Promoting Activity Behaviour in Adults with Multiple Sclerosis: Feasibility, Preliminary Efficacy and Evaluation of Activity Measurement Tools

by

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ABSTRACT

Background: Multiple sclerosis (MS) is the largest cause of non-traumatic neurological disability in young adults. Canada has one of the highest rates of MS in the world, with nearly 1 in every 385 Canadians living with the disease. People with MS deal with a broad range of symptoms including fatigue, pain, depression, cognitive impairment, imbalance, and walking disabilities. They, therefore, are less physically active and more sedentary than healthy peers. The physical activity guidelines specific to people with MS emphasize activities of moderate-intensity, however achieving moderate-intensity physical activity targets may be challenging for many individuals with MS due to associated symptoms. There is also growing evidence that prolonged sitting (sedentary behaviour) has harmful effects on health, regardless of physical activity levels in non-disabled populations. Thus, a new approach focusing on whole day activity behaviour (i.e., sedentary behaviour and light-intensity activities) may be more feasible, sustainable and beneficial to manage MS-related symptoms and function.

Objectives: To test the feasibility and preliminary efficacy of a new physical activity behaviour change intervention on reducing sedentary behaviour, and improving symptoms, quality of life, and physical performance in ambulatory adults with MS. The activity measurement tools used in the intervention have been validated with non-MS populations. To confirm the validity of the tools used, with our sample, two related validity studies were conducted.

Methods: A single-group repeated measure activity behaviour change intervention with the length of 15 weeks in addition to a 7-week follow-up period was designed. The intervention was internet-based and included two stages – 'Sit-Less' stage that focused on interrupting prolonged sitting and

'Move-More' stage that was focusing on increasing steps, improving daily activity levels and reducing overall sitting time. Forty-one persons with MS who were able to walk with or without assistive devices for at least 10 meters were included in the study. Participants attended 3 measurement sessions including pre-intervention (baseline), post-intervention (Week 15) and follow-up (Week 22). At each of these 3 data collection times, participants' activity behaviour and MS-related symptoms, quality of life and physical performance were assessed. They were set up with an ActivPAL3^{TM} to wear for 7 days at each time point. Participants also wore a Fitbit One activity tracker as a motivational and self-monitoring tool for the 15-week intervention period. A laboratory-setting concurrent criterion validity study and a free-living convergent validity study were conducted to evaluate the validity of the 2 activity monitors (ActivePAL3^{TM} and Fitbit One) used in the intervention in people with MS. An unstructured linear mixed-effects model was used to determine change in all outcomes over time. Validity of the ActivPAL3^{TM} and the Fitbit One was tested in several ways including Intraclass correlation coefficients, mean absolute percentage error, and Bland-Altman plots.

Results: There were significant reductions in total sedentary time (d=0.34) and the number of long (≥ 30 minutes) bouts of sedentary time (d=0.39) as measured by the ActivPAL3^{TM} post-intervention. All symptoms and physical performance outcomes improved significantly after the intervention except cognition ($P < 0.05$). Those changes were maintained during the 7-week follow-up, except for sedentary behaviour and sleep quality. The ActivPAL3^{TM} demonstrated validity evidence as a measurement tool for sedentary behaviour (sitting time), standing time and steps (ICC: 0.98). The Fitbit one demonstrated validity evidence (ICC: 0.88) for measurement of steps. There was good agreement between steps recorded by Fitbit One and ActivPAL3^{TM} (ICC:

0.86). On average, the Fitbit One was worn for 85 days (i.e., 85% of the full intervention period) showing that participants were willing to monitor their activity behaviour over a long period and indicated the feasibility of wearing the Fitbit activity tracker in interventions that focus on sedentary behaviour and/or physical activity in the MS population.

Conclusion: This research provides preliminary support for the efficacy of a whole day physical activity behaviour change intervention focused on reducing sitting and increasing light intensity activity for improving outcomes in adults with MS.

PREFACE

This thesis is an original work by Golnoush Mehrabani. Three out of 4 clinical studies in this thesis were part of the larger study called "SitLess with MS" led by Dr. Patricia Manns. The "SitLess with MS" study received research ethics approval from the University of Alberta Health Research Ethics Board, project name "Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?", No. Pro00067657, April 6, 2017. The "SitLess with MS" study also received operational approval from the Northern Alberta Clinical Trials and Research Centre, and the Alberta Health Services Edmonton Zone (operational approval for recruitment through the Northern Alberta MS Clinic).

The study on Chapter 3 was designed by myself, with the assistance of Dr. Saeideh Aminian and Dr. Patricia Manns which received research ethics approval from the University of Alberta Health Research Ethics Board, project name "Validity of ActivPAL3^{TM} and Fitbit One activity monitors in adults with multiple sclerosis in a laboratory setting" No. Pro00067657_AME2, June 14, 2017.

For all studies in this thesis, I was responsible for data collection, data cleaning, data analysis and manuscript preparation with assistance in all aspects from my supervisor Dr. Patricia Manns, my committee member Dr. Doug Gross and Dr. Saeideh Aminian. The data collection, data cleaning and analysis in chapters 2, 3, 4 and 5 and the design of the study in chapter 3 are my original work, as well as the literature review in chapter 1.

Chapter 2 of this thesis has been submitted as Golnoush Mehrabani, Saeideh Aminian, Sarah Norton, Robert W. Motl, and Patricia J. Manns. "Preliminary Efficacy of the "SitLess with

MS" Intervention for Changing Sedentary Behaviour, Symptoms, and Physical Performance in Multiple Sclerosis" and is currently under review in the Disability and Rehabilitation Journal.

Chapter 3 was submitted as Golnoush Mehrabani, Saeideh Aminian, Douglas P. Gross and Patricia J. Manns. "Validity of ActivPAL3™ and Fitbit One activity monitors in adults with multiple sclerosis in a laboratory setting" to the Journal of Medical Engineering and Physics. The paper was rejected with the suggestion to change to a technical report. The deadline for submitting the new manuscript is March 31st.

Chapter 4 was submitted as Golnoush Mehrabani, Douglas P. Gross, Saeideh Aminian, and Patricia J. Manns. "Comparison of Fitbit One and ActivPAL3™ in adults with multiple sclerosis in a free-living environment" to the Journal for the Measurement of Physical Behaviour. After the first review, minor revisions were required and the deadline for submitting the revised manuscript is March 31st.

Dr. Patricia Manns is the supervisory author in all the papers and was involved in concept formation and manuscript edits.

DEDICATION

To Mahnaz, Davoud, Golshid, My grandmother Parvin and Steve

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The introduction and literature review chapter is presented in sections focused on topics related to multiple sclerosis (MS), activity behaviour of persons with MS and its association with health outcomes, and methods for measurement of activity behaviour and their psychometric properties. The information in this chapter provides rationale for the research questions.

1.1 Multiple sclerosis

Multiple sclerosis is a chronic autoimmune inflammatory disease of the central nervous system (CNS), characterized by intermittent and recurrent episodes of inflammation that result in demyelination and consequent damage of the axons in the brain, optic nerve, and spinal cord.[1,2] The exact etiology and particular mechanisms of the MS disease are not known.[3] However, current knowledge suggests that MS comprises an autoimmune process in which the immune system attacks itself against the myelin sheath (i.e., the protective layer surrounding the neural cells) of the CNS axons.[4] Existence of the myelin sheath is essential to carry the electrical signals through a neuron and among neural cells.[5] When the myelin is damaged, it is replaced by hardened scar tissue and the electrical impulses are not conveyed efficiently.[5] The slow or altered conduction of electrical signals has a disrupting influence on almost every physical, sensory, mental, and emotional activity.[5] Early in the disease process, remyelination may take place to repair the damaged myelin sheath but as the disease progresses and the myelin sheath damage increases, there is a significant reduction in the remyelination process.[6]

1.1.1 Epidemiology

MS is the largest cause of non-traumatic neurological disability in young adults.[7] Statistics indicate that 2.5 million individuals live with MS worldwide.[8] The median prevalence of MS is 33 per 100,000 individuals globally with immense variance among different countries.[9] Canada has one of the highest prevalence of MS in the world (260 per 100,000 individuals), with approximately 77,000 Canadians (1 in every 385 Canadians) living with the disease.[10] On average, 11 Canadians are diagnosed with MS every day.[10]

Women are 3 times more likely than men to develop MS.[10] The disease can occur at any age; however, initial symptoms usually emerge during early adulthood, typically between the ages of 20 and 49.[10] The chronic progressive nature of the disease can lead to significant life changes.[11] The reported average survival following an MS diagnosis is 38 years.[11] With the use of disease-modifying therapies, lifespan has substantially increased over the past few decades among individuals with MS.[12] Indeed, approximately 90% of adults with MS live to 70 years of age or older.[12]

1.1.2 Etiology

Although the exact cause of MS is unknown, genetic and environmental factors both appear to impact an individual's susceptibility to developing the disease.[13] MS is not considered a genetic disorder, however, there are many genetic factors that appear to play a role to increase the risk of developing the disease. Research shows that 15-20% of persons with MS have a family history of MS.[14] The risk of developing MS in the general population is about 0.1% while the risk for a child with one parent who has MS is almost 2%.[15] For identical twins, studies show that if one twin has

MS, the risk of developing MS in the other is 30%.[16] These findings support the role of genetics in developing MS since relatives of the affected individuals are more likely to develop MS.

Evidence indicates that MS prevalence is strongly correlated with latitudinal gradient (i.e., farther north, greater prevalence). Latitude is significantly linked to ultraviolet light exposure, which is the main stimulant of cutaneous vitamin D production.[17,18] As expected, the prevalence of MS is greater in more northern countries such as Canada, United States, Norway, Denmark, Sweden and Finland[18] presumably due to the lower ultraviolet radiation and low sun exposure.[19,20] Moving from one geographical region to another also appears to affect the risk of developing MS.[21] Migration studies demonstrate that immigrants tend to obtain the risk level of the region to which they move, nevertheless, the risk is mediated by the age at the time of moving.[21] People who move in early childhood have the same risk level as the native population, however, for persons who move later in life this change in risk level may not appear until the next generation.[21] For example, if an individual moves to Canada from a Middle Eastern country before puberty, they will adapt the risk level of Canada for developing MS the same as a native Canadian.

