's disease, cancer, and other chronic diseases.[28,29] Furthermore, physical activity may be able to partially alleviate stress and depressive symptoms experienced by care-partners.[30]

1.5 Needs assessment for a dyadic physical activity intervention for people with multiple sclerosis and their care-partners

Both individuals with MS and their care-partners can benefit from regular engagement in physical activity as a health promoting behaviour.[20,21] However, physical activity interventions incorporating both individuals in the dyad (i.e., the person with MS and their care-partner) have been limited. Research has demonstrated that physical activity patterns in dyads may be related, meaning that each member of the dyad can mutually influence each other's physical activity levels.[31,32] For instance, Lopes et al.[31] demonstrated an association in moderate-to-vigorous physical activity (MVPA) and sedentary time (ST) within best-friend dyads. A similar relationship was found in mother-daughter dyads and in older adult spouses.[32] Alternatively, one study by Fakolade et al.[21] reported no significant correlations between ST, light physical activity (LPA), and MVPA within MS-care-partner dyads. Altogether, this evidence suggests that it may be beneficial to target the physical activity of both members of the MS-care-partner dyad given the potential reciprocity of the relationship, and importantly, the low levels of physical activity reported in both persons with MS and their care-partners.[21]

While no study has targeted the health and well-being of both the person with MS and their care-partner, research involving other populations has demonstrated that dyadic physical activity interventions have an overall positive impact. One systematic review of dyadic physical activity interventions indicated that dyads with and without chronic illnesses saw an increase in physical activity and a decrease in ST after the intervention.[33] Other studies have also reported that dyadic physical activity interventions can have numerous effects on the physical and psychological health of care-recipients.[34–36] This supports the need for interventions that target the well-being of the MS-care-recipient/care-partner dyad, recognizing them as a reciprocal interdependent partnership, rather than isolated units.

1.5 Overview of *'Physical Activity Together for People with MS and their caregivers'* intervention

'Physical Activity Together for People with MS and their caregivers (PAT-MS)' is the first intervention to target physical activity levels in persons with moderate-to-severe MS and their care-partners. PAT-MS is a 12-week, group-based intervention that is delivered bi-weekly through videoconference by a trained facilitator.[37] Each group session is interspersed with a brief, one-on-one phone call to reinforce concepts learned. The content of the intervention is theoretically grounded in the Theory of Dyadic Illness Management, with direction from Self-Determination Theory (SDT), and Social Cognitive Theory (SCT).[38–40] The facilitator works with dyads to establish physical activity goals, develop strategies to assist in shared dyadic appraisal and dyadic coping, and introduce techniques to stay motivated to increase physical activity long-term. The use of telerehabilitation (i.e., delivering the intervention through videoconference) provides an alternative to face-to-face delivery for persons with MS and their care-partners who may experience challenges to in-person delivery, such as transportation and accessibility.[41]

The PAT-MS intervention was developed based on previous research on physical activity in MS-care-partner dyads and previous trials of a dyadic physical activity intervention in Alzheimer's disease care-partners.[21,42–44] A stakeholder evaluation of intervention content and delivery was then undertaken by our team, and involved persons with MS, MS care-partners, healthcare providers, physical activity and exercise specialists, and members of MS/caregiving organizations.[45] Key recommendations from this evaluation allowed our research team to generate consensus on intervention content and delivery, and improve the quality of the intervention prior to pilot testing.

Following the implementation of these recommendations, a pilot randomized controlled trial was undertaken to evaluate the feasibility and preliminary efficacy of this intervention for persons with moderate-to-severe MS and their care-partners.[37] Preliminary results from this pilot trial are, in part, reported in this dissertation.

1.6 Rationale and specific aims of the dissertation

Physical activity can have numerous physical and mental health benefits for both people with MS and care-partners; however, studies have demonstrated that these individuals, in general, are not meeting physical activity guidelines.[20,21,22,40] Dyadic interventions, in which the care-recipient and care-partner are targeted as an interdependent team, provide an opportunity for dyads to develop positive communication patterns, acquire essential knowledge about physical activity, and develop specific action goals for improving their health together. Dyadic interventions have been effective for increasing physical activity participation in people with other chronic diseases; however, this approach has yet to be examined in dyads affected by MS.[33] The specific aims of this thesis are threefold: (i) to determine the efficacy of PAT-MS for increasing self-reported physical activity (primary outcome) in dyads affected by moderate-to-severe MS compared to a waitlist control condition; (ii) to determine the efficacy of PAT-MS on accelerometer-measured activity (secondary outcome) including reducing ST, and increasing time spent in LPA and MVPA, and daily step counts in dyads affected by moderate-to-severe MS compared to a waitlist control condition; and (iii) to explore the interdependence in physical activity levels in MS-care-partner dyads.

Chapter 2: Review of Literature

2. 1. Overview of multiple sclerosis

2.1.1 Pathophysiology, diagnosis, and management of multiple sclerosis

Multiple sclerosis (MS) is a neurodegenerative, immune-mediated disease characterized by destruction of the myelin sheath and axons in the central nervous system (CNS).[1] Such damage leads to a variety of neurological symptoms and disability.[3] The pathophysiology and etiology of MS remain poorly understood. MS is not a disease that people are born with; rather, environmental agents can trigger the inflammatory disease in genetically susceptible individuals.[48] MS can present at any age; however, onset and diagnosis usually occurs between the ages of 20-40 years old.[49] This makes MS one of the most common neurodegenerative diseases with symptoms presenting in young adults. Furthermore, MS is three times more prevalent in women than men, and the prevalence ratio has increased markedly in recent decades.[50] Because there are no curative treatments for MS, MS management across the lifespan requires a multidisciplinary approach that incorporates pharmacological disease modifying therapies, rehabilitation, lifestyle modifications, and speciality care provided by a comprehensive team of support personnel (i.e., neurologists, nurses, occupational therapists) to reduce the burden of the disease.[9,10]

2.1.2 Prevalence of MS

Canada has one of the highest prevalence of MS in the world at an estimated 260 individuals per 100,000 adults.[2] This number is expected to rise to over 450 individuals per 100,000 by 2031.[51] Longitudinal data from large registries have reported that from 2005 and onwards, the age group with the highest prevalence of MS has steadily shifted from 35-49 years old to those over the age of 50 years old in Canada.[52] This trend is expected to continue for decades to come, highlighting an aging MS population with accumulating health needs.

2.1.3 Clinical manifestations of MS

The clinical manifestations of MS are unpredictable and highly dependent on the location and severity of nerve damage within the CNS.[53] Common physical impairments associated with MS include sensory disturbances,[54,55] walking and gait difficulties,[4,56,57] loss of balance,[58,59] muscle weakness and spasms,[60,61] and visual impairments.[62] Changes in mental and emotional function commonly present in persons with MS as anxiety,[7,8] depression,[7,63] fatigue,[64] and cognitive deficits.[5,65] These symptoms can negatively impact participation in everyday activities and significantly reduce the quality of life for persons living with MS.[3]

2.1.4 Disease course

The clinical course of MS can be classified into three general categories: relapsing-remitting, secondary progressive, and primary progressive MS.[48] The most common disease course is relapsing-remitting MS and is characterized by intermittent episodes of disease relapses, which are associated with demyelinating attacks.[66] These episodes are interspaced with periods of remission where persons with MS typically present with few symptoms.[66] Secondary progressive MS is characterized by an initial relapsing-remitting disease course that eventually transitions into a progressive course.[48,66] This course involves a worsening of symptoms and the accumulation of irreversible neurological disability over time and can occur with or without relapses.[48] Primary progressive MS is defined by ongoing progression from the onset of the disease.[67] The disease course is characterized by a gradual worsening of disability, typically without relapses, but can include periods of recovery or disease plateau.[48,67]

2.1.5 Measuring disease progression

The progression of MS over time can vary depending on several factors, such as the type of MS, age at disease onset, number and severity of relapses, sex, the presence of comorbidities, and the symptoms experience by the individual with MS.[68] The most common and widely used tool used to describe disease progression is the Expanded Disability Status Scale (EDDS).[69] The EDSS ranges between 0 (*normal neurological function*) to 10 (*death due to MS*) and increases by half-point increments where higher scores represent greater disability.[70] Similar to the EDSS, the Patient Determined Disease Steps (PDDS) scale was developed to assess disease status and progression in persons with MS and has nine levels ranging between 0 (*normal*) to 8 (*bedridden due to MS*).[71] Scores on the PDDS and EDSS are strongly correlated; however, a major difference between the scales is that the PDDS is patient-reported, while the EDSS is clinically administered.[71,72] Due to the remote nature of this study, this thesis uses the PDDS to describe the disability level of participants.

2.1.6 The impact of disease progression on persons with MS

As the disease course progresses, individuals with MS encounter new or worsening signs and symptoms which can limit their independence and ability to perform activities of daily living (ADL).[11] It is estimated that 50% of people with MS will experience at least moderate disability within 15-20 years of diagnosis, and this proportion increases to 75% within 45 years.[73] Walking impairment is the primary hallmark of disease progression in MS.[74,75] Nearly all people with MS (93%) report experiencing some mobility impairment within 10 years of disease onset and 50% report requiring an assistive device within 15 years of onset.[12,13] Loss of mobility in MS has been shown to have a negative impact on employment status,[76,77] health-related quality of life,[78,79] and can affect the independence of an individual with MS.[80] Indeed, one prospective study exploring changes in disability status across a 10-year period demonstrated that individuals with moderate-to-severe MS had an increase in wheelchair and walking aid dependency that did not occur in persons with mild MS.[81] They also had a pronounced decline in their walking speed, cognitive processing, quality of life, social participation, and ADL.[81]

2.1.7 The role of MS care-partners

Given the progressive nature of the disease, individuals with MS may require support to participate in daily activities.[82] This support is usually fulfilled by a "care-partner" or support partner.[83] Often, it is family members and friends who take on this role.[84,85] Recent studies report that family caregivers provide up to 80% of the total care received by a person with MS.[15] The role of a care-partner is essential to disease management and can have enriching and fulfilling aspects; however, the challenges experienced by care-partners can also be great. The responsibility of providing emotional and/or physical support, often for extended periods of time, can negatively affect the health and well-being of the care-partner.[17,85,86] For instance, care-partners are more likely to report a lower health-related quality of life and higher rates of anxiety and depression than non-carers.[87,88] In a study of 50 MS care-partners, 30% reported elevated mood scores (i.e., anger, depression, anxiety, confusion), and higher mood scores were significantly correlated with greater functional impacts of MS on the care-recipient (as perceived by the care-partner).[89] Care-partners will often experience strain caused by the physical, emotional, social, and financial demands of the caregiving role.[14,16]

The duration and extent of care provided by MS support-partners can depend on a host of factors, such as the severity of MS and the duration of the illness.[84,90] With more severe symptoms, such as walking impairment, comes greater time commitment and more specialized caregiving which can further increase the strain on the caregiver.[91,92] In addition, with recent advances in treatment and therapeutic options, persons with MS are expected to live on average 7.5 years less than their age- and sex-matched counterparts.[93] Noting the early age of MS onset and diagnosis, this means that the caregiving role can last nearly a lifetime. Hence, MS not only has significant impacts for the well-being of the affected individual, but also for their family members and friends.

The mutual experience of MS is important for care-recipients and care-partners, and is imperative for building a strong and gratifying long-term relationship.[94] Individuals with MS and their care-partners may adapt to the ramifications of the disease by adopting a *dyadic*, interdependent relationship.[94,95] An MS care-partner/care-recipient dyad can be defined as a partnership between two persons who provide caring roles for one another.[96] This partnership may include the individual with MS and a relative or close friend.[96] Positive dyadic relationships have been associated with improved physical and emotional health outcomes in people with MS and their care-partners.[87,97] Collectively, this exemplifies the need for interventions that target the health and well-being of the MS care-recipient/care-partner dyad, recognizing them as a reciprocal interdependent partnership, rather than isolated units.

2.2 Physical activity as a means of managing disease impact

2.2.1 Physical activity as a health-promoting behaviour in people with MS

Physical activity is a health-promoting behaviour that can, in part, mitigate many of the symptoms experienced by people with MS.[26,46,47] Physical activity is defined as “any body movement produced by skeletal muscles that results in energy expenditure” and encompasses household, leisure, and occupation-related activities.[25,98] Physical activity is described along a spectrum and can include light, moderate, and vigorous physical activities. Metabolic equivalents (METS), which provide an indicator of the amount of oxygen used during an activity compared to rest, are often used to classify the intensity of physical activities.[99] Light physical activity (LPA) and moderate-to-vigorous (MVPA) reflect activities that involve between 1-3 and ≥3 METS, respectively.[100] Sedentary time (ST) is defined as time spent in “any waking activity that requires ≤1.5 METS and is characterized by a sitting or reclining posture”.[101]

There is substantial evidence that engaging in adequate physical activity can yield improvements in functional ability, cardiorespiratory fitness, fatigue, symptoms of depression and anxiety, and quality of life in persons with MS.[22–27] Furthermore, sufficient physical activity can reduce the risk of secondary comorbidities, such as diabetes, metabolic syndrome, obesity, and vascular diseases.[102,103] The emergence of physical activity as a modifiable health-promoting behaviour was accompanied by The Canadian Physical Activity Guidelines for Adults with MS.[104] These guidelines recommend at least 30 minutes of moderate intensity aerobic activity twice per week and strength training exercises for major muscle groups twice per week for adults ages 18-64 with mild-to-moderate MS.[104] Furthermore, clinician-based recommendations were recently developed to address and promote physical activity and exercise across the MS disability spectrum.[105] Despite developed guidelines and acknowledged benefits of physical activity, individuals with MS are substantially less active than the general population.[20,106] For instance, one large study reported that persons with MS spend 25% less time in MVPA than the general population.[107] Furthermore, estimates indicate that persons with MS spend approximately 80% of their day in ST, which is 11% greater than the average Canadian adult.[108,109]

2.2.2 Physical activity levels in persons with moderate-to-severe MS

Multiple studies have indicated that individuals with MS with greater disability (i.e., those who experience mobility impairment) may be more physically inactive than persons with MS with lower disability.[110,111] For instance, Anens et al.[112] demonstrated that variation in scores on a self-report physical activity scale was mostly explained by disability level in persons with MS. In support of these findings, Motl & Goldman[113] reported a moderate, negative partial correlation (*pr*= -0.43) between accelerometer-measured physical activity and disability score based on the EDSS, such that persons with MS with higher disability engaged in less activity. The accumulation of impairments (i.e., mobility loss, muscle weakness and spasticity) over time can also make sedentary behaviour more frequent and prolonged in persons with moderate-to-severe MS.[110] Fakolade et al.[21] demonstrated that persons with moderate-to-severe MS spent 76% of their accelerometer wear time (556 minutes/day) in ST. Importantly, only 1% of the day (7.6 minutes/day) was dedicated to engaging in MVPA, and no participants met MVPA guidelines (150 minutes/week).[114] In comparison, persons with MS with lower disability spend an average of 18.7 minutes/day in MVPA, with 19.5% meeting general MVPA guidelines.[115] This evidence points to a worrisome cycle whereby persons with moderate-to-severe MS are unable to engage in sufficient levels of physical activity due to MS symptoms, mobility impairment, and physiological deconditioning, as well as a multitude of other personal and environmental barriers.[116,117] These barriers can include logistic factors, such as accessibility issues, transportation, financial stability, and social/time constraints.[118] Moreover, psychological factors such as lack of motivation, feelings of fear about physical activity and exercise, and beliefs surrounding physical activity can influence physical activity participation.[105] Lack of physical activity can contribute to physiological deconditioning (i.e., loss of aerobic and muscular fitness), which ultimately worsens symptoms and impairments, and can lead to further inactivity.[116]