In addition, higher levels of vitamin D probably have a protective role in susceptible patients[20] as lower rate of MS relapse has been reported in patients with higher serum levels of vitamin D.[19,20] These findings provide support for the theory that early exposure to an environmental factor in genetically susceptible individuals affects the risk of developing MS.

1.1.3 Clinical course in MS

Prior to receiving a diagnosis of MS, individuals may experience Clinically Isolated Syndrome (CIS), defined as one acute or subacute neurological episode that lasts at least 24 hours, with or without recovery, and in the absence of fever or infection.[22] CIS is caused by inflammation or demyelination of the neural cells in CNS and can be either monofocal or multifocal.[22] In a monofocal episode, a single neurologic sign or symptom such as optic neuritis develops which is caused by a single lesion. In a multifocal episode, more than one sign or symptom such as optic neuritis and tingling in the legs is experienced by the individual which are caused by lesions in more than one place.[22] Therefore, CIS can be a single symptom or combination of a few symptoms depending on the location of the lesion(s) but it is only one clinical episode.[22] The conversion rate of CIS to clinically definite MS which is characterised by 1 of the 3 courses (relapsing-remitting MS (RRMS), secondary progressive MS (SPMS), and primary progressive MS (PPMS) is 48.1% at 10 years.[23]

At diagnosis, eighty-five percent of individuals with MS have relapsing-remitting MS.[24,25] A relapse is described as new or recurrent neurologic symptoms which are not associated with fever or infection lasting for at least 24 hours and accompanied by new neurologic signs confirmed by the neurologist.[22] Relapses may last for weeks to months and be followed by relative or complete remission for months to years without disease activity.[9,24] The longer the duration of the disease, it is more probable the relapses leave sequela during the remission phase.[13,26]

Approximately 80% of individuals with RRMS transition into SPMS in 20 years[27,28] which is described as progressive neurologic deterioration in the course of the disease between relapses

without any definite duration of remission.[26,29] Sometimes minor remissions can take place while the occasional relapses exit.[24]

Ten to 15% of individuals with MS are diagnosed with PPMS.[25,30] There is no remission after the first relapse and the progression of neurologic deficits from the beginning is the main characteristic of PPMS.[24,30] However, very minimal and occasional remissions may occur.[24,30] The common age for onset of the PPMS is older than RRMS and is more similar to SPMS (i.e., 40 years or older)[30]. In the relapsing-remitting and secondary progressive forms, women are usually affected two to three times more than men while in PPMS, the numbers of women and men are almost equal.[30]

Awareness of the clinical course of MS provides the opportunity to predict the prognosis and the future course of the disease. It also guides treatment decisions.

1.1.4 Clinical features of MS

Axonal demyelination, transection and loss of the neural cells in the brain and spinal cord over time result in the clinical manifestations of MS.[1] The symptoms experienced by individuals with MS vary significantly depending on the location and size of the CNS lesions.[1,31] For instance, lesions in the frontal and parietal lobes of the brain usually lead to cognitive and emotional impairments, while lesions in the cerebrum, brain stem, and spinal cord result in impairment of the physical function of the extremities.[32] Despite great variability in symptom presentation among individuals with MS, some symptoms are considered hallmark symptoms and are seen more frequently.[5,33] The most common symptoms independent of the clinical course of the disease are fatigue, with a prevalence of 58%, spasticity (47.5%), voiding disorders (44%), ataxia/tremor

(36%), pain (34%), cognitive impairments (33%), and depression (32.5%).[33] Fatigue is the most frequently reported symptom in individuals with RRMS (58%) while spasticity is the most prevalent symptom in persons with SPMS (82%) and PPMS (74%).[33]

The neurodegenerative and progressive nature of MS leads to the accumulation of impairments and dysfunctions in a majority of patients with MS.[34] Based on previous studies, 40% to 50% of persons with MS require walking assistance after 15 years of disease onset due to mobility impairments.[26,35] The great range of impairments result in lower health-related quality of life not only than healthy individuals, [36] but also when compared with patients of other chronic autoimmune and non-autoimmune disorders.[37] The impairments and disabilities also limit daily functioning and participation in physical activities.[38–41]

1.2 Physical activity

Physical activity is defined as body movements produced by skeletal muscle contractions resulting in an increase in energy expenditure of > 1.5 metabolic equivalents (METs).[42] One MET is the oxygen consumed during rest and is equal to 3.5 ml O_2 per kilogram body weight per minute (ml/kg/min).[43] Physical activity is categorized according to the energy expenditure during the activity including light-intensity (1.6-2.9 METs), moderate-intensity (3-5.9 METs) and vigorous-intensity (≥ 6 METs).[44,45] Physical activity can be also subdivided into exercise activities (the regular and structured performance of moderate-to-vigorous intensity physical activity) and non-exercise activities (I.e. light-intensity activities include activities of daily living such as fidgeting, or slow walking).[42]

The 2020 World Health Organization Guidelines for Physical Activity recommend that healthy adults participate in at least 150 to 300 minutes of moderate-intensity aerobic physical activity, or 75 to 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate-and-vigorous intensity aerobic activity.[46] Adults should also perform muscle-strengthening activities of at least moderate-intensity two or more days per week to gain optimal health benefits.[46] These guidelines have been recognized as applicable in patients with disability and chronic diseases, including patients with MS.[46]

1.2.1 Physical activity in adults with multiple sclerosis

Virtually every individual can benefit from regular physical activity participation as it leads to the decreases in the risk of more than 25 chronic health conditions such as overweight and obesity, depression, cancers, hypertension, hyperlipidemia, type 2 diabetes, cardiovascular diseases, and premature mortality.[47] In addition to these benefits, physical activity is associated with reduction in rates of MS relapses and worsening of MS symptoms and slowed disability progression over time.[48–51] Physical activity, therefore, has been suggested as a symptomatic and disease-modifying treatment at the early stages of the disease.[52] Despite the evidence, physical activity levels are significantly reduced in persons with MS.[41,53] The symptoms of MS such as fatigue, pain or depression in addition to disability accumulation represent the primary explanation for low levels of physical activity in the MS population.[54] These manifestations make it difficult for patients with MS to achieve or maintain the recommended amount of moderate-to-vigorous intensity physical activity.[55–57]

Motl et al.,[58] used a self-report measure of physical activity and reported that patients with MS are 2.5 times more likely to report insufficient physical activity (defined by the score of less

than 14 from the Godin-Shephard Leisure-Time Physical Activity Questionnaire[59]) and 2.3 times less likely to report sufficient physical activity levels for health benefits compared with the healthy control group. They found that approximately 60% of individuals with MS are insufficiently active compared to 23% of healthy controls.[58] Another study by Klaren and colleagues with the use of an activity monitor for measurement of physical activity levels reported a significant difference in the rate of meeting physical activity health guidelines among the MS population and the healthy controls.[60] Only 20% of the patients with MS met the physical activity guidelines while the rate of meeting guidelines was 47% in the healthy controls.[60] Partly as a result of the low levels of reported physical activity in those with MS, a set of physical activity recommendations specific to individuals with MS has been developed.[61] According to the Canadian physical activity guidelines for special populations, adults with MS should engage in a minimum of 30 minutes of moderate-intensity aerobic activity twice a week and resistance training activities including all major muscle groups 2 days per week to gain optimal health benefits.[61]

There is a strong association between levels of physical activity and level of disability in people with MS.[62] Individuals with more severe mobility impairment engage in less physical activity and are less likely to meet physical activity guideline' recommendations.[63,64]

Moreover, the manifestations of MS[65] in addition to mobility disabling consequences[65] and concurrent comorbidities such as hypertension, hypercholesterolemia, coronary heart disease, and obesity, which are prevalent and troublesome in patients with MS,[66] may predispose sedentary behaviour in the MS population.

1.3 Sedentary behaviour in adults with multiple sclerosis

Sedentary behaviour refers to any waking activity characterized by an energy expenditure of ≤ 1.5 METs in a sitting or reclining posture.[67] Sedentary behaviour is usually described as a total daily volume (e.g., min/day of sitting), but it can be additionally expressed based on its pattern and distribution (i.e., number of sedentary breaks per day, number of daily prolonged sedentary bouts and average duration of daily sedentary bouts).[68] A break in sedentary behaviour is defined as a point in time where there is a change from a sedentary behaviour to a non-sedentary behaviour.[68] A sedentary bout is a minimum uninterrupted period of sitting, reclining or lying.[68] Furthermore, a prolonged sedentary bout is a sedentary bout with a duration > 30 minutes.[68]

People with MS spend a large amount of time in sedentary behaviour.[65,68,69] A study by Sasaki et al. which assessed the self-reported daily sitting time illustrated that North American adults with MS reported twice as much time sitting (8 hours/day) as the general population of North Americans (4 hours/day).[70] The results showed that participants with moderate or severe disability but ambulatory, or severe disability but non-ambulatory were 1.57, 2.62, and 8.70 times more likely, respectively, to sit excessively (above the 75th percentile of sitting time) than those with mild disability.[70]

Ezeugwu and colleagues assessed objectively-derived patterns of sedentary and physical activity behaviours in people with MS.[68] Patients without mobility disability (Patient Determined Disease Steps score < 3) spent 60% of their daily waking hours (8.4 hours) sedentary while those with mobility disability spent 65% of waking time (8.9 hours) sedentary.[68] They found that higher levels of disability are associated with greater sedentary time and a greater average number of prolonged sedentary bouts (≥ 30 minutes).[68] Their findings were consistent with a study by