2.2.3 Physical activity in MS care-partners

Similarly, care-partners of persons with MS may have limited opportunities to engage in physical activity. This could be due to a variety of circumstances including time constraints, low self-efficacy, lack of social support, and greater physical activity barriers.[119] Fakolade et al.[21] demonstrated that care-partners of persons with moderate-to-severe MS spent a similar amount of time engaging in sedentary behaviour (559.1 minutes/day) and LPA (199.6 minutes/day) as their care-recipients. While care-partners did spend 1% more of their daily time in MVPA (21.4 minutes/day), only 28% of all care-partners in the sample met the Canadian guidelines for MVPA (150 minutes/week).[114] While MS care-partner research has been limited, general care-partner research has demonstrated that regular participation in physical activity can help reduce the strain experienced by care-partners and improve the quality of life of care-partners providing support to individuals with Alzheimer's disease, cancer, and other chronic diseases.[28,29] Furthermore, studies have also demonstrated that regular participation in physical activity can help to alleviate stress and depression experienced by care-partners.[30]

2.2.4 Relationship between physical activity levels within MS-care-partner dyads

Current research is lacking on the relationship, or interdependence, in physical activity levels within MS-care-partner dyads. Only one study to date has investigated the interdependence of physical activity levels within dyads affected by MS. One study by Fakolade et al.[21] found that physical activity levels (including ST, LPA, and MVPA) of persons with MS (n= 15; median PDDS= 5.0) were not significantly related to physical activity levels in their care-partners (n= 15). However, studies investigating physical activity patterns in other dyadic populations have reported contrasting results. For instance, one study by Lopes et al.[31] demonstrated a significant association in vigorous physical activity (ICC= 0.32), moderate physical activity (ICC= 0.31), and sitting time behaviour (ICC= 0.21) within best-friend dyads. Similarly, Freedson & Evenson[32] examined objective dyadic physical activity patterns in mother-daughter dyads. The study involved classifying mothers and daughters into low physical activity and high physical activity categories based on their accelerometer activity counts. Data analysis revealed that familial aggregation of physical activity occurred in 74% of mother-daughter dyads ($\chi^{2\,[1,\,N=30]} = 6.72$, $p<0.05$). One study by Li et al.[120] further supported this association, reporting that physical activity patterns in middle-aged and older couples change in concordance over time, suggesting that this relationship is long-lasting and fluid. While studies investigating physical activity interdependence in other chronic disease populations have been sparse, one study by Mesquita et al.[121] found that patients with chronic obstructive pulmonary disease had a greater likelihood of being physically active when their care-partner was also active (OR= 4.36; 95% CI= 1.41-13.30; $p= 0.01$) compared to patients that had an inactive care-partner. In conclusion, these studies collectively suggest that dyads can exhibit similar physical activity behaviours; however, there is limited research examining if this relationship remains when one partner experiences significant disability.

2.2.5 Dyadic physical activity interventions as a strategy to improve physical activity levels

Collectively, evidence suggests that both individuals with MS and care-partners can benefit from regular engagement in physical activity as a health promoting behaviour. Dyadic physical activity interventions, in which both the person with MS and care-partner are involved, are a potential means for increasing participation in physical activity. Dyads mutually influence each other and can have a significant impact on the health behaviours they each engage in.[122] While no studies have examined the effects of a dyadic physical activity intervention in MS, other areas of research can give insight into the potential benefits of conducting such an intervention.

One systematic review involving healthy participants and people with chronic conditions (i.e., cancer, obesity, osteoarthritis) indicated that dyadic physical activity interventions had a positive effect for increasing physical activity (Hedges g= 0.20; 95% CI= 0.12-0.28) and reducing ST (Hedges g= 0.19; 95% CI= 0.10-0.28).[33] General care-partner research including participants with other chronic conditions (i.e., Alzheimer's disease, cancer, stroke) revealed that engaging in physical activity together as a dyad can reduce caregiver stress and improve quality of sleep, physical activity levels, self-efficacy for caregiving, and quality of life of the care-partner.[123] Other studies have reported that dyadic physical activity interventions can have a multitude of effects on the physical and psychological health of care-recipients as well.[34–36] This evidence has contributed to the development of '*Physical Activity Together For People with MS and their care-partners (PAT-MS)'*, which is the first dyadic physical activity intervention for persons with moderate-to-severe disability and their care-partners.

2.3 The development of PAT-MS intervention and pilot trial

2.3.1 Evolution of PAT-MS intervention and pilot trial and focus of dissertation

The PAT-MS intervention was developed based on intervention mapping and previous trials promoting physical activity in Alzheimer's disease care-partners.[33–36,41,123] Following the development of the intervention, a modified Delphi survey was conducted to evaluate the intervention.[45] A panel of stakeholders (including people with MS, MS care-partners, healthcare providers, physical activity and exercise specialists, and members of MS/caregiving organizations) were consulted to generate consensus on intervention content, intervention delivery, and practical/logistical considerations. After receiving stakeholder feedback and making adjustments to the intervention, a pilot feasibility trial was implemented.[37] The pilot testing of this intervention forms the basis of this dissertation.

2.3.2 Theoretical framework

PAT-MS is a group-based, videoconference delivered intervention designed to increase physical activity behaviour in MS-care-partner dyads.[37] The PAT-MS intervention is theoretically grounded in the Theory of Dyadic Illness Management, with direction from Self-Determination Theory (SDT), and Social Cognitive Theory (SCT).[38,40,124] The basic principle of the Theory of Dyadic Illness Management is that coping with illness is a dyadic process that requires dyads to work together as an interdependent team.[38] The theory focuses on the ways dyads appraise the illness as a unit and how this appraisal can influence the behaviours of the dyad.[38] Furthermore, the health of both members of a dyad are interconnected, and therefore, the adoption of health-promoting behaviours requires cooperation and engagement from both parties.[38]

SDT is a theory of human motivation that focuses on how behaviours are energized through intrinsic and extrinsic factors.[40] Intrinsic factors are internal sources of motivation such as the need to gain knowledge or independence, while extrinsic factors relate to external rewards such as prizes.[40] The theory stresses the concepts of autonomy, competence, and relatedness, emphasizing that these notions provide the energy needed to initiate and maintain health behaviours.[125] Lastly, SCT emphasizes that learning occurs in situations that foster a dynamic and reciprocal interaction between the person, the environment, and the behaviour.[39] The theory takes into consideration personal expectations, the social and environmental context, and individual self-efficacy for performing the health behaviour.[124] Specifically, SDT and SCT guide the PAT-MS intervention through the implementation specific strategies and techniques for increasing physical activity behaviour. Altogether, the content of this intervention is constructed to encourage self-efficacy, autonomy, and collaboration among dyads.

2.3.3 Delivery of the intervention

The PAT-MS intervention will be delivered via group videoconference sessions (detailed below). Telerehabilitation, the use of telecommunication strategies to deliver rehabilitation interventions, provides the opportunity for persons with MS that do not have access to transportation and/or individuals with mobility issues an alternative to face-to-face intervention delivery.[126] Telerehabilitation interventions also allow persons with MS and their care-partners residing in different geographical areas across Canada to participate in this intervention. Multiple studies in MS samples have demonstrated that telerehabilitation interventions are as effective as in-person interventions.[127,128] Furthermore, researchers have shown that telerehabilitation interventions targeting physical activity behaviour were able to increase physical activity participation and improve psychosocial outcomes in persons with MS.[129,130]

2.3.4 Objectives of PAT-MS pilot study

The PAT-MS intervention will be tested using a 12-week, pilot feasibility randomized controlled trial design.[131] The overall objectives of the study are to determine: 1) the feasibility of the PAT-MS intervention for MS-care-partner dyads; 2) the efficacy of the PAT-MS intervention for increasing physical activity in MS-care-partner dyads; and 3) the efficacy of the intervention for improving psychosocial outcomes (i.e., coping, resilience, quality of life, relationship quality). As outlined in Chapter 1, this thesis will solely focus on the <u>second objective</u> within the context of this larger study.

Chapter 3: Methods

3.1 Design

This pilot feasibility study used an assessor-blinded, two-arm, parallel-group randomized controlled trial design.[37,131] Dyads were randomized using a 1:1 allocation into an immediate intervention condition or delayed intervention condition. The study protocol received research ethics approval from the University of Ottawa Health Sciences and Science Research Ethics Board [H-09-19-4886] and Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) [REH-822-21].

3.1.1 Participants and eligibility

Potential dyads were recruited through several mechanisms. Advertisements were distributed through the MS Society of Canada, the North American Research Committee on MS (NARCOMS) registry, caregiver-related organizations, caregiver support groups, and other online outlets. Additionally, information regarding the study was distributed to individuals who had expressed interest in participating in future research opportunities with our group. Interested participants were invited to contact the study coordinator for more information on participation and to undergo eligibility screening. The detailed eligibility criteria for people with multiple sclerosis (MS) and care-partners are described in Table 1.

3.1.2 Outcome measures

3.1.2.1 Demographics

3.1.2.1.1 Demographics and clinical characteristics of persons with MS

We collected demographic information from persons with MS using a questionnaire which captured the participant's age, gender, height, weight, marital status, education level and employment status, and clinical characteristics (e.g., MS clinical course, disease duration).

Participants were also asked to report the amount of paid and unpaid care that they received. Participants were asked to complete the Patient-Determined Disease Steps (PDDS) scale to capture self-reported disability status.[71] Lastly, participants completed the Self-Administered Comorbidities Questionnaire (SAC-Q)[132] and a medication use questionnaire.

3.1.2.1.2 Demographics of care-partners

The same demographic and health history information obtained from participants with MS was collected from care-partners. Additionally, information about the care-partner role, including type and duration of caregiving activities, and the care-partner's relationship to the person with MS was collected.

3.1.2.2 Self-reported physical activity

Self-reported physical activity levels were captured in all participants using the Godin Leisure-Time Exercise Questionnaire (GLTEQ).[133] The GLTEQ is one of the most commonly used self-report physical activity questionnaires in persons with MS.[133] The questionnaire captures the frequency of mild/light (e.g., easy walking), moderate (e.g., fast walking), and strenuous (e.g., running) activity in bouts of 15 minutes or more throughout a seven-day period. The GLTEQ was used in conjunction with an accelerometer to account for types of physical activities (i.e., swimming, cycling) that an accelerometer does not capture. Furthermore, The GLTEQ is influenced less by gait impairment, which is common in persons with moderate-to-severe MS, in comparison to an accelerometer.[134] The GLTEQ is a reliable and valid tool for measuring changes in physical activity in response to behavioural interventions in persons with MS.[135,136]

3.1.2.3 Objectively-measured physical activity

Objective physical activity was measured in all participants using an ActiGraph accelerometer (model wGT3X-BT, ActiGraph, Pensacola, FL). The ActiGraph wGT3X-BT is a small (4.6cm x 3.3cm x 1.5cm) and lightweight (19g) wearable device that contains a triaxial accelerometer. The built-in sensors of the device measure the magnitude of the wearer's acceleration in all three planes. This signal is then converted into activity counts, which are summed over a specific time interval (epoch) using ActiLife software (Version 6, ActiGraph, Pensacola, FL). Data were collected using an epoch length of 60 seconds. Participants were asked to wear the accelerometer at the non-dominant hip for 7 consecutive days. Furthermore, participants were given written instructions and provided a video demonstrating how to wear the device during all waking hours.

3.1.3 Protocol

Figure 1 presents an overview of the study protocol. Eligibility screening was conducted by the study coordinator by telephone or videoconference call. Once dyads were determined eligible for study participation, each individual was sent a unique link via email to access an online survey (SurveyMonkey Inc., San Mateo, CA). The survey first involved completion of consent to participate, followed by a questionnaire battery. Each participant was then mailed a package that included: (i) a copy of the GLTEQ; (ii) an accelerometer and wearing instructions; (ii) a logbook to record device wear time; and (iv) a stamped envelope for the return of study materials. The accelerometer was placed in a pouch on an elastic belt to be worn around the waist. Participants were asked to wear the monitor for 7 days and only take off the device when showering, bathing, or swimming. Participants were not asked to wear the device while sleeping. A lab member called the participants' 2-3 days after receiving their package to remind them to wear the accelerometer and to troubleshoot any concerns. Once baseline testing was completed, participants were randomly allocated to receive the intervention immediately (i.e., intervention group) or after a 12-week delay (i.e., waitlist control group). Participants in the delayed control condition were asked to maintain their usual activities for the proceeding 12 weeks. At the end of the 12 weeks, the same outcomes assessed at baseline were collected once again via online survey and postal mail. Participants in the delayed intervention group were then invited to participate in the same 12-week intervention.

3.1.4 Structure and delivery of the intervention

The intervention consisted of six group-based videoconference sessions (each lasting ~45-60 minutes) every other week for a period of 12-weeks. Each session was structured to include a review of material from the previous week (except for the first session), teaching of new material, a discussion period, and activities to complete before the next session. The group calls were designed to be delivered to 2-3 dyads simultaneously to facilitate discussion and content delivery. The group videoconference sessions were designed to promote an environment that fosters social modelling, social support, and vicarious learning. The intervention was delivered by a facilitator trained in group videoconference delivery and followed a structured intervention manual. Participants were provided a participant manual that contained instructions, lesson content, tracking materials, resources, and practice activities for the intervention.

The videoconference sessions were interspersed with brief, one-on-one support calls (~10-15 minutes) in the weeks that the group sessions did not occur. One-on-one support calls served to help reinforce information that was provided during group sessions, monitor physical activity adherence, and assist with any concerns participants had with the intervention. The group sessions and one-on-one support calls were delivered via videoconference call using Zoom for video communications (Zoom Video Communications, San Jose, CA).

3.1.5 The intervention

The content of the intervention focused on introducing dyads to the concept of shared dyadic appraisal and dyadic coping, following the Theory of Dyadic Illness Management, with direction from Self-Determination Theory (SDT), and Social Cognitive Theory (SCT).[38,40,124] The intervention sought to educate dyads on the health benefits of regular physical activity and reinforce physical activity as a healthy coping strategy. The facilitator worked with dyads to establish realistic physical activity goals (e.g., an increase in physical activity by 25% over the course of the 12-week intervention), develop problem-solving techniques to help address common barriers to physical activity, and foster techniques to stay motivated to increase physical activity long-term. Participants received guidance from the facilitator throughout the intervention and feedback to increase self-efficacy for engaging in physical activity. Dyads were also provided with various support outlets to help them continue to participate in physical activity (i.e., links to community physical activity programs and opportunities to engage and learn from other dyads). The table of contents from the participant manual is included in Appendix 1.

3.2 Data processing

3.2.1 Self-reported physical activity

The weekly frequencies of light, moderate, and strenuous leisure-time exercise reported on the GTLEQ were multiplied by three, five, and nine, respectively, and then summed to yield a total physical activity score. The total physical activity score was then used to classify participants as active (24 units), moderately active (14-23 units), or insufficiently active (<14 units).[135]

3.2.2 Objective physical activity

Raw data recorded on the accelerometer was downloaded using the ActiLife 6 Software (Actigraph, Pensacola, FL). Accelerometer data were checked for compliance by comparing the accelerometer wear time to the participant activity logbook. Non-wear time was defined as a period registering a zero-count for a minimum of 60 minutes. A day was considered valid when there was a minimum of 10 hours of wear time and no consecutive periods of zero exceeding 60 minutes.[137] Activity monitoring resulting in at least 4 valid days of data was included in the study.[138] If the participant returned the accelerometer with less than 4 days of valid data, they were asked to wear the device again for another week.[138] Accelerometer data was captured in activity counts per minute and converted to time spent in sedentary behaviour (ST), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) using activity count cut-points. Based on previous research in the general population, an activity count of less than 100 counts/minute was classified as ST, 100-2019 counts/minute was classified as LPA, and ≥2020 counts/minute was classified as MVPA for care-partners in this study.[139] MS-specific accelerometer cut-points for were used to classify physical activity levels of participants with MS. An activity count of less than 100 counts/minute was classified as ST, 100-1583 counts/minute was classified as LPA, and ≥1584 counts/minute was classified as MVPA.[140] We calculated mean daily minutes spent in ST, LPA, and MVPA, as well as the percentage of wear time spent in each activity category (calculated to adjust for differences in individual wear time). Mean daily step counts were also calculated. The physical activity levels of participants were compared to Canadian physical activity guidelines for MVPA and ST.[114] If participants accumulated ≥150 minutes of MVPA/week, the MVPA criterion was considered met, and if participants accumulated <8 hours/day of ST, the ST criterion was considered met.

3.3 Statistical analysis

All data are presented in the text as mean (SD), unless specified otherwise. Data were analyzed using IMB SPSS Statistics, version 28.0 (IBM Corporation, Armonk, NY). Demographics and clinical characteristics, as well as self-reported and objective physical activity levels were summarized using descriptive statistics. Given the sample size, study design and phase, inferential statistics were not used to examine intervention effects. Effect sizes (ES) were used to demonstrate the efficacy of the intervention (i.e., the difference between groups over time) on physical activity outcomes, and were calculated as *Cohen's d*.[141] ESs were calculated as the mean change from before to after the intervention for the intervention group minus the mean change in the control group per outcome, divided by the pooled SD for each respective outcome.[142] The magnitude of ESs was interpreted as small, medium, or large based on criteria of 0.2, 0.5, and 0.8, respectively.[141]

Spearman's correlation coefficients (*rs*) were calculated to investigate the interdependence of physical activity within dyads at baseline and in response to the intervention. Baseline interdependence in physical activity was determined as the relationship within partners' self-reported and objective physical activity levels recorded at baseline. The change in physical activity interdependence was determined by calculating the difference in physical activity levels between baseline and 12-weeks in persons with MS and care-partners. Correlations in the change in physical activity over time within dyads were then performed. The magnitude of the correlation coefficients was interpreted as weak, moderate, or strong based on criteria of 0.1, 0.3, and 0.5, respectively.[141]

Chapter 4: Results

4.1 Participants

4.1.1 Study sample

80 participants made contact with the research coordinator and 58 participants were assessed for eligibility (Figure 2). Eleven dyads (22 participants) were enrolled to the study and completed baseline data collection. One dyad discontinued participation after baseline data collection. Ten dyads were randomized to the intervention (n= 10 participants) and control (n= 10 participants) conditions. Five dyads (n= 10 participants) were involved in the first wave of the study (delivery and data collection complete), and five dyads (n= 10 participants) were involved in the second wave of the study (delivery and data collection ongoing). Relative to wave one, one dyad in the intervention condition dropped-out of the study after randomization. As only one dyad remained in the intervention condition, the first wave of the intervention was not delivered in group format. Eight participants (n= 2 intervention; n= 6 control) completed baseline and 12-week data collection and are presented in this pilot case study of the *'Physical Activity Together for Persons with MS and their caregivers'* intervention. Flow of all participants through the study is presented in Figure 2.

4.2 Baseline characteristics and physical activity

4.2.1 Overall participant characteristics

Characteristics of all participants (n= 22) at baseline are presented for people with multiple sclerosis (MS) and care-partners in Table 2. The mean age of persons with MS was 53.1 (11.1) years and the sample was predominantly female (n= 8, 72.7%). The sample consisted primarily of individuals with relapsing-remitting MS (n=8, 72.7%) with a median Patient-Determined Disease Steps (PDDS) scale score of 4.0 (IQR= 1.0), indicating that participants required bilateral assistance for ambulation. The mean number of years since diagnosis of MS was 10.7 (9.7) years. On average, care-partners were women with a mean age of 50.1 (12.7) years. Most care-partners were spouses/partners (n= 8, 72.7%) and had been providing care to their partners for 6.6 (5.0) years.

4.2.2 Baseline physical activity levels

Table 3 presents self-reported and objective physical activity levels for persons with MS and care-partners at baseline (n= 20). The mean Godin Leisure-Time Exercise Questionnaire (GLTEQ) score for participants with MS was 13.8 (11.8). Two persons with MS (20%) met the criteria for ‘active’, four persons (40%) met the criteria for ‘moderately active’, and four persons (40%) were classified as ‘insufficiently active’. The mean GLTEQ score for care-partners was 15.5 (17.0). Three care-partners (30%) met the criteria for ‘active’, one care-partner (10%) met criteria for ‘moderately active’, and 6 care-partners (60%) were ‘insufficiently active’.

Persons with MS spent an average of 76.1% (10.9%) of their wear time (658.2 (130.1) minutes/day) in sedentary time (ST), 22.8% (10.7%) of their wear time (184.9 (82.4) minutes/day) in light physical activity (LPA), and 1.2% (1.4%) of their wear time (10.3 (12.3) minutes/day) in moderate-to-vigorous physical activity (MVPA). Persons with MS engaged in a mean of 2937.6 (1766.5) steps/day. Only one person with MS met the Canadian physical activity guidelines for ST and two met the guidelines for MVPA based on accelerometer data. Care-partners spent an average of 67.4% (8.6%) of their wear time (577.6 (112.9) minutes/day) in ST, 31.3% (8.8%) of their wear time (259.1 (56.8) minutes/day) in LPA, and 1.2% (1.2%) of their wear time (11.7 (10.3) minutes/day) in MVPA. Only two care-partners met the Canadian physical activity guidelines for ST and MVPA.

4.3 Case study of the PAT-MS intervention

4.3.1 Participant characteristics

Baseline characteristics of participants who were involved in the first wave of the study (n= 10 participants; 4 intervention, 6 control), are presented in Table 4. Overall, participants in the intervention group were female (n= 4, 100%) and had a mean age of 51.8 (3.3) years old. Dyads in the intervention group included spouses and siblings that lived together and apart. Care-partners in the intervention group provided care for an average of 4.0 (1.4) years. Participants in the control group were mostly female (n= 4, 66.7%) and had a mean age of 49.2 (17.8) years old. Dyads in the control group were connected as spousal or parent-child relationships. All dyads lived in the same household. Care-partners provided an average of 7.7 (6.7) years of care to their partner.

4.3.2 Efficacy of PAT-MS on self-reported physical activity

Table 5 provides data on self-reported physical activity levels at baseline and 12-weeks (i.e., post-intervention) for participants who completed the study to date (n= 8). Both participants in the intervention group reported an increase in self-reported physical activity levels; the overall increase was large in magnitude (mean change= 152.4%; *d*= 1.08). The change in self-reported physical activity shifted participants from the ‘insufficiently active’ to ‘active’ category.

Overall, participants in the delayed control group reported no change in physical activity levels over the 12-week period (mean change= 2.0%; *d*= 0.03). A large effect of the PAT-MS intervention was observed in self-reported physical activity compared with the control condition over 12-weeks (*d*= 0.98), suggesting an increase in self-reported physical activity in response to the PAT-MS intervention.

4.3.3 Efficacy of PAT-MS on objective physical activity

Table 6 provides data on objective physical activity levels at baseline and 12-weeks (i.e., post-intervention) for participants who completed the study (n= 8). Both participants in the intervention group demonstrated a decrease in ST; the overall decrease was large in magnitude (mean change= -14.8%; *d*= -3.03). Conversely, participants in the delayed control group saw no change in ST over the 12-week period (mean change= -1.3%; *d*= -0.09). A large effect of the PAT-MS intervention was observed on ST compared with the control group over 12-weeks (*d*= -1.26), suggesting a decrease in ST in response to the intervention.

Both participants in the intervention group also demonstrated a decrease in percent of wear time spent in ST; the overall decrease was large in magnitude (mean change= -6.4%; *d*= -0.87). Participants in the delayed control group observed a small increase in percent of wear time spent in ST over the 12-week period (mean change= 2.7%; *d*= 0.23). A large effect of the PAT-MS intervention was observed in percent of wear time spent in ST compared with the control group over 12-weeks (*d*= -0.93), suggesting a decrease in percent of the day spent sedentary in response to the intervention.

In terms of LPA, both participants in the intervention group experienced an increase over the 12-week period; the overall increase was moderate in magnitude (mean change= 9.3%; *d*= 0.47). Participants in the delayed control group demonstrated no change in LPA over the 12-week period (mean change= -1.2%; *d*= -0.03). A moderate effect of the PAT-MS intervention was observed in LPA compared with the control group over 12-weeks (*d*= 0.40), suggesting an increase in LPA in response to the intervention.

Participants in the intervention group demonstrated an increase in their percent of wear time spent in LPA that was large in magnitude (mean change= 17.2%; *d*= 0.90). There was no change in percent of wear time spent in LPA over the 12-week period (mean change= -3.5%; *d*= -0.11). A large effect of the PAT-MS intervention was observed for the change in percent of wear time spent in LPA compared with the control group over 12-weeks (*d*= 0.85), suggesting an increase in daily time spent in LPA in response to the intervention.

Both participants in the intervention group experienced a large decline in MVPA after the intervention (mean change= -48.0%; *d*= -1.67). Participants in the control group also demonstrated a large decline in MVPA over the 12-week period (mean change= -50.7%; *d*= -0.83). A large effect of the PAT-MS intervention was observed in MVPA compared with the control group over 12-weeks (*d*= 1.40), suggesting that participants involved in the PAT-MS intervention had a smaller decline in MVPA compared to the control group.

A similar trend was observed for percent of wear time spent in MVPA, as both participants in the intervention group experienced a decrease in this outcome over time (mean change= -33.3%; *d*= -1.59). Participants in the control group demonstrated a moderate-to-large decline in percent of wear time spent in MVPA (mean change= -47.8%; *d*= -0.72). However, a large effect of the PAT-MS intervention was observed in percent of wear time spent in MVPA compared with the control group over 12-weeks (*d*= 1.20), suggesting that participants involved in the PAT-MS intervention had a smaller decline in their MVPA compared to the control group.

Lastly, while both participants in the intervention experienced an increase in daily steps, this increase was small in magnitude (mean change= 4.8%; *d*= 0.23). Participants in the control group, however, experienced a small decline in daily steps (mean change= -20.1%; *d*= -0.39), and there was a moderate effect of the PAT-MS intervention on daily steps compared to the control group (*d*= 0.70).

4.4 Physical activity interdependence in dyads

Table 7 provides data on the interdependence in physical activity within dyads at baseline (n= 20) and over 12-weeks (n= 8). There were strong correlations at baseline between care-partner and care-recipient ST (*rs*= 0.72), and percent of wear time spent in LPA (*rs*= 0.55). There were moderate correlations between care-partner and care-recipient percent of wear time spent in ST (*rs*= 0.41), LPA (*rs*= 0.41), and daily steps (*rs*= 0.33). All other baseline correlation coefficients were weak in magnitude.

There were strong correlations between change in care-partner and care-recipient self-reported physical activity (*rs*= 0.60), LPA (*rs*= 0.60), percent of wear time spent in ST (*rs*= 0.80), percent of wear time spent in LPA (*rs*= 0.60), and percent of wear time spent in MVPA (*rs*= 0.80) over the 12-week intervention. There was also a moderate correlation between care-partner and care-recipient MVPA (*rs*= 0.40) and ST (*rs*= -0.40). All other correlation coefficients investigating physical activity interdependence over time were weak in magnitude.

Chapter 5: Discussion and Conclusion

5.1 Summary

The objectives of this thesis were: (i) to determine the efficacy of *'Physical Activity Together for Persons with MS and their caregivers (PAT-MS)'* for increasing self-reported physical activity in dyads affected by moderate-to-severe multiple sclerosis (MS) compared to a waitlist control condition; (ii) to determine the efficacy of PAT-MS on accelerometer-measured activity including sedentary time (ST), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA), and daily step counts in dyads affected by moderate-to-severe MS compared to a waitlist control condition; and (iii) to explore the interdependence in physical activity levels in MS-care-partner dyads.

Findings from this case study suggest that a videoconference-delivered dyadic physical activity intervention may be effective for increasing self-reported physical activity, LPA and daily steps, while reducing ST in MS-care-partner-care-recipient dyads. Furthermore, our results demonstrated moderate-to-strong interdependence in ST, LPA and daily steps within dyads at baseline and moderate-to-strong interdependence in self-reported physical activity, LPA, and MVPA over 12-weeks. Collectively, this pilot study supports the potential of the PAT-MS intervention for modifying physical activity behaviour in MS-care-partner dyads, and suggests physical activity behaviour is related within this population. No study to date has investigated the effects of a dyadic physical activity intervention in persons with MS and their care-partners; therefore, the results of this pilot case study can be used to inform the development of larger dyadic physical activity interventions.