Hubbard et al., that included an objective measurement of sedentary behaviour and found a significant correlation between the disability status and sedentary time in patients with MS.[71] The results of these 2 studies[68,71] with use of devices for measurement of sedentary behaviour were in agreement with the findings of Sasaki et al.[70]

1.3.1 Sedentary behaviour and health outcomes

In general, there is a consistent link between high levels of sedentary behaviour and increased morbidity and mortality in epidemiological studies.[72–77] A strong association between high levels of sedentary time with larger waist circumference, greater probability of overweight or obesity, higher triglycerides and lower HDL-cholesterol levels, higher amount of C-reactive protein, fasting plasma glucose and insulin resistance have also been found.[72–74] Decrease in protective factors such as HDL-cholesterol and increase in the cardiometabolic risk factors (e.g., triglyceride and fasting plasma glucose) leads to higher prevalence of hypertension, hyperlipidaemia, type 2 diabetes, cardiovascular diseases, cancers and cardiovascular mortality in sedentary individuals.[75–78] These associations are independent of physical activity levels[75,79] and sedentary behaviour is considered an additional and separate detrimental factor to the negative effects of low levels of physical activity on health.[80]

In addition to the negative effects of sedentary behaviour on cardiometabolic health,[78,81,82] a recent systematic review[81] supporting the new Canadian 24-hour movement guidelines[83] demonstrates an association between high levels of sedentary time with cognitive function, fatigue, disability, depression, physical activity levels and physical health-related quality of life in healthy adults. Fatigue, depression and cognitive impairments are amongst the most common symptoms of MS[33] and, based on the results of the systematic review,[81] large amounts of sedentary time in

people with MS worsens those symptoms over time in addition to all other negative health consequences.[68,71,84,85] There is also some evidence regarding the detrimental effects of sedentary behaviour on health outcomes among persons with MS such as increase in blood pressure.[86] Moreover, sedentary behaviour is negatively associated with disability status,[68,71,84] function,[85] walking endurance and walking speed[71] in the MS population. However, there is a lack of research on the consequences of high sedentary time on the risk of cardiovascular disease, cancer, diabetes and mortality in the MS population.[87]

Despite the significant impact of the total amount of daily sedentary time on health, the pattern of accumulation of sedentary behaviour throughout the day is also important.[73,88] Evidence indicates that fewer breaks in daily sedentary time, longer durations of uninterrupted sedentary bouts and more long sitting bouts (≥ 30 min) are negatively associated with several cardiometabolic biomarkers including body mass index, waist circumference, HDL cholesterol, triglycerides, blood pressure, 2-hour postprandial glucose and fasting plasma glucose in adults.[89–91] Nevertheless, it is unknown whether the rates or patterns of sedentary behaviour predict the physical or mental health outcomes and/or quality of life in the MS population. Putting all together, a new approach focusing on reduction of sedentary time and promoting activity level in individuals with MS is needed.

1.3.2 Light-intensity physical activity and its association with sedentary behaviour

The results of the National Health and Nutrition Examination Survey showed that adults spent an average of 7.7 hours daily in sedentary behaviour, 7.8 hours in light-intensity physical activities, 0.2 hours in moderate-to-vigorous intensity physical activities and 8.3 hours in sleep.[92]

Moderate-to-vigorous intensity physical activities make up a very small portion of an individual's waking hours (3-6%)[93] and thus focus has broadened to light-intensity physical activities.

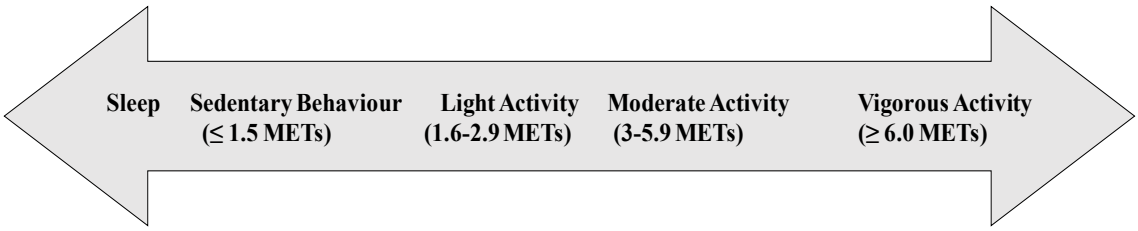

Figure 1-1: Activity Continuum

Figure adapted from Canadian 24-Hour Movement Guidelines: Glossary of Terms at https://csep.ca/CMFiles/Guidelines/24hrGlines/24HourGuidelinesGlossary_2017.pdf

METs: Metabolic equivalent.

Light-intensity activities (non-exercise physical activity) include activities such as standing, slow walking, washing dishes, and other routine domestic or occupational tasks.[94] Evidence indicates that when sedentary time is reduced, it is typically replaced by light-intensity physical activity and not moderate-to-vigorous physical activity.[93] These non-exercise physical activities (light intensity activities), constitute a large portion (30%-40%) of an individual's daily activities[95] and are the main determining factor of variability in total daily energy expenditure.[96]

A recent systematic review which included 72 studies showed that higher levels of light-intensity physical activity were associated with adults' cardiometabolic health and decrease mortality risk in non-disabled populations.[97] Dunstan et al. reported that breaking up periods of prolonged sitting with 2-min bouts of light-intensity activity each 20-minutes led to a 24% reduction in postprandial glucose and a 23% decrease in insulin resistance in comparison with uninterrupted sitting in obese and overweight individuals.[98] Another study by Healy and colleagues

illustrated that increased breaks in sedentary time lasting at least 1 minute, led to a significant decrease in the levels of triglycerides and 2-hour plasma glucose, BMI, and waist circumference independent of total sedentary time.[99] These studies provide a better understanding of how adults' metabolic health is related to the pattern of accumulation of physical activity behaviour throughout the day.[98–100] Since the evidence suggests that interrupting sedentary time with light-intensity activities such as walking with even a relatively short duration (e.g. 1 minute) is associated with benefits to metabolic health, activity guidelines advise to regularly break up sedentary time.[90,99,101–103]

It is therefore important to consider all activity behaviours across the energy expenditure spectrum (Figure 1-1), and not only focus on the least frequently performed activity behaviour (moderate-to-vigorous intensity physical activity) in spite of the greatest health benefits through moderate-to-vigorous intensity physical activity.[104] Based on previous research, sedentary behaviour and light-intensity physical activity play an important role in maintaining health since they make up 93-96 % of the total daily activity behaviours during waking hours.

Sedentary behaviour is considered a health-behaviour target on the non-exercise end of the activity continuum for promoting activity level since it comprises a large volume of an individual's daily waking hours.[105] Consequently, reducing time spent in sedentary behaviour and increasing light-intensity physical activity might be a more feasible and accessible behavioural change approach to promote physical activity in patients with disability such as persons with MS. It is probably more feasible to interrupt sedentary time with short breaks of light-intensity activity such as standing or slow walking across various settings, including home or workplace. Strategies to break up sitting include getting up during television advertisements or taking short breaks during prolonged periods of sitting at work.[99] Frequent breaks in the sitting time with activities as minimal

as standing lead to significant increases in total daily energy expenditure and battle fat gain.[106,107] However, to date, no research has explored an approach that mainly incorporates decreasing prolonged sitting, (i.e., breaking up sitting) and increasing light intensity activities (i.e., frequently standing or walking) in the MS population.[87]

1.3.3 Interventions to reduce sedentary behaviour in non-disabled individuals

Older adults are one of the main groups with the greatest amount of time spent on sedentary behaviour[108–110] and therefore, are more predisposed to negative impacts of prolonged sitting on their health.

One of the first sedentary behaviour interventions was conducted by Gardiner et al.[111] who examined the feasibility of an acute 1-week intervention to reduce overall sedentary time in older adults. The effect of the intervention on total daily sedentary time, light-intensity and moderate-to-vigorous-intensity physical activities were evaluated using ActiGraph.[111] The main intervention message was to stand up and move after 30 minutes of uninterrupted sitting.[111] There was a significant reduction (- 3.2%) in total daily sedentary time and a significant increase in the number of breaks in sedentary time (4 more breaks per day) and the time spent on light-intensity (2.2%) and moderate-to-vigorous intensity physical activities (4.6%) at post-intervention.[111] The results supported the feasibility, safety, and positive effects of an intervention mainly targeting reduction in sedentary behaviour and this work provided the foundation for subsequent sedentary behaviour interventions with longer duration and more complex research designs.

A recent systematic review assessed the feasibility, safety and effectiveness of the interventions focusing on reducing sedentary behaviour in non-working older adults.[112] A total of 6 studies were included, 3 of which incorporated control groups, whereas the other three were repeated-measures pre-post designs.[112] There was no follow-up in the included studies indicating lack of evidence regarding the sustainability of the intervention effect. Three of the included studies used self-report measure of sedentary behavior and the other three studies used accelerometers for measurement of sedentary time. The intervention duration varied from 2 to 8 weeks with a mean of 5.5 weeks.[112] The results demonstrated that those interventions were feasible and safe and had the potential to decrease sitting time.[112] They found between 3.2 % to 5.3% reduction (up to 53.9 minutes reduction per day) in objectively measured daily sedentary time following the intervention.[112] A recent review also evaluated 15 sedentary behaviour intervention studies in adults.[113] Most interventions (n = 12) were implemented in the workplace, two in the neighbourhood environment and one in an education institution setting.[113] Nine out of 15 studies included a randomised control trial design.[113] Two studies used self-report, nine studies used objective measures, and four used a combination of objective and self-report measures of sedentary behaviour.[113] The results showed a significant reduction in total daily sedentary behaviour, including total sitting time, work sitting time and leisure sitting time in more than 50% of the included studies (n = 9) in adults.[113] On average, there was an 8 to 122 minutes per day reduction in total sedentary behaviour across studies.[113]

In relation to the effects of sedentary behaviour on cardiometabolic health, a systematic review by Saunders et al. which included 25 intervention studies, assessed the effect of long sitting bouts on cardiometabolic risk in healthy adults.[100] They found that uninterrupted sedentary behaviour led to moderate and detrimental changes in insulin sensitivity, glucose tolerance, and

plasma triglyceride levels and increases in metabolic risk.[100] Another recent systematic review and meta-analysis evaluated the effects of interventions targeting reductions in sedentary behaviour only or combined with increases in physical activity on cardiometabolic biomarkers in adults and the elderly.[114] Small significant beneficial effects on weight, waist circumference, percentage body fat, systolic blood pressure, insulin, and high-density lipoprotein cholesterol were reported.[114]

All the above studies demonstrate the feasibility and effectiveness of interventions with a primary focus on reducing sedentary behaviour on increasing daily activity levels and improving health outcomes.