5.2 Physical activity levels in MS-care-partner dyads

5.2.1 Physical activity levels in persons with MS

Persons with MS in our sample had a mean Godin Leisure-Time Exercise Questionnaire (GLTEQ) score of 13.8 at baseline (i.e., ‘insufficiently active’). This score is lower than most studies that have measured self-reported physical activity using the GLTEQ in persons with MS.[135,143,144] For instance, Silveira & Motl[144] reported a mean GLTEQ score of 19.1 for 588 persons with MS (median Patient-Determined Disease Steps (PDDS) score= 2.0; range= 0-8) and Hubbard et al.[143] reported a mean GLTEQ score of 23.9 in 1081 people with MS (median PDDS= 2.0; range= 0-8). Therefore, people with moderate-to-severe MS in our sample reported lower levels of physical activity compared to previous samples with milder disability. This aligns with previous research in persons with MS.[112,115,145] For instance, research by Anens et al.[112] demonstrated that disease severity was a predictor of physical activity levels in persons with MS, such that those with higher disability reported lower activity levels ($ß= -0.30$, $p< 0.02$). Furthermore, one study by Motl et al.[145] reported that worsening symptoms, a common feature of greater disability, was independently associated with lower self-reported physical activity ($p= 0.04$).

Persons with MS in our sample spent an average of 76.1% (658.2 minutes/day) of their wear time in ST, 22.8% (184.9 minutes/day) of their wear time in LPA, and 1.2% (10.3 minutes/day) of their wear time in MVPA. These results align with a previous study by Fakolade et al.[21] which reported that persons with MS (median PDDS= 5.0; IQR= 1.0) spent about 76% (566 minutes/day) of their wear time in sedentary behaviour, 23% (167 minutes/day) of their wear time in LPA, and 1% (5 minutes/day) in MVPA. When compared to samples with lower disability,[115] persons with MS in our study spent more total wear time sedentary and less time engaging in LPA and MVPA. Furthermore, individuals in our sample spent a greater percentage of their wear time sedentary, and a lower percentage engaged in LPA and MVPA. For instance, in one study Klaren et al.,[115] 662 middle-aged adults (median PDDS= 2.0; IQR= 2.0) spent 64% (533 minutes/day) of their wear time in ST, 34% (288 minutes/day) in LPA and 2% (19 minutes/day) in MVPA. The difference between studies in physical activity levels is expected given that greater MS disability is associated with increased barriers to physical activity, such as mobility issues and physiological deconditioning, which can limit one's engagement in physical activity.[110,146] In fact, one study by Ezeugwu et al.[110] comparing persons with MS with (PDDS≥ 3) and without (PDDS≤ 3) mobility impairment demonstrated that individuals with mobility impairment spent 5% (28.8 minutes/day) more accelerometer wear time in ST, 3% (27.7 minutes/day) less time in LPA, and 2% (14.3 minutes/day) less time in MVPA.

The lower levels of physical activity in persons with moderate-to-severe MS extends to daily steps, as our sample averaged 2938 steps/day. Other studies reporting daily steps in persons with MS with lower disability report considerably greater daily step counts. For instance, one study by Dlugonski et al.[147] reported a daily step count of 7167 in participants with mild MS (PDDS≤ 2; n= 255), compared to 4257 steps/day in 194 persons with greater disability (PDDS≥ 3; n= 194). The substantially lower step count reported herein makes sense in the context of previous MS literature; one study by Block et al.[148] reported a strong correlation between daily steps and Expanded Disability Status Scale (EDSS) scores (Spearman's r= -0.71, p<0.001).

Only one participant with MS met the Canadian guidelines for ST. The large portion of participants (n= 9, 90%) engaging in more than 8 hours/day of ST is concerning, as increased ST is associated with negative health outcomes in persons with MS.[149] In fact, ST in persons with MS is assocaited with comorbid conditions such as hypertension, and can exaccerbate symptoms such as spasms and pain.[150] Similarly, only two persons with MS met the Canadian Physical Activity Guidelines criteria for MVPA. MVPA levels have been associated with vascular comorbidity in persons with MS, and vascular comorbidities have been linked with disease progression and an increased rate of relapses.[151,152] It is imperative that future interventions targeting physical activity in persons with MS include specific strategies to reduce ST and increase MVPA, as these are related but different health behaviours.

5.2.2. Physical activity levels in MS care-partners

Our results show that care-partners of people with moderate-to-severe MS spent 67.4% (577.6 minutes/day) of their wear time in ST, 31.3% (259.1 minutes/day) of their wear time in LPA and 1.2% (11.7 minutes/day) of their wear time in MVPA and took 4614 steps/day. In the study by Fakolade et al.,[21] MS care-partners spent slightly more time sedentary (71.8%, 551.9 minutes/day), and engaged in more MVPA (2.8%, 21.4 minutes/day), but spent less time in LPA (25.4%, 199.6 minutes/day). Participants in that study also averaged over 1500 more steps per day compared to our sample. Discrepancies between the two studies may be due to the fact that our study was conducted during the COVID-19 pandemic which could impact physical activity participation.[153] In accordance with our results, Sanudo et al.[154] reported a large decrease in daily step counts (d= 1.61) and MVPA (d= 0.62) during the COVID-19 pandemic in 20 adults without a chronic disease. However, based on the study by Greaney et al. which reports that family care-partners saw an increase in ST during the COVID-19 pandemic, we would have expected similar results in our sample.[155] In other chronic disease populations such as Dementia, care-partners engaged in 259.3 minutes/day of LPA, and 8.3 minutes/day of MVPA.[29] ST was not reported in that study. These findings closely align with the physical activity levels of care-partners in our study.

Only two care-partners in our study met the Canadian ST guidelines. This is worrisome as greater ST is independently associated with inactivity-related comorbidities, such as type 2 diabetes and cardiovascular disease in the general population.[153] Increased ST also increases the risk of colon cancer and high blood pressure. According to the World Health Organization, approximately 2 million deaths each year are attributed to physical inactivity and inactivity is among the top 10 leading causes of mortality and disability.[157] Furthermore, only two care-partners met the Canadian physical activity guidelines for MVPA. Low levels of MVPA may lead to poor cardiometabolic health and increased risk of heart disease, cancer, and depression in the general population.[151,158] Evidently, the development of programs and interventions to address physical inactivity in care-partners of persons with MS are essential to overall health and well-being, and should be a focal point for researchers moving forward.

5.3 Case study of the PAT-MS intervention

No study to date has investigated the effects of a dyadic physical activity intervention in dyads affected by MS, and a limited number of studies have investigated the effects in other populations with chronic disease. Additionally, many of the studies using a dyadic physical activity intervention target improvement in psychosocial outcomes as their primary end-point, rather than physical activity levels, and do not include control groups for comparison.[33,34] One study involving nine dyads affected by dementia reported an increase in LPA and MVPA of 23.9 minutes/week and 36.5 minutes/week, respectively, following a dyadic physical activity intervention.[159] Similarly, participants in the PAT-MS intervention demonstrated an increase in LPA (160 minutes/week) after the intervention; however, they demonstrated a decline in MVPA (6.6 minutes/week). The discrepancy between studies may be due to the different study populations, as persons with moderate-to-severe MS experience physical impairments and physiological deconditioning which might limit their ability to participate in higher intensity physical activity compared to individuals with dementia.[25] In agreement with our study, Boudreau et al.[160] also observed a 4.5% decrease in daily MVPA for dyads affected by obesity following a dyadic physical activity intervention. This phenomenon may be because the PAT-MS intervention did not specifically targeted MVPA, as physical activity was self-selected by participants in our intervention. Furthermore, the intensity of physical activity was self-reported, rather than objectively-measured using a device such as a heart rate monitor. Such an approach may have helped participants increase the intensity of physical activity within the MVPA range.

Nonetheless, the PAT-MS intervention still had a large effect (d= 1.40) on MVPA in dyads participating in the intervention compared to the control condition, indicating that the intervention seemingly prevented some of the decline in MVPA that could have occurred for various reasons (i.e., change in seasons, pandemic-related). One randomized controlled trial by Schneider investigated long-lasting changes in health behaviours (i.e., physical activity, sedentary behaviour, fruit and vegetable intake, and fat consumption) in 73 African American adolescents and their caregivers. The study reported that this family-oriented intervention, while having a large effect on ST (d= -0.61) similar to our study, reported a small main effect of treatment on MVPA (d= 0.28) compared to the control group.[161] The same trend was observed in a study by Berli & Scholz[162] where they reported that 121 obese couples experienced no change in self-reported MVPA or accelerometer-measured MVPA following a 14-day action-control dyadic physical activity intervention (F[1,98]= 0.36, p= 0.553, $\eta^2_p = 0.004$) compared to the control group. The discrepancy between studies may be attributed to differences in methodologies, such as the accelerometers used, the study population, or the length and content of the interventions.

With respect to self-reported physical activity in MS dyads, Sher et al. also reported similar improvements in self-reported physical activity (d= 0.82) in persons with cardiac disease and their partners following a couple's oriented physical activity intervention compared to a control group.[163] Individuals in the control, similarly to our study, experienced an improvement in self-reported physical activity after the 24-week period; however, this improvement mostly occurred in the initial stages of the intervention and physical activity actually decelerated over time (quadratic slope: β= -0.004).

5.4 Interdependence of physical activity in MS-care partner dyads

Our findings provide new insight into the interdependence of physical activity patterns among persons with MS and their care-partners. Our results demonstrated a strong correlation between ST of care-partners and care-recipients and a moderate correlation in the percent of wear time spent in ST. These results are mostly consistent with previous studies that have investigated physical activity interdependence in other populations. For instance, one study by Lopes et al.[31] also demonstrated a significant association in sitting time behaviour (ICC= 0.21) within best-friend dyads. Similarly, one study by Ashe et al.[164] reported that ST was significantly correlated within elderly couples (r= 0.44, p<0.001). Furthermore, in a study by Harada et al.,[165] multiple regression analyses revealed that ST of one spouse explained a significantly amount of variation in ST of the other spouse (β= 0.30-0.47). The correlations between care-partner and care-recipient LPA (*rs*= 0.41), percent of wear time spent in LPA (*rs*= 0.55), and daily steps (*rs*= 0.33) in the current study, also align with previous research which demonstrates that people are more likely to be active when their partners are also active. For instance, patients with COPD had a greater likelihood of being physically active when their care-partners were also active when compared to patients with an inactive care-partner (OR= 4.36; 95% CI= 1.41-13.30; p= 0.01).[121] In other chronic disease populations, this association has also been observed. For instance, one study measuring the physical activity patterns of 169 dyads affected by osteoarthritis, reported that both MVPA and daily steps of patients with osteoarthritis were significantly and positively correlated to their partners physical activity.[166] In contrast, an unexpected result from our study was that MVPA was not correlated within MS-care-partner dyads. A possible explanation for the difference in these findings is that the former study did not include dyads who are affected by a chronic neurodegenerative disease such as MS. Persons with MS may experience symptom exacerbation, disease progression, environmental barriers, and low self-efficacy for engaging in physical activity, which may impact their ability to become and stay physically active.[112] These factors become even more apparent when persons with MS are engaging in higher intensity physical activity and may explain the low levels of MVPA observed in this population.[108,167] As a result, it may be difficult for persons with MS and their care-partners to engage in the same type and intensity of physical activity. Indeed, our findings are supported by previous research in dyads with MS, as Fakolade et al.[21] also reported no significant correlation in MVPA within dyads.

No study to date has investigated dyadic physical activity interdependence over time in MS-care-partner dyads. Our results demonstrated positive correlations between care-partner and care-recipient self-reported physical activity, and objective physical activity levels. This is expected as many health behaviours are concordant among couples, such as dietary intake and smoking habits.[168] Furthermore, when one partner adopts a health-promoting behaviour, the other is likely to adopt it as well.[169,170] Indeed, this trend is applicable for changes in physical activity over time in partners.[164] For instance, in a longitudinal study by Jackson et al.,[169] having a partner consistently engage in health promoting behaviours predicted an increase in the physical activity of the other partner (OR= 1.92; 95% CI= 1.37-2.70). Moreover, one study by Homish & Leonard[171] found that there was a significant prospective association between wives who engaged in regular exercise before marriage and husbands' exercise habits over the first four years of marriage (OR= 2.16; 95% CI= 1.54-3.03; $p < 0.001$). This finding demonstrates the potential influence a person can have on the change in physical activity behaviour of their partner. In the chronic disease context, one study by Berli & Scholz[162] also reported a strong correlation between care-recipients' and care-partners' change in MVPA ($r = 0.50$). Unfortunately, due to the small sample size we were unable to investigate if dyadic physical activity interdependence over time was different between intervention and control groups. We would anticipate that many of the topics covered during the PAT-MS intervention, such as dyadic coping, goal setting, and collaborative planning would drive physical activity changes in both partners. Future research should investigate group differences using quantitative and qualitative approaches to shed light on the potential processes driving changes in physical activity in MS-care-partner dyads. Nonetheless, our results support previous work emphasizing the bi-directional relationship of care-recipient-care-partner health and physical activity behaviours.[172]

5.5 Strengths and Limitations

This thesis is unique in several ways. Firstly, the randomized controlled trial design of the study reduces bias and provides an accurate method to determine the efficacy of an intervention on specific outcomes, such as physical activity.[173] Furthermore, the design and content of the intervention is theory-based and incorporates recommendations from various experts and stakeholders within the MS community. These recommendations, including transitioning to a videoconference-delivered intervention, and the inclusion of a participant manual made the intervention more participant-friendly and practical. This thesis extends current literature by including both persons with moderate-to-severe MS and their care-partners for the first time in a dyadic physical activity intervention. This study employed both self-reported and objective methods to characterize physical activity levels. Accelerometers were used simultaneously with self-reported activity to explore the change in and interdependence of physical activity patterns in this sample.

While this thesis did have its strengths, there were also important limitations to note. Firstly, our sample consisted mostly of participants that were middle-aged to older women with relapsing-remitting MS, and therefore, our results may not be generalizable to other MS support-partner dyads. Another limitation of this thesis is the small sample of participants included. While our results suggest potential benefits of the PAT-MS intervention on dyadic physical activity, these findings should be confirmed in larger samples using high-quality designs. Thirdly, all assessments were conducted remotely which may have resulted in misinterpretation of study instructions. We included strategies to address this concern, such as detailed instructions for completing the online surveys, instructions and a video for wearing the accelerometers, as well as completing follow-up calls to ensure information was effectively communicated. Additionally, while the intervention was designed to be delivered to multiple dyads simultaneously, this pilot case study only included one dyad who received the PAT-MS intervention, as one dyad withdrew from the study after randomization. This is a limitation as the intervention lacked a group-based component which could have altered the social dynamics and experience of the videoconference-delivered sessions. Moving forward, it is essential to test the efficacy of the intervention in group-based format, as designed. Lastly, our results could be biased by the Hawthorne effect as participants in the intervention group may have been more motivated to increase their physical activity in response to the intervention, but this behaviour change may not be long-lasting. Future studies should consider including an additional follow-up assessment after completion of the intervention to examine potential lasting effects.

5.6 Conclusions

Despite these limitations, our study is the first to examine the effects of a dyadic physical activity intervention in MS-care-partner-care-recipient dyads. Our findings demonstrate that the PAT-MS intervention may be beneficial for reducing daily ST and increasing engagement in physical activity, particularly LPA. Physical activity within dyads was interdependent at baseline and over 12-weeks, suggesting the potential for both members of the MS-care-partner dyad to influence each other's physical activity levels. This study is a first step towards the development of larger dyadic physical activity interventions for improving overall physical activity levels in persons with moderate-to-severe MS and their care-partners.

Chapter 6: References

1. Dendrou, C. A., Fugger, L. & Friese, M. A. Immunopathology of multiple sclerosis. *Nat. Rev. Immunol.* **15**, 545-558 (2015).
2. Poppe, A. Y., Wolfson, C. & Zhu, B. Prevalence of multiple sclerosis in Canada: A systematic review. *Can. J. Neurol. Sci.* **35**, 593-601 (2008).
3. Kister, I. *et al.* Natural history of multiple sclerosis symptoms. *Int. J. MS Care* **15**, 146–156 (2013).
4. Cameron, M. H. & Wagner, J. M. Gait abnormalities in multiple sclerosis: Pathogenesis, evaluation, and advances in treatment. *Curr. Neurol. Neurosci. Rep.* **11**, 507–515 (2011).
5. Islas, M. Á. M. & Ciampi, E. Assessment and impact of cognitive impairment in multiple sclerosis: An overview. *Biomedicines* **7**, 22 (2019).
6. Krupp, L. B. Fatigue in multiple sclerosis: Definition, pathophysiology and treatment. *CNS Drugs* **17**, 225–234 (2003).
7. Boeschoten, R. E. *et al.* Prevalence of depression and anxiety in Multiple Sclerosis: A systematic review and meta-analysis. *J. Neurol. Sci* **372**, 331–341 (2017).
8. Korostil, M. & Feinstein, A. Anxiety disorders and their clinical correlates in multiple sclerosis patients. *Mult. Scler.* **13**, 67–72 (2007).
9. Gholamzad, M. *et al.* A comprehensive review on the treatment approaches of multiple sclerosis: currently and in the future. *Inflamm. Res.* **68**, 25–38 (2019).
10. McGinley, M. P., Goldschmidt, C. H. & Rae-Grant, A. D. Diagnosis and Treatment of Multiple Sclerosis: A Review. *JAMA* **325**, 765–779 (2021).
11. Månsson, E. & Lexell, J. Performance of activities of daily living in multiple sclerosis. *Disabil. Rehabil.* **26**, 576–585 (2004).
12. LaRocca, N. G. Impact of walking impairment in multiple Sclerosis: perspectives of patients and care partners. *Patient* **3**, 189-201 (2011).
13. van Asch, P. Impact of mobility impairment in multiple sclerosis 2-patients' perspectives. *Eur. Neurol. Rev.* **6**, 115-120 (2011).
14. Buhse, M. Assessment of caregiver burden in families of persons with Multiple sclerosis. *J. Neurosci. Nurs.* **40**, 25–31 (2008).
15. Buchanan, R. J., Radin, D. & Huang, C. Caregiver burden among informal caregivers assisting people with multiple sclerosis. *Int. J. MS Care* **13**, 76–83 (2011).
16. Arnett, P. A. Caregiver burden in multiple sclerosis. *J. Neurol. Neurosurg. Psychiatry* **78**, 1041 (2007).
17. van der Hiele, K. *et al.* Caregiver strain among life partners of persons with mild disability due to relapsing-remitting multiple sclerosis. *Mult. Scler. Relat. Disord.* **31**, 5–11 (2019).
18. Figved, N., Myhr, K. M., Larsen, J. P. & Aarsland, D. Caregiver burden in multiple sclerosis: the impact of neuropsychiatric symptoms. *J. Neurol. Neurosurg. Psychiatry* **78**, 1097 (2007).
19. Schulz, R. & Beach, S. R. Caregiving as a risk factor for mortality: the Caregiver Health

Effects Study. *JAMA* **282**, 2215–2219 (1999).

20. Motl, R. W., McAuley, E. & Snook, E. M. Physical activity and multiple sclerosis: A meta-analysis. *Mult. Scler.* **11**, 459–463 (2005).
21. Fakolade, A., Finlayson, M., Parsons, T. & Latimer-Cheung, A. Correlating the physical activity patterns of people with moderate to severe multiple sclerosis disability and their family caregivers. *Physiother. Canada* **70**, 373–381 (2018).
22. Motl, R. W. & Pilutti, L. A. The benefits of exercise training in multiple sclerosis. *Nat. Rev. Neurol.* **8**, 487–497 (2012).
23. Turner, A. P. *et al.* Improving fatigue and depression in individuals with multiple sclerosis using telephone-administered physical activity counseling. *J. Consult. Clin. Psychol.* **84**, 297–309 (2016).
24. Morrison, J. D. & Mayer, L. Physical activity and cognitive function in adults with multiple sclerosis: an integrative review. *Disab. Rehabil.* **39**, 1909–1920 (2017).
25. Halabchi, F., Alizadeh, Z., Sahraian, M. A. & Abolhasani, M. Exercise prescription for patients with multiple sclerosis; potential benefits and practical recommendations. *BMC Neurol.* **17**, 185 (2017).
26. Motl, R. W. & Gosney, J. L. Effect of exercise training on quality of life in multiple sclerosis: A meta-analysis. *Mult. Scler.* **14**, 129–135 (2008).
27. Gascoyne, C., Karahalios, A., Demaneuf, T. & Marck, C. Effect of exercise interventions on anxiety in people with multiple sclerosis; A systematic review and meta-analysis. *Int. J. MS Care* **22**, 103–109 (2020).
28. Orgeta, V. & Miranda-Castillo, C. Does physical activity reduce burden in carers of people with dementia? A literature review. *Int. J. Geriatr. Psychiatry* **29**, 771–783 (2014).
29. Marquez, D. X., Bustamante, E. E., Kozey-Keadle, S., Kraemer, J. & Carrion, I. Physical activity and psychosocial and mental health of older caregivers and non-caregivers. *Geriatr. Nurs.* **33**, 358–365 (2012).
30. Loi, S. M. *et al.* Physical activity in caregivers: What are the psychological benefits? *Arch. Gerontol. Geriatr.* **59**, 204–210 (2014).
31. Lopes, V. P., Gabbard, C. & Rodrigues, L. P. Physical activity in adolescents: examining influence of the best friend dyad. *J. Adolesc. Health* **52**, 752–756 (2013).
32. Freedson, P. S. & Evenson, S. Familial aggregation in physical activity. *Res. Q. Exerc. Sport* **62**, 384–389 (1991).
33. Carr, R. M. *et al.* Dyadic interventions to promote physical activity and reduce sedentary behaviour: systematic review and meta-analysis. *Health Psychol. Rev.* **13**, 91–109 (2019).
34. Lamotte, G., Shah, R. C., Lazarov, O. & Corcos, D. M. Exercise training for persons with Alzheimer's disease and caregivers: A review of dyadic exercise interventions. *J. Mot. Behav.* **49**, 365–377 (2017).
35. Martire, L. M., Schulz, R., Helgeson, V. S., Small, B. J. & Saghafi, E. M. Review and meta-analysis of couple-oriented interventions for chronic illness. *Ann. Behav. Med.* **40**, 325–342 (2010).

36. Prick, A. E., De Lange, J., Scherder, E., Twisk, J. & Pot, A. M. The effects of a multicomponent dyadic intervention with physical exercise on the cognitive functioning of people with dementia: A randomized controlled trial. *J. Aging Phys. Act.* **25**, 539–552 (2017).
37. Fakolade, A. *et al.* Physical Activity Together for People With Multiple Sclerosis and Their Care Partners: Protocol for a feasibility randomized controlled trial of a dyadic intervention. *JMIR Res. Protoc.* **10,** e18410 (2021)
38. Lyons, K. S. & Lee, C. S. The Theory of Dyadic Illness Management. *J. Fam. Nurs.* **24**, 8–28 (2018).
39. Bandura, A. Social Cognitive Theory of Self-Regulation. *Organ. Behav. Hum. Decis. Process.* **50**, 248–287 (1991).
40. Ryan, R. M., Deci, E. L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* **55**, 68-78 (2000).
41. Fakolade, A., Walters, A. J., Cameron, J., Latimer-Cheung, A. E. & Pilutti, L. A. Healthy together: A systematic review of theory and techniques used in health interventions for persons with chronic neurological conditions and their caregivers. *Patient Educ. Couns.* **103**, 788–803 (2020).
42. CJ, F. *et al.* Effect of moderate to vigorous physical activity intervention on improving Dementia family caregiver physical function: A randomized controlled trial. *J. Alzheimer's Dis. Park.* **6**, 253 (2016).
43. Farran, C. J. *et al.* A lifestyle physical activity intervention for caregivers of persons with Alzheimer's disease. *Am. J. Alzheimers. Dis. Other Demen.* **23**, 132–42 (2008).
44. Etkin, C. D., Farran, C. J., Barnes, L. L. & Shah, R. C. Recruitment and enrollment of caregivers for a lifestyle physical activity clinical trial. *Res. Nurs. Health* **35**, 70–81 (2012).
45. Fakolade, A. *et al.* Prioritizing components of a dyadic physical activity intervention for people with moderate-to-severe MS and their care-partners: A modified e-Delphi study. *Int. J. MS Care.* (2022). doi:10.7224/1537-2021-079
46. Canning, K. L. & Hicks, A. L. Benefits of adhering to the canadian physical activity guidelines for adults with multiple sclerosis beyond aerobic fitness and strength. *Int. J. MS Care* **22**, 15–21 (2020).
47. Motl, R. W. & Sandroff, B. M. Benefits of exercise training in multiple sclerosis. *Curr. Neurol. Neurosci. Rep.* **15**, 62 (2015).
48. Ghasemi, N., Razavi, S. & Nikzad, E. Multiple sclerosis: Pathogenesis, symptoms, diagnoses and cell-based therapy. *Cell J.* **19**, 1–10 (2017).
49. Tao, C. *et al.* Higher latitude is significantly associated with an earlier age of disease onset in multiple sclerosis. *J. Neurol. Neurosurg. Psychiatry* **87**, 1343–1349 (2016).
50. Harbo, H. F., Gold, R. & Tintora, M. Sex and gender issues in multiple sclerosis. *Ther. Adv. Neurol. Disord.* **6**, 237–248 (2013).
51. Amankwah, N. *et al.* Multiple sclerosis in Canada 2011 to 2031: Results of a microsimulation modelling study of epidemiological and economic impacts. *Heal.*

Promot. Chronic Dis. Prev. Canada **37,** 37-42 (2017).

52. Vaughn, C. B. *et al.* Epidemiology and treatment of multiple sclerosis in elderly populations. *Nat. Rev. Neurol.* **15**, 329-342 (2019).
53. Ford, H. Clinical presentation and diagnosis of multiple sclerosis. *Clin. Med. J. R. Coll. Physicians London* **20**, 380–383 (2020).
54. Beiske, A. G., Pedersen, E. D., Czujko, B. & Myhr, K. M. Pain and sensory complaints in multiple sclerosis. *Eur. J. Neurol.* **11**, 479–482 (2004).
55. Rae-Grant, A. D., Eckert, N. J., Bartz, S. & Reed, J. F. Sensory symptoms of multiple sclerosis: A hidden reservoir of morbidity. *Mult. Scler.* **5**, 179–183 (1999).
56. Comber, L., Galvin, R. & Coote, S. Gait deficits in people with multiple sclerosis: A systematic review and meta-analysis. *Gait and Posture* **51**, 25–35 (2017).
57. Bethoux, F. Gait disorders in multiple sclerosis. *Continuum (Minneap Minn).* **19**, 1007–1022 (2013).
58. Martin, C. L. *et al.* Gait and balance impairment in early multiple sclerosis in the absence of clinical disability. *Mult. Scler.* **12**, 620–628 (2006).
59. Sosnoff, J. J. *et al.* Mobility, balance and falls in persons with multiple sclerosis. *PLoS One* **6**, e28021 (2011).
60. Hoang, P. D., Gandevia, S. C. & Herbert, R. D. Prevalence of joint contractures and muscle weakness in people with multiple sclerosis. *Disabil. Rehabil.* **36**, 1588–1593 (2014).
61. Rizzo, M. A., Hadjimichael, O. C., Preiningerova, J. & Vollmer, T. L. Prevalence and treatment of spasticity reported by multiple sclerosis patients. *Mult. Scler.* **10**, 589–595 (2004).
62. Costello, F. Vision Disturbances in Multiple Sclerosis. *Semin. Neurol.* **36**, 185–195 (2016).
63. Arnett, P. A., Barwick, F. H. & Beeney, J. E. Depression in multiple sclerosis: Review and theoretical proposal. *J. Int. Neuropsychol. Soc.* **14**, 691–724 (2008).
64. Braley, T. J. & Chervin, R. D. Fatigue in multiple sclerosis: Mechanisms, evaluation, and treatment. *Sleep* **33**, 1061–1067 (2010).
65. Chiaravalloti, N. D. & DeLuca, J. Cognitive impairment in multiple sclerosis. *Lancet Neurol.* **7**, 1139–1151 (2008).
66. Lublin, F. D., Coetzee, T., Cohen, J. A., Marrie, R. A. & Thompson, A. J. The 2013 clinical course descriptors for multiple sclerosis: A clarification. *Neurology* **94**, 1088–1092 (2020).
67. Hurwitz, B. J. The diagnosis of multiple sclerosis and the clinical subtypes. *Ann. Indian Acad. Neurol.* **12**, 226–230 (2009).
68. Meca-Lallana, V. *et al.* Deciphering multiple sclerosis progression. *Front. Neurol.* **12**, 477 (2021).
69. Kurtzke, J. F. Rating neurologic impairment in multiple sclerosis: An expanded disability status scale (EDSS). *Neurology* **33**, 1444–1452 (1983).

70. Kragt, J. J., Neilsen, I. M., Van der Linden, F. A. H., Utidehaag, B. M., Polam, C. H. How similar are the commonly combined criteria for EDSS progression in multiple sclerosis? *Mult. Scler.* **12**, 782-786, 2006

71. Learmonth, Y. C., Motl, R. W., Sandroff, B. M., Pula, J. H. & Cadavid, D. Validation of patient determined disease steps (PDDS) scale scores in persons with multiple sclerosis. *BMC Neurol.* **13**, 1–8 (2013).

72. Lo, A. C., Hadjimichael, O. & Vollmer, T. L. Treatment patterns of multiple sclerosis patients: A comparison of veterans and non-veterans using the NARCOMS registry. *Mult Scler* **11**, 33–40 (2005).