1.3.4 Interventions to measure and reduce sedentary behaviour in MS population

To date, only one sedentary behaviour intervention study specific to patients with MS with mild to moderate disability has been conducted.[115] Klaren et al. designed a 6-month internet-based behavioural change intervention including startegies according to social cognitive theory constructs for behaviour change and assessed sedentary behaviour by a self-reported questionnaire before and after the intervention. No follow-up measurement was done to determine whether the results are sustainable over time.[115] Participants who received the intervention showed a significant reduction in total daily sitting time[115] which is promising. However, although sedentary behaviour was the main outcome of the study[115], the use of a self-report measure of sedentary time which is limited by issues such as memory recall, social desirability and underestimation,[116,117] and differences between the intervention and the control groups in reported sedentary time at baseline limited the conclusions drawn from the study.[115]

Education (i.e., providing information regarding the beneficial and/or detrimental effect of a behaviour on health), behavioural change strategies using social cognitive theory and exercise prescription are the most common methods used in the design of interventions with focus on promoting physical activity levels in people with MS.[118–120] In addition, social cognitive theory is the most frequently used behavioural change strategy for understanding, modifying, and promoting physical activity behaviour in person with MS[120] which might be the reason for use of this theory in the design of the first sedentary behaviour intervention in people with MS.[115] Social cognitive theory consists of four main constructs including self-efficacy, outcome expectations, goal setting, and perceived barriers and facilitators.[121] Self-efficacy refers to the level of an individual's confidence in their ability to successfully perform or change a behavior.[121] Outcome expectations refers to the expected costs and benefits and predicted consequences of an individual's behavior and may or may not be health-related.[121] Goal setting refers to setting realistic, measurable and achievable goals to ensure success from beginning.[121] Understanding, perceived barriers and facilitators, and how to overcome or utilize them to change behaviour is the final part of social cognitive theory. [121]

Social cognitive theory constructs have been studied in young, middle-aged and older adults with MS,[122–126] and significant associations between those constructs and physical activity behaviour were observed. Furthermore, a recent study by Motl et al. showed that both self-reported and device-measured sedentary behaviour is correlated with self-efficacy, goal setting, planning and perceived barriers for reducing sedentary behavior.[127] All those constructs except goal setting independently explained 33 % of variance in self-reported sedentary behaviour[127] while only self-efficacy independently explained 10% of variance in device-measured sedentary behavior.[127]

Therefore, social cognitive theory constructs might be reasonable and modifiable targets for decreasing sedentary behavior in people with MS following activity behavior interventions.

Another recent study[128] examined the feasibility and initial efficacy of a 3-month behaviour change intervention on activity behaviour outcomes and levels of fatigue and pain in adults with MS. The intervention was comprised of a handbook and four one-on-one face-to-face physical activity sessions with participants, along with the usual care services.[129] The handbook included effective methods for prompting physical activity levels that were draw from several behaviour change theories and did not focus on a particular behaviour change theory.[129] They used the ActivPAL for the measurement of sedentary behaviour.[128] Despite the objective measurement of sedentary behaviour, the intervention primarily focused on increasing physical activity levels and largely did not focus on reducing sedentary behaviour. [129] There was a decrease in sedentary time in both groups post-intervention, but no significant difference in the total daily sedentary time was found between groups.[128] Moreover, fatigue and pain were the only MS symptoms that were tested before and after the intervention.[128]

To date, no research has focused on the design and evaluation of an intervention that primarily targets reduction of daily sedentary time and increasing light intensity activities during the day in the MS population. There is also no research on the effectiveness of a sedentary behaviour intervention on activity behaviour change, and on several common MS symptoms such as fatigue, depression, anxiety, and cognitive impairment in persons with MS. Therefore, a new activity behaviour change intervention with the main focus on reducing sedentary time and evaluation of the changes in sedentary and activity behaviours, MS symptoms and physical function is required. However, accurate measurement of sedentary behaviour and physical activity

is essential to identify current activity levels and to allow assessment of the effectiveness of activity interventions.

1.4 Measurement of physical activity behaviour

A first step to changing a behaviour is to understand that behaviour. In order to understand an activity behaviour, it has to be measured accurately; self-report and/or observation. Self-report assessment relies on the individuals' ability to recall the activities that they were engaged in during the last few days, few weeks or even a few months.[130,131] Questionnaires, surveys, diaries and logbooks are self-reported tools that can be used to measure physical activity and sedentary behaviour.[116,130] Questionnaires are the most frequently used example of the self-report assessment.[132]They contain a number of selected items with the intention to standardize the collection of specific information about facts or opinions of an individual.[132] For example, sedentary behaviour consists of various activities in different domains.[133] By self-report measurement of sedentary time, categorization into particular behaviours such as TV viewing time or specific domains including work, domestic or transportation is feasible.[134] Furthermore, self-report assessment is suitable for measuring the activity levels of a large sample size as it is inexpensive and easy to use. Nevertheless, it may be influenced by overestimation and difficulties with memory recall.[116,117]

On the other hand, objective measurement (observational measurement) relies on information generated through direct observation or from activity monitors.[135,136] Although self-report assessment provides researchers useful information, observed measurement appears more accurate.[131] Accelerometry and pedometry are the most commonly used measurement tools, yielding outcomes such as activity counts, sitting time and steps taken. [136–140] Accelerometers are

typically consumer-grade such as Fitbit[141,142] or research-grade such as ActivPAL3™.[143,144] Research-grade accelerometers are generally more expensive, more accurate, and not utilised by the public.[143,144] However, consumer-grade accelerometers are increasingly used by people because of their accessibility and lower price.[141,142]

When researchers decide to measure sedentary behaviour, they have to consider the measurement method with the ability to assess the frequency, duration, and volume of the exposure with minimal bias.[132] Objective measurement of sedentary behaviour is more accurate[131] and provides information regarding the overall sedentary time, the number of interruptions in sedentary time known as breaks and the number of sedentary bouts across a day.[134]

1.4.1 Objective measurement of activity behaviour

Accelerometry is the most frequently used objective measurement tool.[135,139] Accelerometers are motion sensors that detect and measure the accelerations of body movements.[135] They have the ability to estimate the duration and intensity of movements. Movement counts are the summation of accelerations during a specific period and demonstrate a quantitative measurement related to the intensity of participants' movements.[135]

1.4.1.1 Research-grade Accelerometers

There are many different research-grade accelerometers, but two of the most frequently used ones are the ActiGraph and the ActivPAL.

ActiGraph

The ActiGraph activity monitor (ActiGraph, Pensacola, FL, USA) is a lightweight (27 g),

compact (3.8×3.7×1.8 cm) triaxial accelerometer with a rechargeable lithium-polymer battery.[145] It collects motion data on 3 axes and measures the frequency and amplitude of accelerations of the body segment it is attached to.[146] The ActiGraph uses a proprietary filtering algorithm to convert accelerations to activity counts per minute. They are then reported in specific time intervals or epochs, usually 1-minute epochs.[146] Activity counts per minute are stored in the ActiGraph's memory and the data can be downloaded and processed using ActiLife software. The activity count reflects the energy cost of physical activity.[145] The device is able to provide information regarding the different levels of activity including sedentary behaviour, light and moderate-to-vigorous intensity physical activity levels, according to the specified cut points, with sedentary behaviour being <100 counts per minute.[146] The device is worn on the hip attached by an elastic belt during waking hours and is a valid and reliable measure of physical activity.[44]

Distinguishing between sitting and standing is an important component of understanding and quantifying sedentary behaviour.[147] The ActiGraph does not distinguish postures (i.e. sitting versus standing) and in case of the lack of movement, such as standing still (a stationary, non-sedentary behaviour), counts may go below 100 counts per minute leading to misclassification of behaviour.[148] This limits the use of the ActiGraph for the measurement of sedentary behaviour.

ActivPAL3™

The ActivPAL^{3TM} (PAL Technologies Ltd, Glasgow, UK) is a light and small (3.5 cm × 5.3 cm × 0.7 cm; 15 gr) triaxial activity monitor that measures accelerations of the thigh at a sampling frequency of 20 Hz.[149] The device has an in-built inclinometer to determine posture based on the thigh inclination [149,150] and summarizes data in 15-second intervals (epochs) over a 24-hour period. The ActivPAL provides output for body postures (lying/sitting, standing, and stepping) by use of the proprietary algorithm in the manufacturer-provided software. In general, the

ActivPAL^{3TM} measures time spent on sedentary behaviour (sitting or lying), upright positions (standing and walking), numbers of sit-to-stand and stand-to-sit transitions, and step counts.[149] The ActivPAL^{3TM} monitor is attached to the midline of the anterior aspect of the thigh by waterproof non-allergic adhesive pads (3M Tegaderm ^{TM}).[147]

Accelerometers worn on the thigh such as the ActivPAL3^{TM} have a greater ability to differentiate between standing (thigh vertical) and sitting (thigh horizontal) in comparison with the waist- or wrist-worn accelerometers such as ActiGraphs.[147] The ActivPAL3^{TM} monitor has previously shown excellent ability to measure sitting and upright times, number of postural transitions and step counts in healthy adults,[151,152] people with disability such as patients with stroke,[153] and the elderly.[153] There is also evidence regarding the validity of the ActivPAL3^{TM} for measuring upright time and step counts in people with MS with moderate disability in a laboratory-setting.[154] Nevertheless, no research on the validity of the ActivPAL3^{TM} for measurement of upright time and step counts has been conducted in persons with MS with mild disability.

Sedentary behaviour has been measured in previous studies with the MS population. However, self-report measurements that might lead to underestimation of total daily sedentary time [65,70] and objective measurements including ActiGraph which is not able to differentiate between standing and sitting have been utilized. [68] Although evidence suggests that the ActivPAL may be the gold standard for measuring sedentary time,[131,148] to date, no study has examined the validity of the ActivPAL3^{TM} in assessing sedentary behaviour in individuals with MS. Therefore, sedentary behaviour has not been accurately measured as currently defined in previous studies in the MS population.[65,68,70]

1.4.1.2 Consumer-grade Accelerometers

There are numerous consumer-grade wearable activity monitors on the market. Many of which have been tested with those with disabilities, including those with MS. Fitbit devices are amongst the most popular and user-friendly ones. Low cost, interface capabilities, ease of use, and wide commercial availability of these activity trackers have attracted the attention of researchers and clinicians to monitor their patients' physical activity by providing remote access to patient-generated data.[155] The device provides the opportunity for the patients to monitor their daily physical activity and can be synchronized to smartphones and computers to generate immediate feedback. These activity trackers, thus, can encourage individuals to promote their activity levels by increasing the daily number of steps taken as a surrogate for physical activity.

Recently, a secondary analysis of randomized controlled trials evaluated the influence of using a consumer-grade activity tracker on daily sedentary time and prolonged sedentary bouts.[156] The changes in sedentary time and prolonged sedentary bouts were not significantly different between the intervention and control groups. However, increases in step counts were associated with decreases in sedentary time and prolonged sedentary bouts, regardless of intervention.[156] They reported that the use of a consumer-grade activity tracker on a daily basis may indirectly prevent an increase in sedentary behaviour by increasing daily steps- a surrogate of light-intensity physical activities. Another recent study found that using consumer-grade activity trackers interrupts workplace sedentary behaviour.[157] Participants were asked to stand at least once every 30 minutes throughout the workday. The purpose of the study was to find out whether standing once every 30 minutes was a feasible strategy for reducing workplace sedentary behaviour.[157] These results showed that using an activity tracker is effective for recording and tracking

interruptions in sitting time.[157] These studies[156,157] confirm that using a consumer-grade activity tracker for monitoring daily activity levels will help with increasing physical activity levels and indirectly reducing sedentary behaviour.

Older individuals and people with mobility disability may especially benefit from the utilization of activity monitors since they tend to be less physically active and more sedentary than healthy younger populations.[70,158,159] Many patients with MS have walking disability, and use assistive devices [160–162] and as a result, have slower walking speed than the non-disabled peers. The majority of people who have MS do walk – and despite the use of walking aids or walking slowly – walking is still the most likely way they will get physical activity. Therefore, an activity tracker that can precisely record steps even at slower walking speeds[163,164] may be beneficial for both health professionals and patients with MS to monitor walking activity goals. A laboratory-setting study by Balto et al.[165] reported the Fitbit One (Fitbit Inc, San Francisco, CA, USA) as the most accurate and precise device in comparison with other consumer-grade activity monitors for measuring steps in ambulatory adults with MS. Nevertheless, there was no criterion measure used in their study.

Fitbit

The Fitbit activity tracker (Fitbit One, Canada) is a small and light device (0.5 cm x 2.03 cm x 5.58 cm; 8.5 gr) that records the steps, stairs climbed, sleep, and calories expended. It has a 5-day battery life and is synchronized to computers and smartphones. It is a relatively affordable device that can provide instant feedback on either the device itself or via simple software accessed via the internet. The device summarizes data in 60-second intervals (epochs). The Fitbit activity trackers are attached to the waistline and ankle with a clip and a flexible band, respectively. Waist

attachment is in accordance with the manufacturers' guidelines. Earlier studies demonstrated the validity of the Fitbit One for measuring step counts in healthy adults[166], the elderly[164,167] and patients admitted in rehabilitation wards[163] in a laboratory setting. Furthermore, there is evidence regarding the validity of the Fitbit One for measurement of steps in healthy adults,[144,168] female adults,[169] men with prostate cancer[170] and stroke survivors[171] in free-living environments. However, different gait patterns including frequent bilateral gait deficits and/or slower walking[172] in individuals with MS as compared to non-disabled people or patients with stroke can impact the activity tracker accuracy. Moreover, the use of walking aid (e.g., cane, or walker) is also prevalent in people with MS which probably influences the accuracy of the activity tracker. Therefore, it will be useful if the Fitbit be a valid instrument for self-monitoring of daily steps in both laboratory-setting and the free-living environment in patients with MS. To date, no study has assessed the criterion and/or convergent validity of the Fitbit One activity tracker in measuring steps in the MS population.

1.4.1.3 Feasibility of the use of consumer-grade activity trackers in people with disability

Adherence to wearing an activity tracker is important in order to reap the potential benefits of increasing awareness of activity behaviour through monitoring. For example, a systematic review conducted by Bravata et al. found that consistent use of a pedometer activity tracker is associated with 26.9 % higher levels of physical activity.[159] The use of pedometers significantly increased the physical activity levels by 2491 and 2183 steps per day in randomized control trials and observational studies, respectively.[159] Another study by Hartman et al. using the Fitbit One activity tracker with breast cancer survivors illustrated a significant increase in the moderate-to-vigorous physical activity level in favour of the intervention group.[173] Vandelanotte et al.

conducted a study to examine the effect of a 12-week web-based physical activity intervention on the physical activity behaviour recorded by a Fitbit activity tracker in Australian adults.[174] A significant increase in the total weekly physical activity level recorded by the Fitbit was reported.[174] Hultquist et al.[175] reported that sedentary women who were given a pedometer and were instructed to walk 10,000 steps a day, took approximately 2,000 more steps per day than women who were only instructed to walk briskly for 30 minutes every day. Based on all these studies,[159,173–175] the use of an activity tracker such as a Fitbit that constantly records and displays the real-time physical activity level and provides instant feedback may increase awareness and help to reduce inactivity.[176,177]

A study conducted with 248 ambulatory adults with MS who were asked to wear the Fitbit One over a 23-day study period showed an average of 20 days of wearing the device and a mean of 4,393 steps per day.[178] At the end of the study, the adherence rate of the participants for using the Fitbit One was 87%, and 68% of participants reported the device useful for self-management of activity behaviour.[178] Therefore, their results[178] showed that it is feasible to integrate these technologies with the everyday life of individuals with MS in order to measure and increase physical activity levels and improve MS symptoms and health-related quality of life. Nevertheless, it is unknown whether it is feasible to use a consumer-grade activity monitor such as the Fitbit One over a longer period such as a few months.

Feasibility studies are "an overarching concept for studies assessing whether a future study, project or development can be done".[179] They also help researchers to find out whether some components of the main study can and/or should be done, and, if so, how it could/should be conducted.[180] Feasibility studies play a significant role in the preliminary planning of a complex intervention with a randomized clinical trial (RCT) design and are also used to help making

decisions on the outcome measures (e.g., a consumer-grade activity tracker) used in the intervention.[181] Conducting a feasibility study is, therefore, the first step with the purpose of determining whether a full intervention will be feasible to perform and if all the essential components of an intervention such as outcome measures will work properly together.[181]

The evidence indicates that four main feasibility metrics including process (e.g., recruitment), resources (e.g., monetary costs), management (e.g., personnel time requirements) and scientific outcomes (e.g., clinical/participant objective or reported outcome measures) required to be assessed before conducting an intervention.[182] A scoping systematic review showed that one major limitation of prior research on activity interventions in MS is the lack of systematic feasibility testing (i.e., of the processes, resources, management and scientific outcomes of clinical trials) before conducting the intervention.[182] It may lead to not achieving efficacy or effectiveness for changing the target outcome and consequently, misinterpretation of the intervention results.[182] Thus, researchers must conduct feasibility studies as the first step before designing an intervention study and selecting the outcome measures.

1.5 Thesis Objectives and hypotheses

The main objectives of this project were to:

1) Explore the preliminary efficacy of an intervention targeting reducing daily sedentary behaviour and increasing light-intensity activities on physical activity behaviour, symptoms and physical performance outcomes in persons with MS. The related hypothesis was that a new activity behaviour change intervention with focus on reducing daily sedentary behaviour and increasing light-intensity activities decreases daily sedentary time,

increases light-intensity activities and improves symptoms and physical performance in persons with MS;

2) Evaluate the concurrent criterion validity of the ActivPAL3^{TM} activity monitor to measure sedentary time and step counts against direct observation, and the concurrent criterion validity of the Fitbit One activity tracker in detecting step counts against direct observation in patients with MS in a laboratory setting. The related hypothesis was that a) the ActivPAL3^{TM} activity monitor is a valid tool to measure sedentary time and step counts against direct observation in patients with MS in a laboratory setting and b) the Fitbit One activity tracker is a valid tool in detecting step counts against direct observation in patients with MS in a laboratory setting;
3) Examine the convergent validity of the Fitbit activity tracker and the ActivPAL3^{TM} activity monitor for measurement of step count in a free-living environment in patients with MS; The related hypothesis was that there is a strong association (convergent validity) between steps recorded by the Fitbit One activity tracker and the research-grade ActivPAL3^{TM} activity monitor in a free-living environment in patients with MS.
4) Test the feasibility of the use of a Fitbit activity tracker in patients with MS over a long period. The related hypothesis was that It is feasible to use a consumer-grade activity tracker such as the Fitbit One to monitor daily activity behaviour over a few months in patients with MS.