73. Tremlett, H., Paty, D. & Devonshire, V. Disability progression in multiple sclerosis is slower than previously reported. *Neurology* **66**, 172–177 (2006).

74. Motl, R., Goldman & Benedict, B. Walking impairment in patients with multiple sclerosis: exercise training as a treatment option. *Neuropsychiatr. Dis. Treat.* **6**, 767 (2010).

75. Langeskov-Christensen, D. *et al.* Performed and perceived walking ability in relation to the Expanded Disability Status Scale in persons with multiple sclerosis. *J. Neurol. Sci.* **382**, 131–136 (2017).

76. Genevie, L., Kallos, J. E. & Struening, E. L. Job retention among people with multiple sclerosis. *Neurorehabil. Neural Repair* **1**, 131–135 (1987).

77. Salter, A. R., Cutter, G. R., Tyry, T., Marrie, R. A. & Vollmer, T. Impact of loss of mobility on instrumental activities of daily living and socioeconomic status in patients with MS. *Curr. Med. Res. Opin.* **26**, 493–500 (2010).

78. Sutliff, M. H. Contribution of impaired mobility to patient burden in multiple sclerosis. *Curr. Med. Res. Opin.* **26**, 109–119 (2010).

79. Pike, J., Jones, E., Rajagopalan, K., Piercy, J. & Anderson, P. Social and economic burden of walking and mobility problems in multiple sclerosis. *BMC Neurol.* **12**, 1–8 (2012).

80. Edmonds, P., Vivat, B., Burman, R., Silber, E. & Higginson, I. J. Los and change: Experiences of people severely affected by multiple sclerosis. *Palliat. Med.* **21**, 101–107 (2007).

81. Conradsson, D., Ytterberg, C., von Koch, L. & Johansson, S. Changes in disability in people with multiple sclerosis: a 10-year prospective study. *J. Neurol.* **265**, 119–126 (2018).

82. Ertekin, Ö., Özakbaş, S. & Idiman, E. Caregiver burden, quality of life and walking ability in different disability levels of multiple sclerosis. *NeuroRehabilitation* **34**, 313–321 (2014).

83. Maguire, R. & Maguire, P. Caregiver burden in multiple sclerosis: Recent trends and future directions. *Curr. Neurol. Neurosci. Rep.* **20**, 18 (2020).

84. Bayen, E., Papeix, C., Pradat-Diehl, P., Lubetzki, C. & Joël, M. E. Patterns of objective and subjective burden of informal caregivers in multiple sclerosis. *Behav. Neurol.* **2015**, (2015).

85. Katsavos, S. *et al.* Predicting caregiving status and caregivers' burden in multiple

sclerosis. A short report. *Neurol. Res.* **39**, 13–15 (2017).

86. Kaschowitz, J. & Brandt, M. Health effects of informal caregiving across Europe: A longitudinal approach. *Soc. Sci. Med.* **173**, 72–80 (2017).
87. Giordano, A. *et al.* Low quality of life and psychological wellbeing contrast with moderate perceived burden in carers of people with severe multiple sclerosis. *J. Neurol. Sci.* **366**, 139–145 (2016).
88. Rafnsson, S. B., Shankar, A. & Steptoe, A. Informal caregiving transitions, subjective well-being and depressed mood: Findings from the English Longitudinal Study of Ageing. *Aging Ment. Heal.* **21**, 104–112 (2017).
89. Pooyania, S., Lobchuk, M., Chernomas, W. & Ann Marrie, R. Examining the relationship between family caregivers' emotional states and ability to empathize with patients with multiple sclerosis: A pilot study. *Int. J. MS Care* **18**, 122–128 (2016).
90. Pakenham, K. I. The nature of caregiving in multiple sclerosis: Development of the caregiving tasks in multiple sclerosis scale. *Mult. Scler.* **13**, 929–938 (2007).
91. Aronson, K. J., Cleghorn, G. & Goldenberg, E. Assistance arrangements and use of services among persons with multiple sclerosis and their caregivers. *Disabil. Rehabil.* **18**, 354–361 (1996).
92. Dunn, J. Impact of mobility impairment on the burden of caregiving in individuals with multiple sclerosis. *Expert Rev. Pharmacoecon. Outcomes Res.* **10**, 433–440 (2010).
93. Karamyan, A. & Sellner, J. Journal Club: Effect of comorbidity on mortality in multiple sclerosis. *Neurology* **87**, 646 (2016).
94. Pakenham, K. I. & Samios, C. Couples coping with multiple sclerosis: A dyadic perspective on the roles of mindfulness and acceptance. *J. Behav. Med.* **36**, 389–400 (2013).
95. Bertschi, I. C., Meier, F. & Bodenmann, G. Disability as an interpersonal experience: A systematic review on dyadic challenges and dyadic coping when one partner has a chronic physical or sensory impairment. *Front. Psychol.* **0**, 430 (2021).
96. Fakolade, A. *et al.* Understanding leisure-time physical activity: Voices of people with MS who have moderate-to-severe disability and their family caregivers. *Heal. Expect.* **21**, 181–191 (2018).
97. King, K. E. & Arnett, P. A. Predictors of dyadic adjustment in multiple sclerosis. *Mult. Scler.* **11**, 700–707 (2005).
98. Beckerman, H., de Groot, V., Scholten, M. A., Kempen, J. C. E., Lankhorst, G. J. Physical activity behavior in people with multiple sclerosis: Understanding how they can become more physically active. *Phys. Ther*. **90**, 1001-1013 (2010).
99. Jetté, M., Sidney, K. & Blümchen, G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin. Cardiol.* **13**, 555–565 (1990).
100. Cederberg, K. L., Motl, R. W. & McAuley, E. Physical activity, sedentary behavior, and physical function in older adults with multiple sclerosis. *J. Aging Phys. Act.* **26**, 177–182 (2018).

101. Veldhuijzen Van Zanten, J. J. C. S., Pilutti, L. A., Duda, J. L. & Motl, R. W. Sedentary behaviour in people with multiple sclerosis: Is it time to stand up against MS? *Mul. Scler.* **22**, 1250–1256 (2016).

102. Swift, D. L., Johannsen, N. M., Lavie, C. J., Earnest, C. P. & Church, T. S. The role of exercise and physical activity in weight loss and maintenance. *Prog. Cardiovasc. Dis.* **56**, 441–447 (2014).

103. Ewanchuk, B. W., Gharagozloo, M., Peelen, E. & Pilutti, L. A. Exploring the role of physical activity and exercise for managing vascular comorbidities in people with multiple sclerosis: A scoping review. *Mult. Scler. Relat. Disord.* **26**, 19–32 (2018).

104. Latimer-Cheung, A. E. *et al.* Development of evidence-informed physical activity guidelines for adults with multiple sclerosis. *Arch. Phys. Med. Rehabil.* **94**, 1829-1836 (2013).

105. Kalb, R. *et al.* Exercise and lifestyle physical activity recommendations for people with multiple sclerosis throughout the disease course. *Mult. Scler. J.* **26**, 1459–1469 (2020).

106. Kinnett-Hopkins, D., Adamson, B., Rougeau, K. & Motl, R. W. People with MS are less physically active than healthy controls but as active as those with other chronic diseases: An updated meta-analysis. *Mult. Scler. Relat. Disord.* **13**, 38–43 (2017).

107. Marrie, R. A. *et al.* High frequency of adverse health behaviors in multiple sclerosis. *Mult. Scler.* **15**, 105–113 (2009).

108. Motl, R. W. *et al.* Physical activity, sedentary behavior, and aerobic capacity in persons with multiple sclerosis. *J. Neurol. Sci.* **372**, 342–346 (2017).

109. Colley, R. C. *et al.* Physical activity of canadian adults: Accelerometer results from the 2007 to 2009 canadian health measures survey. *Heal. Reports* **22**, 7–14 (2011).

110. Ezeugwu, V., Klaren, R. E., Hubbard, E. A., Manns, P. & Motl, R. W. Mobility disability and the pattern of accelerometer-derived sedentary and physical activity behaviors in people with multiple sclerosis. *Prev. Med. Reports* **2**, 241–246 (2015).

111. Fjeldstad, C., Fjeldstad, A. S. & Pardo, G. Use of accelerometers to measure real-life physical activity in ambulatory individuals with multiple sclerosis. *Int. J. MS Care* **17**, 215–220 (2015).

112. Anens, E., Zetterberg, L., Urell, C., Emtner, M. & Hellström, K. Self-reported physical activity correlates in Swedish adults with multiple sclerosis: A cross-sectional study. *BMC Neurol.* **17**, (2017).

113. Motl, R. W. & Goldman, M. Physical inactivity, neurological disability, and cardiorespiratory fitness in multiple sclerosis. *Acta Neurol. Scand.* **123**, 98–104 (2011).

114. Tremblay, M. S. *et al.* New Canadian physical activity guidelines. *Appl. Physiol. Nutr. Metab.* **36**, 36–46 (2011).

115. Klaren, R. E., Motl, R. W., Dlugonski, D., Sandroff, B. M. & Pilutti, L. A. Objectively quantified physical activity in persons with multiple sclerosis. *Arch. Phys. Med. Rehabil.* **94**, 2342–2348 (2013).

116. Sandroff, B. M., Klaren, R. E. & Motl, R. W. Relationships among physical inactivity, deconditioning, and walking impairment in persons with multiple sclerosis. *J. Neurol.*

Phys. Ther. **39**, 103–110 (2015).

117. Beckerman, H., de Groot, V., Scholten, M. A., Kempen, J. C. E. & Lankhorst, G. J. Physical activity behavior of people with multiple sclerosis: Understanding how they can become more physically active. *Phys. Ther.* **90**, 1001–1013 (2010).
118. Ploughman, M. Breaking down the barriers to physical activity among people with multiple sclerosis – a narrative review. *Phys. Ther. Rev*. **22**, 124–132 (2017).
119. Doyle, K. L. *et al.* Systematic review of exercise for caregiver-care recipient dyads: What is best for spousal caregivers—Exercising together or not at all? *Gerontologist* **61**, e283-e301 (2021).
120. Li, K. K., Cardinal, B. J. & Acock, A. C. Concordance of physical activity trajectories among middle-aged and older married couples: Impact of diseases and functional difficulties. *Journals Gerontol. Ser. B* **68**, 794–806 (2013).
121. Mesquita, R. *et al.* Activity levels and exercise motivation in patients with COPD and their resident loved ones. *Chest* **151**, 1028–1038 (2017).
122. Samios, C., Pakenham, K. I. & O'Brien, J. A dyadic and longitudinal investigation of adjustment in couples Coping with multiple sclerosis. *Ann. Behav. Med.* **49**, 74–83 (2015).
123. Lambert, S. D. *et al.* A descriptive systematic review of physical activity interventions for caregivers: Effects on caregivers' and care Recipients' psychosocial outcomes, physical activity levels, and physical health. *Ann. Behav. Med*. **50**, 907–919 (2016).
124. Bandura, A. Social cognitive theory: An agentic perspective. *Annu. Rev. Psychol.* **52**, 1-26 (2001).
125. Deci, E. L., Eghrari, H., Patrick, B. C. & Leone, D. R. Facilitating internalization: The Self-Determination Theory perspective. *J. Pers.* **62**, 119–142 (1994).
126. Peretti, A., Amenta, F., Tayebati, S. K., Nittari, G. & Mahdi, S. S. Telerehabilitation: Review of the state-of-the-art and areas of application. *JMIR Rehabil. Assist. Technol.* **4**, (2017).
127. Fjeldstad-Pardo, C., Thiessen, A. & Pardo, G. Telerehabilitation in multiple sclerosis: Results of a randomized feasibility and efficacy pilot study. *Int. J. Telerehabilitation* **10**, 55–64 (2018).
128. Barksdale, H. *et al.* Tele-Rehabilitation for individuals with multiple sclerosis and mobility disorders-A feasibility and pilot study. *Tele. Med. Today* **5** (2020)
129. Bombardier, C. H. *et al.* The efficacy of telephone counseling for health promotion in people with multiple sclerosis: A randomized controlled trial. *Arch. Phys. Med. Rehabil.* **89**, 1849–1856 (2008).
130. Bombardier, C. H. *et al.* Telephone-based physical activity counseling for major depression in people with multiple sclerosis. *J. Consult. Clin. Psychol.* **81**, 89–99 (2013).
131. Eldridge, S. M. *et al.* CONSORT 2010 statement: Extension to randomised pilot and feasibility trials. *BMJ* **355**, i5239 (2016).
132. Sangha, O., Stucki, G., Liang, M. H., Fossel, A. H. & Katz, J. N. The Self-Administered Comorbidity Questionnaire: A new method to assess comorbidity for clinical and health services research. *Arthritis Care Res.* **49**, 156–163 (2003).

133. Motl, R. W., McAuley, E., Snook, E. M. & Scott, J. A. Validity of physical activity measures in ambulatory individuals with multiple sclerosis. *Disabil. Rehabil.* **28**, 1151–1156 (2006).

134. Sosnoff, J. J., Goldman, M. D. & Motl, R. W. Real-life walking impairment in multiple sclerosis: Preliminary comparison of four methods for processing accelerometry data. *Mult. Scler.* **16**, 868–877 (2010).

135. Motl, R. W., Bollaert, R. E. & Sandroff, B. M. Validation of the godin leisure-time exercise questionnaire classification coding system using accelerometry in multiple sclerosis. *Rehabil. Psychol.* **63**, 77–82 (2018).

136. Motl, R. W., Dlugonski, D., Wójcicki, T. R., McAuley, E. & Mohr, D. C. Internet intervention for increasing physical activity in persons with multiple sclerosis. *Mult. Scler. J.* **17**, 116–128 (2011).

137. Lee, S. T., Wong, J. E., Chan, G. K. L. & Poh, B. K. Association between compliance with movement behavior guidelines and obesity among malaysian preschoolers. *Int. J. Environ. Res. Public Health* **18**, 4611 (2021).

138. Tudor-Locke, C. *et al.* Improving wear time compliance with a 24-hour waist-worn accelerometer protocol in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE). *Int. J. Behav. Nutr. Phys. Act.* **12**, 1–9 (2015).

139. Troiano, R. P. *et al.* Physical activity in the United States measured by accelerometer. *Med. Sci. Sports Exerc.* **40**, 181–188 (2008).

140. Sandroff, B. M., Motl, R. W. & Suh, Y. Accelerometer output and its association with energy expenditure in persons with multiple sclerosis. *J. Rehabil. Res. Dev.* **49**, 467–476 (2012).

141. Cohen, J. Statistical Power Analysis for the Behavioral Sciences Second Edition. (Routledge, New York, 1988)

142. Pilutti, L. A., Edwards, T., Motl, R. W. & Sebastião, E. Functional electrical stimulation cycling exercise in people with multiple sclerosis: Secondary effects on cognition, symptoms, and quality of life. *Int. J. MS Care* **21**, 258 (2019).