1.6 Structure of the Dissertation

A comprehensive literature review on activity behaviour in individuals with MS and its measurement, interventions to reduce daily sedentary behaviour in persons with MS and the gap in the literature is provided in chapter 1. Chapter 2 addresses the primary objective of the dissertation and evaluates the preliminary efficacy of a new activity behaviour change intervention on reducing daily sedentary behaviour, increasing light intensity activities, and improving symptoms and physical performance in adults with MS. Chapter 3 contains a concurrent criterion validity study assessing the validity of the Fitbit One activity tracker and the ActivPAL3^{TM} activity monitor as compared to direct observation (reference standard) in a laboratory setting which addresses the second objective of the dissertation. Chapter 4 addresses the third objective of the dissertation, a study examining the convergent validity of the Fitbit One activity tracker and the ActivPAL3^{TM} activity monitor in a free-living environment in adults with MS. Chapter 5 addresses the fourth objective and discusses the feasibility of the use of the Fitbit One activity tracker to monitor daily activity behaviour over a few months in patients with MS. Chapter 6, the final chapter, summarizes the contributions and clinical implications of this research and provides recommendations for future research.

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CHAPTER 2. Preliminary Efficacy of the "SitLess with MS" Intervention for Changing Sedentary Behaviour, Symptoms, and Physical Performance in Multiple Sclerosis

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Abstract

Background: People with multiple sclerosis (MS) engage in more sedentary behaviour than healthy peers, and this might contribute towards worse symptoms, function, and quality of life (QOL).

Purpose: We examined the preliminary efficacy of an intervention that focuses on sitting less and moving more for changing sedentary behaviour outcomes, symptoms, QOL, and physical performance in adults with MS.

Methods: Persons with mild-to-moderate MS disability took part in a 15-week pre-post trial. Sedentary behaviour, symptoms, QOL, and physical performance were measured pre-post intervention and at follow-up. An unstructured linear mixed-effects model determined change over time per outcome.

Results: Forty-one persons with MS participated (age 50±10.3 years). There were significant reductions in total sedentary time (d=0.34) and the number of long (≥ 30 minutes) bouts of sedentary time (d=0.39) post-intervention. Fatigue, depression, anxiety, sleep quality, total pain, QOL, gait speed, walking endurance and function improved significantly after the intervention ($P < 0.05$). There was no significant change in cognition. Those changes were maintained during the 7-week follow-up, except for sedentary behaviour and sleep quality.

Conclusions: This study provides preliminary support for the efficacy of an intervention focused on reducing sitting and increasing light intensity activity for improving outcomes in adults with MS.

Keywords: Multiple sclerosis, sedentary behaviour, MS-related symptoms, physical performance, activity behaviour change, ActivPAL

2.1 Introduction

The provision of exercise training is recognized as a symptomatic and disease-modifying treatment during the early stages of MS [1]. Exercise training has yielded improvements in function, symptoms, and quality of life (QOL) in persons with MS, and has been associated with the reduction in rates of MS relapses and disability progression over time [1,2]. To date, only 1 in 5 persons with MS participate in sufficient amounts of moderate-to-vigorous intensity physical activity (MVPA) necessary for health benefits [3]. Current interventions and programs focusing on exercise training as a form of physical activity are not changing population levels of physical activity in MS [4].

There has been recent interest in sedentary behaviour among persons with MS, as persons with this disease spend a large proportion of the day sitting [5,6]. There is consistent evidence of a link between high levels of sedentary behaviour and increased morbidity (e.g. obesity, cardiovascular disease, diabetes and colon, endometrium and lung cancers) and mortality in epidemiological studies [7–9]. Recently, a comprehensive review of sedentary behaviour literature by the United States Physical Activity Guidelines Advisory Committee (PAGAC) [10] reported a strong dose-response relationship between sedentary behaviour and both all-cause mortality and cardiovascular disease mortality in adults and the elderly. These associations are independent of physical activity levels [11,12]. A recent systematic review [13] supporting the new Canadian 24-hour movement guidelines [14] demonstrated an association between high levels of sedentary time with cognitive function, disability, depression, physical activity levels and physical health-related quality of life in healthy adults. In addition, the evidence indicates the substantial association between sedentary behaviour and disability status [5,15,16], walking endurance [15], walking speed [15], function [17] and blood-pressure outcomes [18] in individuals with MS.

The growing body of evidence documenting the negative outcomes of too much sitting overall and in MS supports a new approach for activity promotion. A focus on decreasing sedentary behaviour may be more feasible than focusing on increasing MVPA levels in those with disability [9,19] such as persons with MS. Nevertheless, sedentary behaviour interventions have been infrequently studied in the MS population [20].

To date, two studies have tested behavioural interventions for reducing sedentary behaviour in people with MS. One study reported a significant reduction in self-reported sedentary time following a 6-month internet-based behavioural intervention based on the social cognitive theory [21]. The study was limited by the inclusion of a self-report measure of sedentary time, and differences between the intervention and control group in reported sedentary time at baseline [21]. Another study examined the feasibility and initial efficacy of a 3-month behaviour change intervention on the levels of fatigue, pain and objectively measured activity behaviour immediately and 6-months post-intervention [22]. No difference in the total daily sedentary time was observed between the intervention and control groups [22]. Not primarily and explicitly focusing on the reduction of sedentary behaviour and more focus on the increase of physical activity levels in the intervention group might be responsible for no difference in sedentary behaviour outcomes between groups following the intervention.

To date, there is little information on interventions that focus on reducing sedentary behaviour and secondary improvements in symptoms and physical performance in the MS population. Therefore, we evaluated the preliminary efficacy of a sedentary behaviour intervention on sedentary behaviour, symptoms and physical performance outcomes immediately post-intervention and 7-weeks post-intervention.

2.2 Material and Methods

2.2.1 Study Design

The protocol for the "SitLess with MS" study has been published [23]. The study involved a single group, repeated measures design, and was approved by the Health Research Ethics Board of the University of Alberta (# Pro000667657), the Northern Alberta Clinical Trials and Research Centre, and the Alberta Health Services Edmonton Zone (operational approval for recruitment through the Northern Alberta MS Clinic). We have further published a manuscript describing the feasibility outcomes (process and management, and progression criteria) of the intervention [24]. This paper focuses on efficacy outcomes.

2.2.2 Intervention

Briefly, the 15-week intervention included behavioural change strategies based on principles from social cognitive theory including self-monitoring, goal setting, and self-efficacy for sedentary behaviour change [23]. The intervention encompassed two 7-week stages (SitLess and MoveMore), with an interim week between stages which allowed for interim activity measurement. The SitLess stage focused on interrupting prolonged sitting and the MoveMore stage was focusing on maintaining reduction in overall sitting time and replacing it with light-intensity physical activity during the day. The intervention was internet-based and included weekly coaching sessions with an intervention coach and the participant (excluding Weeks 0 and 15). The individual coaching sessions were used to expedite knowledge translation and strategies for activity behaviour change and to help accountability and compliance with the intervention [23]. A newsletter designed according to the core determinants of social cognitive theory (i.e., self-efficacy, goal setting, facilitators, and barriers) accompanied each coaching session [23].

2.2.3 Participants and Recruitment

Participants were recruited through community programs and the Northern Alberta MS Clinic at the University of Alberta as detailed in the protocol paper [23]. Participants were included based on the following criteria: (1) diagnosis of MS confirmed by a neurologist; (2) one-year post-diagnosis; (3) age ≥ 18 years old; (4) mild or moderate neurological disability (defined by Expanded Disability Status Scale (EDSS) score of 1-6.5) [25]; (5) relapse-free within the previous 3 months; (6) stable use of disease-modifying drugs and rehabilitation over the previous 6 months; (7) physically inactive (defined as insufficiently active by a score of less than 14 from the Godin-Shephard Leisure-Time Physical Activity Questionnaire) [26]; (8) able to walk 10 meters with or without a walking aid; and (9) mobile phone access. The sample size target was in accordance with previous activity behaviour interventions with persons with MS and stroke populations [27–30].

2.2.4 Study Procedures

There were 3 measurement points including pre-intervention (baseline), post-intervention (Week 15) and follow-up (Week 22) (see figure 2-1 for the timeline of study activities). At each measurement point, we assessed sedentary behaviour, symptoms (fatigue, depression, anxiety, pain, sleep quality, cognitive impairment and QOL), and physical performance based on gait speed, walking endurance, lower extremity strength and function. Participants wore an ActivPAL3^{TM} (PAL Technologies Ltd, Glasgow, UK) for 7 days without removal at each measurement point. An ActivPAL log was given to each participant to record wake and bedtimes, and any instances that they removed the device for any reason. After completion of 7 full days of monitoring, participants mailed the monitor to the research team.

A Fitbit One was given to each participant at the baseline measurement session and they were asked to wear it daily during waking hours, throughout the 15-week intervention.

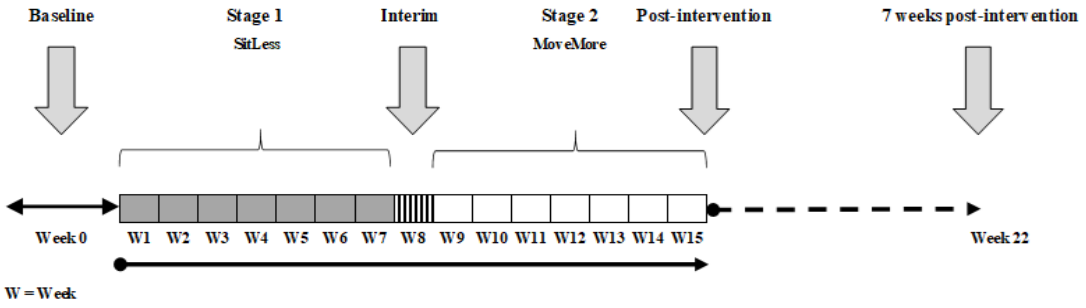

Figure 2-1: Timeline of the "SitLess with MS" intervention program.

The figure is redrawn based on the figure from P.J. Manns, G. Mehrabani, S. Norton, S. Aminian, R.W. Motl, The SitLess With MS Program: Intervention Feasibility and Change in Sedentary Behavior, Arch. Rehabil. Res. Clin. Transl. (2020) 100083.

2.2.5 Measures

Data on sociodemographic characteristics were collected at baseline. MS-related characteristics (i.e., type and duration), anthropometric measures, and disability status were collected at all 3-time points.

2.2.5.1 Symptoms and physical performance

Symptoms, QOL, and physical performance outcome measurements are provided in table 2-1. The full description of each outcome measure and its psychometric properties is provided in the protocol paper [23].

Table 2-1: Measures of symptoms, quality of life, and physical performance in adults with MS

Variable	Measure	Score
Disability Status	Clinician-measured Expanded Disability Status Scale,	Total score: 0 - 10
	Self-reported Patient Determined Disease Steps Scale	Total score: 0 - 8
Fatigue	Self-reported Fatigue Severity Scale	Total score: 1 - 7
	Self-reported Modified Fatigue Impact Scale	Total score: 0 - 84
Depression	Self-reported Hospital Anxiety and Depression Scale	Depression subscale total score: 0 - 21
Anxiety	Self-reported Hospital Anxiety and Depression Scale	Anxiety subscale total score: 0 - 21
Pain	Self-reported Short-form McGill Pain Questionnaire	Total pain score: 0 - 45
Sleep problems	Self-reported Pittsburgh Sleep Quality Index	Total score: 0 - 21
Cognition	Performance-based Symbol Digit Modalities Test	Total score: Depending on age and education status
Quality of Life	Self-reported Medical Outcomes Study Short-Form Health Survey	Subs cores and Total score
Gait-speed	Clinician-measured 10-meter Walk Test	Total score: meters/seconds
Walking Endurance	Clinician-measured 6-minute Walk Test	Total score: meters
Function	Clinician-measured Short Physical Performance Battery Test	Total score: 0 - 12

2.2.5.2 Sedentary Behaviour

Sedentary behaviour was objectively measured by the ActivPAL3^{TM}. The ActivPAL3^{TM} provides output about body postures (lying/sitting, standing, and stepping) by use of the proprietary algorithm in the manufacturer-provided software [31,32]. It reports time spent in sedentary behaviour (sitting or lying), time spent in upright positions (standing and walking), numbers of sit-to-stand and stand-to-sit transitions, and step counts [31]. The ActivPAL3^{TM} monitor has excellent validity in measuring sedentary and upright time and the number of postural transitions in healthy adults [33], people with disability, and the elderly [34]. Three main sedentary behaviour outcomes were collected from the ActivPAL3^{TM} including average total sedentary time per day (minutes), average number of daily breaks in sedentary time (sit-to-stand transitions) and the average number of prolonged sedentary bouts ≥ 30 minutes per day. The ActivPAL3^{TM} monitor was attached to the midline of the anterior aspect of each participant's stronger thigh by waterproof non-allergic adhesive pads (3M Tegaderm^{TM}, 3M Company, Canada).

ActivPAL3^{TM} data for each participant was downloaded to a computer for analysis in Excel spreadsheet (Microsoft Corporation) in 15-second epochs during a 24-hour day, using Professional Research Edition software (PAL Software Suite Version 8). Participants who wore the ActivPAL3^{TM} for at least 5 valid days at each time point were included in the analysis. A valid day was defined as a day where the ActivPAL3^{TM} reported movement (standing or stepping) for at least 6 hours during wake time [35]. Wake and bedtimes were determined using the Chastin method [36], with a few adjustments. Wake time was defined as the first standing event after a long continuous period ≥ 2.5 hours of non-upright posture. Bedtime was defined by the last standing event before a long continuous period ≥ 3 hours of non-upright posture. Standing or stepping with a duration of ≥ 15 minutes occurring before 1:00 AM and

after a sedentary bout of ≥ 2.5 hours was classified as waking time [37]. Wear time was calculated as bedtime minus wake time. Logs were reviewed for verification after preliminary wake and bedtimes were determined using the event files. Once event files were prepared with documented wake and bedtimes, the R package version 3.6.1 (PAactivpal) [38] was used to determine sedentary outcomes.

2.2.6 Data analysis

Descriptive statistics (mean, SD) were used to describe the participants, sedentary behaviour outcomes, symptoms and physical performance at pre-intervention, immediate post-intervention and follow-up. Linear mixed-effects models were used to determine whether sedentary behaviour outcomes, symptoms and physical performance outcomes changed over time (from pre-intervention (Week 0) vs immediate post-intervention (Week 15) vs follow-up (Week 22)). An unstructured variance-covariance structure (ie., each time point was assumed to have its variance) was used. Mixed-effects models were used because they are more rigorous in the analysis of repeated measure designs compared to conventional methods such as repeated measures analysis of variance [39]. The fixed-effect part of the model included the outcome variable adjusted for the participants' age and sex (known covariates of activity behaviour) [40]. Pairwise comparisons with Bonferroni corrections were used to compare differences. Effect sizes were calculated using Cohen's d (d) and were interpreted as small (0.20), medium (0.50) or large (0.80). All analysis was conducted in SPSS software version 24 (IBM SPSS Statistics for Windows, Version 24.0; Armonk, NY: IBM Corp) at a significance level of $P < 0.05$.

2.3 Results

Forty-one persons with MS participated. Participants had mild to moderate disability and ranged in age from 31-72 years with a mean age of 50 ± 10.3 years. Ninety percent of participants were female. Twenty-six (63.4%) of participants had relapsing-remitting MS and average disease duration was 14.3 ± 11.3 years. Participant characteristics are provided in table 2-2. Of the 41 participants who were enrolled at baseline, 39 completed the program and post-intervention assessment, and 36 completed the follow-up assessment. The flow of participants and reasons for loss to post- intervention and follow-up has been displayed in the feasibility paper [24].

Table 2-2: Participant characteristics

Characteristics	N (%) or Mean (SD)	Range
Age (Years old)		31-72
< 40	7 (17.07%)	
40 ≤ age < 65	28 (68.2%)	
≥ 65	6 (14.6)	
Clinician measured disability status		1.5-6.5
Mild disability (EDSS < 4)	18 (43.9%)	
Moderate disability (4 ≤ EDSS ≤ 6.5)	23 (56.1%)	
Self-reported measure disability status		0-6
No disability (PDDS = 0)	2 (4.8%)	
Mild disability (PDDS < 3)	10 (24.3%)	
Moderate disability (3 ≤ PDDS ≤ 6)	29 (70.7%)	
Disease duration (Years)		1-50
< 5	8 (19.5%)	
5-10	10 (24.4%)	
11-20	15 (36.6%)	
>20	8 (19.5%)	
Use of walking Aid		
None	18 (43.9%)	
Single Cane	6 (14.6%)	
Double Cane	6 (14.6%)	
Walker	9 (22.0%)	
Quad Cane	2 (4.9%)	
Weight (Kilograms)	77.5 (19.1)	45-122
Height (Metres)	1.6 (0.07)	1.5-1.8
BMI (Kilograms/metres^2)		17.2-44.3
BMI< 25	17 (41.4%)	
25 ≤ BMI < 30	7 (17.07%)	
BMI ≥ 30	17 (41.4%)	
Education		
High school or less	10 (24.4%)	
College/Diploma	15 (36.6%)	
Bachelors	11 (26.8%)	
Masters	5 (12.2%)	

EDSS: Expanded Disability Status Scale; PDDS: Patients Determined Disease Steps Scale; BMI: Body Mass Index.

Forty, 37 and 30 participants had valid ActivPAL data at baseline, post-intervention and follow-up, respectively. The average total daily sedentary time, total number of breaks in sedentary time and total number of long sedentary bouts (≥ 30 minutes) per day were 626.4 minutes (69% of daily wake time), 54.6 per day and 5.8 bouts at baseline, respectively. There was a significant reduction in total daily sedentary time and total number of long sedentary bouts ≥ 30 minutes per day from baseline to immediate post-intervention (table 2-3). Levels of fatigue, depression, anxiety, sleep quality, total pain, QOL, gait speed, walking endurance and function improved from baseline to immediate post-intervention (tables 2-4 and 2-5). There was no significant change in cognition and the total number of sedentary breaks per day (tables 2-3 and 2-4). The changes that occurred from baseline to immediate post-intervention were sustained at follow-up (i.e., there was no change from immediate post to follow-up) for the majority of the outcomes except for sleep quality and sedentary behaviour outcomes (tables 2-3, 2-4 and 2-5). The effect sizes per outcome are provided in table 2-6. The largest effect size was observed for depression (d=0.79), followed by fatigue (d=0.63) and anxiety (d=0.55).