143. Hubbard, E. A., Motl, R. W. & Manns, P. J. The descriptive epidemiology of daily sitting time as a sedentary behavior in multiple sclerosis. *Disabil. Health J.* **8**, 594–601 (2015).

144. Silveira, S. L. & Motl, R. W. Environmental correlates of health-promoting leisure physical activity in persons with multiple sclerosis using a social cognitive perspective embedded within social ecological model. *Prev. Med. Reports* **15**, 100921 (2019).

145. Motl, R. W. *et al.* Worsening of symptoms is associated with lower physical activity levels in individuals with multiple sclerosis. *Mult. Scler.* **14**, 140–142 (2008).

146. Langeskov-Christensen, M., Heine, M., Kwakkel, G. & Dalgas, U. Aerobic capacity in persons with multiple sclerosis: a systematic review and meta-analysis. *Sports Med.* **45**, 905–923 (2015).

147. Dlugonski, D. *et al.* Steps per day among persons With multiple sclerosis: Variation by demographic, clinical, and device characteristics. *Arch. Phys. Med. Rehabil.* **94**, 1534–1539 (2013).

148. Block, V. J. *et al.* Continuous daily assessment of multiple sclerosis disability using remote step count monitoring. *J. Neurol.* **264**, 316 (2017).

149. Motl, R. W., Snook, E. M., Wynn, D. R. & Vollmer, T. Physical activity correlates with neurological impairment and disability in multiple sclerosis. *J. Nerv. Ment. Dis.* **196**, 492–495 (2008).

150. Fortune, J. *et al.* Patterns and correlates of sedentary behaviour among people with multiple sclerosis: a cross-sectional study. *Sci. Rep.* **11**, 1–10 (2021).

151. Huynh, T., Jeng, B. & Motl, R. W. Physical activity and vascular comorbidity in Black and White persons with multiple sclerosis: A cross-sectional study. *Disabil. Health J.* **8**, 101314 (2022).

152. Marrie, R. A. *et al.* Vascular comorbidity is associated with more rapid disability progression in multiple sclerosis. *Neurology* **74**, 1041 (2010).

153. Stockwell, S. *et al.* Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. *BMJ Open Sport Exerc. Med.* **7**, e000960 (2021).

154. Sañudo, B., Fennell, C. & Sánchez-Oliver, A. J. Objectively-assessed physical activity, sedentary behavior, smartphone use, and sleep patterns pre- and during-COVID-19 quarantine in young adults from Spain. *Sustain.* **12**, 5890 (2020).

155. Greaney, M. L. *et al.* Self-reported changes in physical activity, sedentary behavior, and screen time among informal caregivers during the COVID-19 pandemic. *BMC Public Health* **21**, 1–9 (2021).

156. Vancampfort, D., Stubbs, B. & Koyanagi, A. Physical chronic conditions, multimorbidity and sedentary behavior amongst middle-aged and older adults in six low- and middle-income countries. *Int. J. Behav. Nutr. Phys. Act.* **14**, 1–13 (2017).

157. Physical inactivity a leading cause of disease and disability, warns WHO. Available at: https://www.who.int/news/item/04-04-2002-physical-inactivity-a-leading-cause-of-disease-and-disability-warns-who. (Accessed: 28th May 2022)

158. Bakker, E. A. *et al.* Dose–response association between moderate to vigorous physical activity and incident morbidity and mortality for individuals with a different cardiovascular health status: A cohort study among 142,493 adults from the Netherlands. *PLOS Med.* **18**, e1003845 (2021).

159. Ptomey, L. T. *et al.* The feasibility of remotely delivered exercise session in adults with Alzheimer disease and their caregivers. *J. Aging Phys. Act.* **27**, 670–677 (2019).

160. Boudreau, A. D. A., Kurowski, D. S., Gonzalez, W. I., Dimond, M. A. & Oreskovic, N. M. Latino families, primary care, and childhood obesity: a randomized controlled trial. *Am. J. Prev. Med.* **44**, (2013).

161. Schneider, E. M. The role of family context in moderating treatment effectiveness for an adolescent family-based health intervention. (2013).

162. Berli, C. & Scholz, U. Long-term and transfer effects of an action control intervention in overweight couples: A randomized controlled trial using text messages. *Front. Psychol.* **12**, 5434 (2021).

163. Sher, T. *et al.* The Partners for Life Program: A couples approach to cardiac risk reduction. *Fam. Process* **53**, 131 (2014).

164. Ashe, M. C. *et al.* Linked Lives: Exploring gender and sedentary behaviors in older adult couples. *J. Appl. Gerontol.* **39**, 1106–1114 (2020).

165. Harada, K., Masumoto, K. & Kondo, N. Spousal concordance for objectively measured sedentary behavior and physical activity among middle-aged and older couples. *Res. Q. Exerc. Sport* **89**, 440–449 (2018).

166. Soto, S. H. *et al.* The role of cohabitating partner and relationship characteristics on physical activity among individuals with osteoarthritis. *Int. J. Behav. Med.* **26**, 522 (2019).

167. Klaren, R. E. *et al.* Levels and rates of physical activity in older adults with multiple sclerosis. *Aging Dis.* **7**, 278 (2016).

168. Arden-Close, E. & McGrath, N. Health behaviour change interventions for couples: A systematic review. *Br. J. Health Psychol.* **22**, 215 (2017).

169. Jackson, S. E., Steptoe, A. & Wardle, J. The influence of partner's behavior on health behavior change: The english longitudinal study of ageing. *JAMA Intern. Med.* **175**, 385–392 (2015).

170. Wilson, S. E. The health capital of families: an investigation of the inter-spousal correlation in health status. *Soc. Sci. Med.* **55**, 1157–1172 (2002).

171. Homish, G. G. & Leonard, K. E. Spousal influence on general health behaviors in a community sample. *Am. J. Health Behav.* **32**, 754–763 (2008).

172. Horton, S., Macdonald, D. J., Erickson, K. & Dionigi, R. A. A qualitative investigation of exercising with MS and the impact on the spousal relationship. *Eur. Rev. Aging Phys. Act.* **12**, 1-10 (2015).

173. Hariton, E. & Locascio, J. J. Randomised controlled trials—the gold standard for effectiveness research. *BJOG* **125**, 1716 (2018).

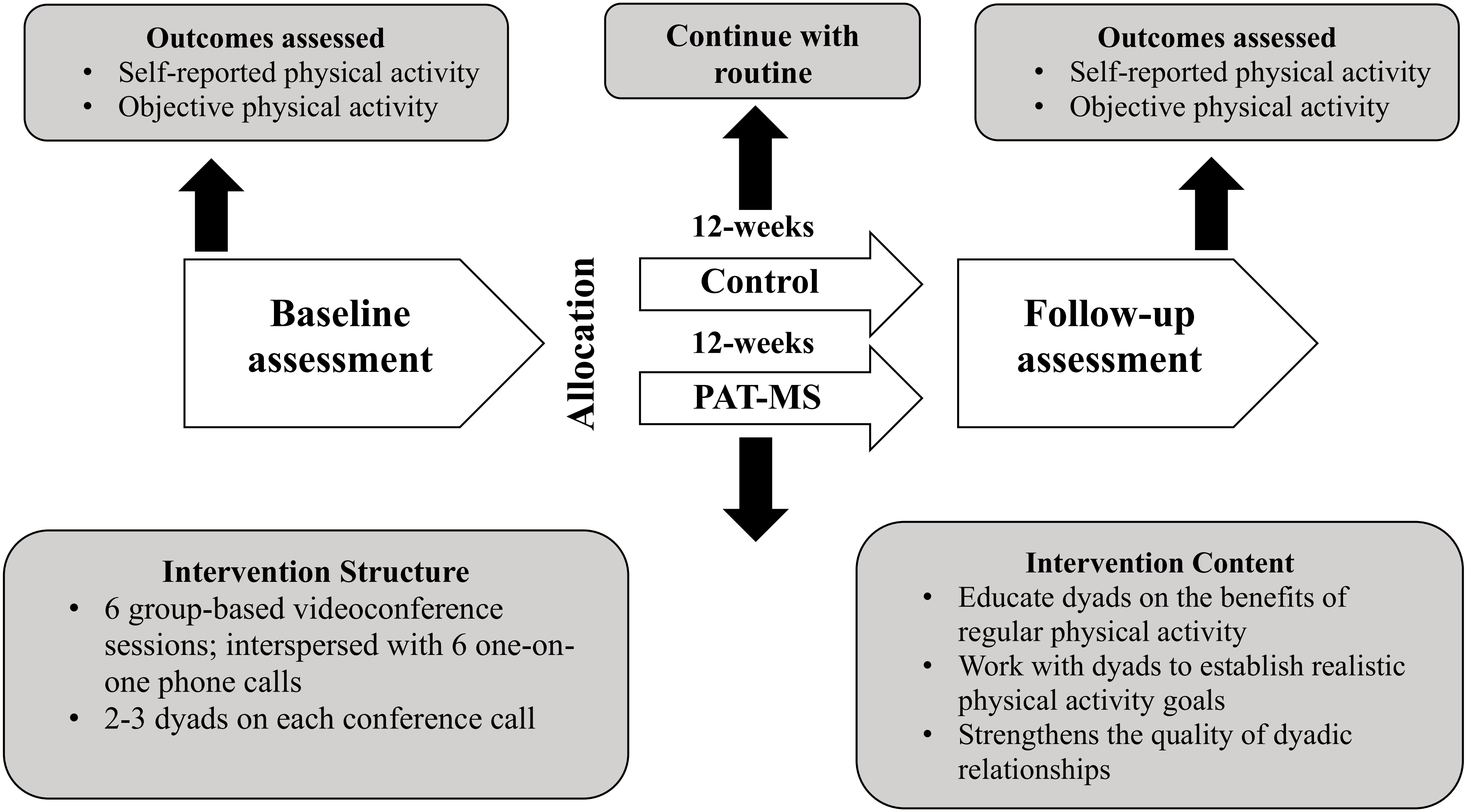


Figure 1: Study protocol.

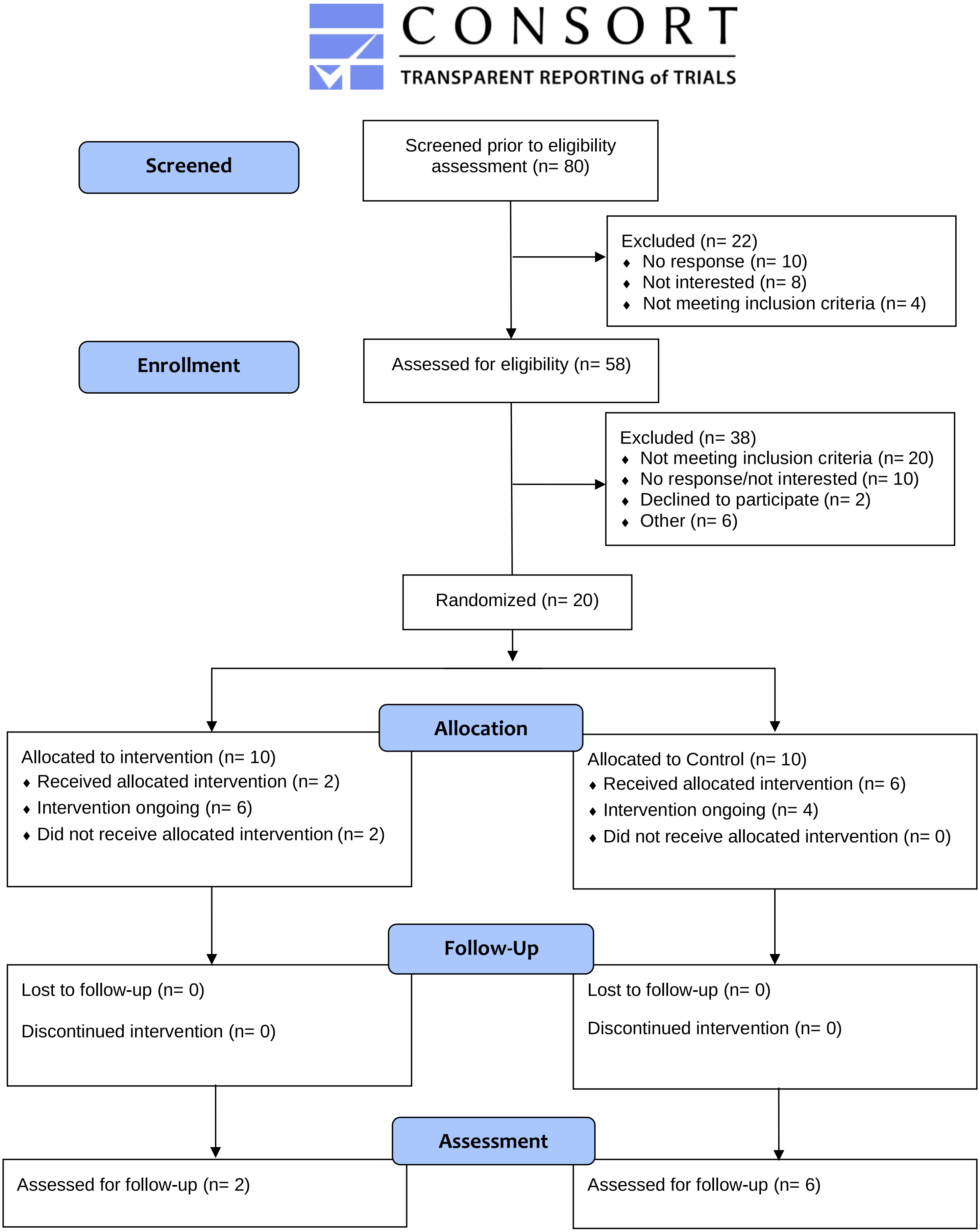


Figure 2: Flow of participants through the study.

Citation: Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. BMJ. 2016;355.

Table 1. Eligibility criteria for persons with MS and care-partners.

Inclusion criteria
1. Self-reported MS diagnosis and stable course of disease modifying therapies[†]
2. PDDS score between 3-6
3. Relapse free in the last 30 days[†]
4. Support partner who provides greater than or equal to 1.0 hour of unpaid assistance per day [†]
5. ≥18 years of age*
6. Currently inactive (i.e., purposeful exercise less than or equal to 2 days/week for 30 minutes)*
7. Asymptomatic based on the Get Active Questionnaire*
8. Able to communicate in English*
9. Access to an internet-enabled device (e.g., phone or laptop)*
10. No diagnosis of another neurological condition

[†] Applies to people with MS.
*Applies to both people with MS and care-partners.

Table 2. Characteristics of all participants at baseline (n=22). Values are reported as n (%), unless indicated otherwise.

Variable	Persons with MS (n=11)	Care-partners (n=11)
Age (years), M (SD)	53.1 (11.1)	50.1 (12.7)
Gender		
Female	8 (72.7%)	7 (63.6%)
Male	3 (27.3%)	4 (36.4%)
Height (cm), M (SD)	166.7 (7.2)	170.8 (12.6)
Weight (kg), M (SD)	85.5 (19.5)	90.9 (23.1)
PDDS, MDN (IQR)	4.0 (1.0)	-
MS course		
RRMS	8 (72.7%)	-
PPMS	3 (27.3%)	-
Disease duration (years), M (SD)	10.7 (9.7)	-
Marital status		
Single, never married	2 (18.2%)	2 (18.2%)
Married or common law	8 (72.7%)	8 (72.7%)
Separated or divorce	1 (9.1%)	1 (9.1%)
Relationship with person with MS		
Spouse/partner	-	8 (72.7%)
Child	-	1 (9.1%)
Sibling	-	1 (9.1%)
Friend	-	1 (9.1%)
Living status		
With person with MS	-	9 (81.2%)
Without person with MS	-	2 (18.2%)
Education		
Technical or trade school	0 (0.0%)	1 (9.1%)
College	7 (63.6%)	4 (36.4%)
Bachelor’s degree	2 (18.2%)	2 (18.2%)
Master’s degree	2 (18.2%)	2 (18.2%)
I’d rather not say	0 (0.0%)	2 (18.2%)
Employment Status		
Full time (40+ hours/week)	3 (27.3%)	7 (63.6%)
Unemployed (unable to work due to disability)	5 (45.5%)	0 (0.0%)
Retired	3 (27.3%)	4 (36.4%)
Paid care received (minutes/day), M (SD)	0 (0)	-
Unpaid care received (minutes/day), M (SD)	101.8 (117.6)	-
Unpaid care provided (minutes/day), M (SD)	-	254.6 (441.1)
Years providing care, M (SD)	-	6.6 (5.0)
Comorbidities reported		
Yes	10 (90.9%)	5 (45.5%)
No	1 (9.1%)	6 (54.5%)

PDDS = Patient-Determined Disease Steps scale; RRMS = Relapsing-remitting multiple sclerosis; PPMS = Primary progressive multiple sclerosis

Table 3. Self-reported and objective physical activity at baseline (n=20). Values are reported as mean (SD), unless indicated otherwise.

Variable	Persons with MS (n=10)	Care-partners (n=10)
Self-reported physical activity		
GLTEQ score	13.8 (11.8)	15.5 (17.0)
Accelerometer-measured physical activity		
ST (minutes/day)	658.2 (130.1)	577.6 (112.9)
LPA (minutes/day)	184.9 (82.4)	259.1 (56.8)
MVPA (minutes/day)	10.3 (12.3)	11.7 (10.3)
Step count (steps/day)	2937.6 (1766.5)	4614.0 (1736.3)
Percent of day spent in physical activity		
ST (%)	76.1 (10.9)	67.4 (8.6)
LPA (%)	22.8 (10.7)	31.3 (8.8)
MVPA (%)	1.2 (1.4)	1.2 (1.2)
Meeting guidelines		
ST (n, %)	1 (10.0%)	2 (20.0%)
MVPA (n, %)	2 (20.0%)	2 (20.0%)

GLTEQ = Godin Leisure-Time Exercise Questionnaire; ST = sedentary time; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity.

Table 4. Characteristics of participants included in the case study (n=10). Values are reported as n (%), unless indicated otherwise.

Variable	Intervention (n=4)	Control (n=6)
Age (years), M (SD)	51.8 (3.3)	49.2 (17.8)
Gender		
Female	4 (100.0%)	4 (33.3%)
Male	0 (0.0%)	2 (66.7%)
Height (cm), M (SD)	162.8 (7.9)	170.3 (8.5)
Weight (kg), M (SD)	77.3 (23.8)	86.3 (15.1)
Marital status		
Single, never married	0 (0.0%)	2 (33.3%)
Married or common law	2 (50.0%)	4 (66.7%)
Separated or divorce	2 (50.0%)	0 (0.0%)
Education		
College	3 (75%)	2 (33.3%)
Bachelor’s degree	1 (25%)	1 (16.7%)
Master’s degree	0 (0.0%)	1 (16.7%)
I’d rather not say	0 (0.0%)	2 (33.3%)
Employment Status		
Full time (40+ hours/week)	2 (50.0%)	2 (33.3%)
Unemployed (unable to work due to disability)	2 (50.0%)	1 (16.7)
Retired	0 (0.0%)	3 (50.0%)
Relationship*		
Spouse/partner	1 (50%)	2 (66.7%)
Child	0 (0.0%)	1 (33.3%)
Sibling	1 (50%)	0 (0.0%)
Living status		
With partner	2 (50.0%)	6 (100.0%)
Without partner	2 (50.0%)	0 (0.0%)
Care provided (minutes/day), M (SD)*	90.0 (84.9)	90.0 (30.0)
Care received (minutes/day), M (SD) †	45.0 (21.2)	220.0 (173.2)
Years providing care*, M (SD)	4.0 (1.4)	7.7 (6.7)

* Reported in care-partners only

† Reported in persons with MS only

Table 5. GLTEQ scores at baseline and 12-weeks after the intervention.

Participant	Baseline	12-Weeks	ES (within groups)
Intervention			
1	21	41	
2	0	12	
Mean (SD)	10.5 (14.8)	26.5 (20.5)	**1.08**
Control			
3	0	25	
4	9	14	
5	30	43	
6	40	12	
7	33	27	
8	40	34	
Mean (SD)	25.3 (16.8)	25.8 (11.8)	**0.03**
ES (between-groups)	**0.98**		

Odd numbers represent persons with MS and even numbers represent care-partners.

Table 6. Accelerometer-measured physical activity at baseline (pre) and 12-weeks after (post) the intervention.

	ST		**% in ST**		**LPA**		**% in LPA**		**MVPA**		**% in MVPA**		**Steps/day**	
Participants	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Intervention														
1	628	505	76.1	68.2	195	237	23.6	31.8	2	0	0.2	0.0	2547	2678
2	586	531	68.6	67.0	265	273	31.1	32.7	3	2.5	0.4	0.3	3420	3603
Mean (SD)	607.0 (29.60)	516.9 (19.6)	72.3 (5.4)	67.7 (1.0)	230.0 (49.5)	253.1 (27.9)	27.4 (5.2)	32.1 (0.8)	2.5 (0.8)	1.3 (1.7)	0.3 (0.1)	0.2 (0.2)	2983.6 (617.8)	3126.6 (673.4)
ES (within groups)	**-3.03**		**-0.87**		**0.47**		**0.90**		**-1.67**		**-1.59**		**0.23**	
Control														
3	868	679	92.7	92.4	41	54	7.1	7.4	1	1	0.3	0.2	288	327
4	675	772	70.9	80.4	249	187	27.8	19.3	12	3	0.6	0.3	3476	2140
5	613	604	71.7	67.8	210	271	24.6	30.5	32	15	3.7	1.7	5239	4439
6	606	646	68.6	70.1	247	259	27.9	28.3	31	14	3.5	1.6	6735	5486
7	634	640	71.0	72.7	229	222	25.7	25.6	30	15	3.3	1.7	4514	4124
8	630	634	74.6	78.3	196	165	20.2	20.1	19	13	2.2	1.6	4688	3398
Mean (SD)	671.0 (99.5)	662.5 (58.8)	74.9 (8.9)	76.9 (9.0)	195.3 (78.5)	193.0 (79.3)	22.7 (7.9)	21.9 (8.3)	20.7 (12.7)	10.2 (6.4)	2.3 (1.5)	1.2 (0.8)	4156.6 (2175.3)	3319.1 (1840.9)
ES (within groups)	**-0.09**		**0.23**		**-0.03**		**-0.11**		**-0.83**		**-0.72**		**-0.39**	
ES (between-groups)	**-1.26**		**-0.93**		**0.40**		**0.85**		**1.40**		**1.20**		**0.70**	

Odd numbers represent persons with MS and even numbers represent care-partners; ST = sedentary time; % in ST = percent of wear time spent in sedentary time; LPA = light physical activity; % in LPA = percent of wear time spent in light physical activity; MVPA = moderate-to-vigorous physical activity; % in MVPA = percent of wear time spent in moderate-to-vigorous physical activity.

Table 7. Correlations in physical activity levels within dyads at baseline and over 12-weeks.

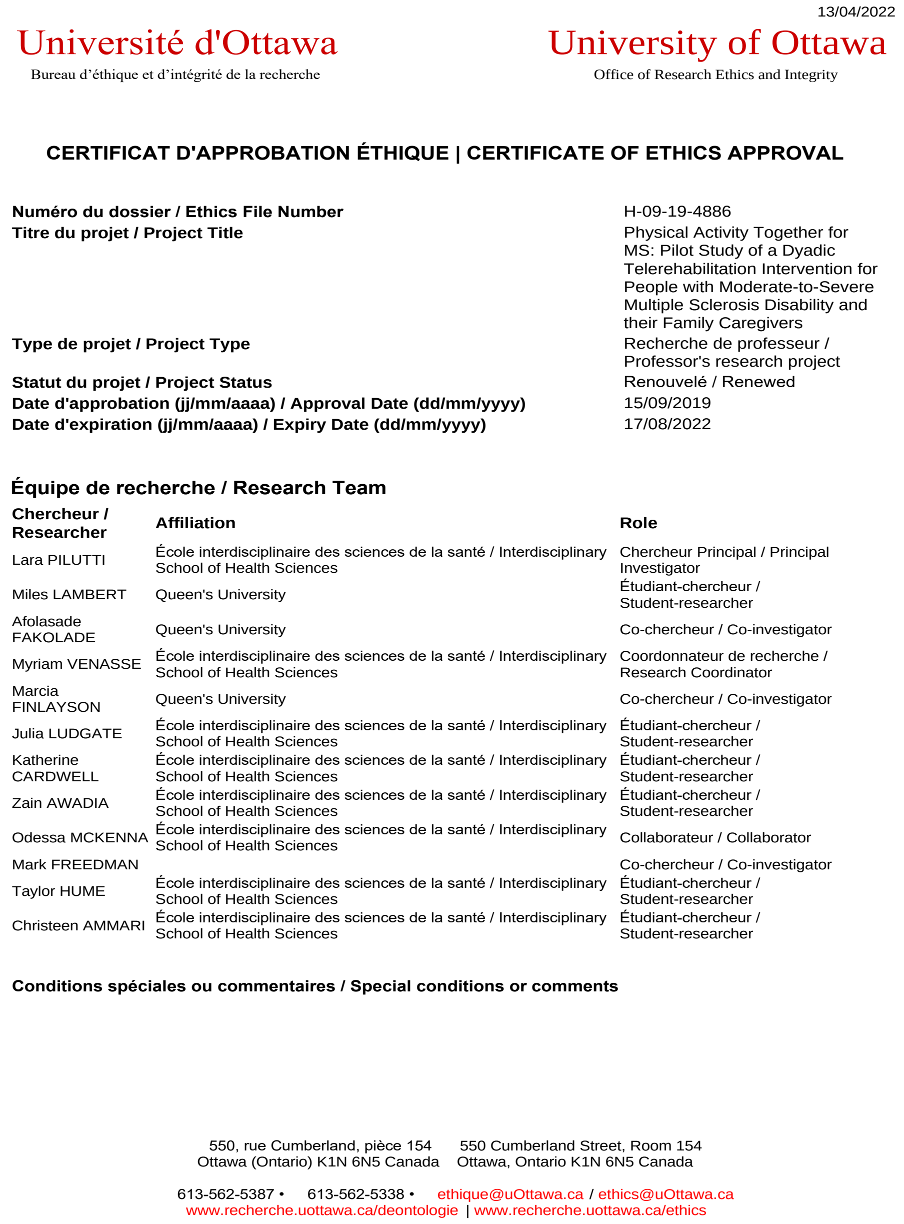
Variable	Baseline (n=20)	Δ over 12-weeks (n=8)
Self-reported physical activity		
GLTEQ	0.24	0.60
Objective physical activity		
ST	0.72	-0.40
% in ST	0.41	0.80
LPA	0.41	0.80
% in LPA	0.55	0.60
MVPA	0.13	0.40
% in MVPA	0.14	0.80
Step count	0.33	0.20

GLTEQ = Godin Leisure-Time Exercise Questionnaire; ST = sedentary time; % in ST = percent of wear time spent in sedentary time; LPA = light physical activity; % in LPA = percent of wear time spent in light physical activity; MVPA = moderate-to-vigorous physical activity; % in MVPA = percent of wear time spent in moderate-to-vigorous physical activity

Appendix 1. PAT-MS lesson plan

Table of Contents

Appendix 2. uOttawa REB Approval letter



13/04/2022

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE | CERTIFICATE OF ETHICS APPROVAL

Numéro du dossier / Ethics File Number	H-09-19-4886
Titre du projet / Project Title	Physical Activity Together for MS: Pilot Study of a Dyadic Telerehabilitation Intervention for People with Moderate-to-Severe Multiple Sclerosis Disability and their Family Caregivers
Type de projet / Project Type	Recherche de professeur / Professor's research project
Statut du projet / Project Status	Renouvelé / Renewed
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	15/09/2019
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	17/08/2022

Équipe de recherche / Research Team

Chercheur / Researcher	**Affiliation**	**Role**
Lara PILUTTI	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Chercheur Principal / Principal Investigator
Miles LAMBERT	Queen's University	Étudiant-chercheur / Student-researcher
Afolasade FAKOLADE	Queen's University	Co-chercheur / Co-investigator
Myriam VENASSE	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Coordonnateur de recherche / Research Coordinator
Marcia FINLAYSON	Queen's University	Co-chercheur / Co-investigator
Julia LUDGATE	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Étudiant-chercheur / Student-researcher
Katherine CARDWELL	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Étudiant-chercheur / Student-researcher
Zain AWADIA	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Étudiant-chercheur / Student-researcher
Odessa MCKENNA	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Collaborateur / Collaborator
Mark FREEDMAN		Co-chercheur / Co-investigator
Taylor HUME	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Étudiant-chercheur / Student-researcher
Christeen AMMARI	École interdisciplinaire des sciences de la santé / Interdisciplinary School of Health Sciences	Étudiant-chercheur / Student-researcher

Conditions spéciales ou commentaires / Special conditions or comments

550, rue Cumberland, pièce 154
Ottawa (Ontario) K1N 6N5 Canada

550 Cumberland Street, Room 154
Ottawa, Ontario K1N 6N5 Canada

613-562-5387 • 613-562-5338 • ethique@uOttawa.ca / ethics@uOttawa.ca
www.recherche.uottawa.ca/deontologie | www.recherche.uottawa.ca/ethics