Table 2-3: Change in sedentary behaviour outcomes across three time points

Variable	B (Week 0) N = 40		PI (Week 15) N = 37		PI - B N = 37		FU (Week 22) N = 30		FU - B N = 30		FU - PI N = 30	
	Mean	SD	Mean	SD	MD (95%CI)	p	Mean	SD	MD (95%CI)	p	MD (95%CI)	p
Total sedentary minutes per day from [a]ActivPAL	626.41	141.59	577.93	131.60	-38.11 (-73.12, -3.10)	0.034	596.53	145.90	-30.52 (-73.88, 12.83)	0.162	7.59 (-25.00,40.19)	0.637
Total number of breaks per day from [a]ActivPAL	54.59	19.31	55.84	20.58	0.309 (-3.46, 4.08)	0.869	54.12	21.28	-0.492 (-4.59, 3.56)	0.817	-0.801 (-4.97, 3.37)	0.698
Total number of sedentary bouts ≥ 30 minute per day from [a]ActivPAL	5.81	2.13	4.98	1.86	-0.702 (-1.26, -0.14)	0.015	5.38	2.33	-0.338 (-1.02, 0.34)	0.324	0.364 (-0.15, 0.88)	0.161
Wake time (minutes per day)	907.80	79.20	887.40	75	-17.22 (-40.62, 6.24)	0.145	913.80	53.40	-1.02 (-24.66, 22.62)	0.931	16.02 (-5.82, 38.16)	0.144

B: Baseline; PI: Post-intervention; FU: Follow-up; p: Level of significance, N: Number of participants; MD: Mean difference; CI: Confidence interval.

Table 2-4: Change in symptoms and quality of life across three time points

Variables	B (Week 0)		PI (Week 15)		PI - B		FU (Week 22)		FU – B		FU - PI	
					N = 39				N = 36		N = 36	
	Mean	SD	Mean	SD	MD (95%CI)	p	Mean	SD	MD (95%CI)	p	MD (95%CI)	p
FSS Score	5.49	1.23	4.62	1.29	-0.84 (-1.14, -0.55)	0.000	4.86	1.63	-0.57 (-0.85, -0.29)	0.000	0.27 (-0.06, 0.61)	0.114
MFIS Total Score	47.66	15.43	38.03	15.17	-9.33 (-13.56, -5.11)	0.000	38.17	15.45	-8.01 (-11.95, -4.06)	0.000	1.32 (-2.29, 4.94)	0.463
Depression	7.07	4.20	4.08	3.00	-2.91 (-4.13, -1.70)	0.000	4.64	3.25	-2.23 (-3.41, -1.05)	0.000	0.68 (0.01, 1.35)	0.047
Anxiety	8.32	4.75	5.77	4.22	-2.48 (-3.64, -1.31)	0.000	6.50	4.45	-1.74 (-2.90, -0.58)	0.004	0.73 (-0.41, 1.88)	0.202
Sleep quality	8.80	4.11	7.33	4.10	-1.31 (-2.53, -0.10)	0.034	7.39	3.98	-1.09 (-2.34, 0.15)	0.085	0.22 (-0.71, 1.15)	0.635
Sensory pain	10.86	7.28	9.59	6.88	-1.23 (-2.99, 0.52)	0.162	7.58	5.82	-2.93 (-4.30, -1.55)	0.000	-1.69 (-3.31, -0.07)	0.041
Affective Pain	3.17	2.31	2.17	2.30	-0.99 (-1.59, -0.39)	0.002	2.11	2.35	-0.94 (-1.61, -0.28)	0.006	0.04 (-0.58, 0.68)	0.879
Total Pain	14.03	9.08	11.76	8.60	-2.22 (-4.24, -0.20)	0.032	9.69	7.74	-3.87 (-5.64, -2.10)	0.000	-1.64 (-3.67, 0.38)	0.108
Cognition	44.20	10.40	45.90	11.82	1.98 (-0.01, 3.98)	0.051	46.47	11.66	2.23 *(-0.12, 4.59)	0.063	0.25 *(-1.78, 2.28)	0.805
QoL (General health)	48.41	25.74	56.92	21.01	8.05 (3.17, 12.93)	0.002	56.52	20.76	6.26 (0.77, 11.75)	0.026	-1.78 (-6.04, 2.47)	0.400
QoL (Fatigue)	31.95	19.13	49.30	18.26	17.18 (10.41, 23.96)	0.000	43.19	18.67	10.54 (2.86, 18.22)	0.008	-6.64 (-12.72, -0.55)	0.033
QoL (Physical functioning)	43.17	25.75	51.02	25.24	8.24 (3.69, 12.80)	0.001	51.38	24.74	6.37 (2.90, 9.84)	0.001	-1.87 (-6.57, 2.81)	0.423
QoL (Emotional wellbeing)	60.78	23.31	71.15	16.61	10.26 *(4.44, 16.07)	0.001	71.00	16.73	9.39 (2.89, 15.90)	0.006	-0.86 (-5.12, 3.40)	0.684

B: Baseline; PI: Post-intervention; FU: Follow-up; p: Level of significance; FSS: Fatigue Severity Scale; MFIS: Modified Fatigue Impact scale; QoL: Quality of Life; N: Number of participants; MD: Mean difference; CI: Confidence interval. * The number of participants was 34 for cognition and emotional wellbeing QoL

Table 2-5: Change in physical performance outcomes across three time points

Variables	B (Week 0)		PI (Week 15)		PI - B			FU (Week 22)		FU - B			FU - PI		
	Mean	SD	Mean	SD	N	MD (95%CI)	p	Mean	SD	N	MD (95%CI)	p	N	MD (95%CI)	p
Gait Speed (10-meter walk test)	0.99	0.42	1.04	0.43	39	0.077 (0.03, 0.12)	0.002	1.12	0.38	33	0.096 (0.03, 0.15)	0.002	33	0.019 (-0.03, 0.07)	0.45
6-minute walk distance	283.34	133.80	308.59	149.53	39	31.37 (17.91, 44.84)	0.000	339.20	140.20	33	43.34 (24.76, 61.92)	0.000	33	11.96 (-1.80, 25.73)	0.086
SPPB-Balance score	3.00	1.26	2.82	1.21	39	-0.19 (-0.48, 0.09)	0.174	3.22	1.12	32	0.11 (-0.17, 0.39)	0.431	32	0.30 (0.06, 0.55)	0.015
SPPB-Chair sit-stand score	1.76	1.46	2.29	1.55	38	0.53 (0.20, 0.85)	0.002	2.53	1.45	32	0.70 (0.31, 1.08)	0.001	32	0.17 (-0.09, 0.43)	0.193
SPPB-Gait Speed score	3.22	1.12	3.41	1.06	39	0.20 (0.07, 0.33)	0.003	3.67	0.77	33	0.33 (0.15, 0.50)	0.000	33	0.13 (-0.00, 0.26)	0.064
SPPB total score	7.98	3.43	8.50	3.43	38	0.54 (0.15, 0.94)	0.008	9.45	2.97	31	1.13 (0.60, 1.65)	0.000	31	0.58 (0.16, 0.99)	0.007

B: Baseline; PI: Post-intervention; FU: Follow-up; p: Level of significance; SPPB: Short Physical Performance Battery; N: Number participants; MD: Mean difference; CI: Confidence interval.

Table 2-6: Effect size of the "SitLess with MS" intervention on sedentary behaviour outcomes, symptoms and physical performance outcomes

Variables	Effect Size	
	PI-B	Fu-B
Total sedentary minutes per day from the ActivPAL	0.34	0.21
Total number of breaks in sedentary time from the ActivPAL	0.06	0.02
Number of long sedentary bouts ≥ 30 minutes per day from the ActivPAL	0.39	0.20
Fatigue (Fatigue Severity Scale)	0.61	0.44
Fatigue (Modified Fatigue Impact Scale)	0.60	0.59
Depression	0.79	0.64
Anxiety	0.55	0.39
Sleep Problems	0.35	0.34
Total Pain	0.26	0.50
Cognition	0.15	0.20
Quality of Life (General health)	0.37	0.35
Gait Speed	0.12	0.31
Walking endurance	0.17	0.39
Short Physical Performance Battery-Balance score	0.15	0.18
Short Physical Performance Battery-Chair sit-stand score	0.35	0.50
Short Physical Performance Battery-Total score	0.15	0.44

B: Baseline; PI: Post-intervention; FU: Follow-up.

2.4 Discussion

This study examined the preliminary efficacy of a sedentary behaviour change intervention for improving symptoms and physical performance in adults with MS with mild to moderate disability. Participants significantly reduced daily sedentary time and the number of long sedentary bouts ≥ 30 minutes per day pre-post intervention. This indicates that the intervention had the intended impact of changing sedentary behaviour. There further were improvements in fatigue,

depression, anxiety, sleep quality, total pain, QoL, gait speed, walking endurance and function. The significant change in sedentary behaviour outcomes was not sustained at follow-up, however, the improvements were sustained for symptoms and physical performance measures, except for sleep quality. Cognition, as measured by the SDMT, was the only outcome that did not change from baseline to post-intervention or follow-up.

One previous study [22] tested the efficacy of a 6-month sedentary behaviour intervention in adults with MS using a self-report measure of sedentary time and reported a 99-min reduction in total daily sedentary time in favour of the intervention group with a small effect size (η^2: 0.06) [21]. The effect sizes of the present study on reducing total daily sedentary time and total daily number of long sedentary bouts ≥ 30 minutes were 0.34 and 0.39, respectively, and these effects are small in magnitude. Nevertheless, the use of a device measure of sedentary behaviour (i.e. ActivPAL3^{TM}) in the present study may provide more accurate data (less bias than self-report), and better capture the complexity and various dimensions of sedentary behaviour with more continuous assessment of free-living sedentary behaviour [41,42].

Another recent study [22] examined the feasibility and initial efficacy of a 3-month behaviour change intervention on activity behaviour outcomes and levels of fatigue and pain in adults with MS with use of the ActivPAL3µ for measurement of sedentary behaviour. As described in the study protocol, the intervention was comprised of a handbook and four one-on-one face-to-face physical activity sessions with participants, along with the usual care services [29]. The control group received usual care services [29]. The handbook primarily focused on increasing physical activity levels and largely did not focus on reducing sedentary behaviour [29]. The intervention and control groups reduced total daily sedentary time by 54 and 24 minutes,

respectively, and there was no significant difference in the total daily sedentary time between groups post-intervention [22]. The small number of participants in the trial likely resulted in underpowered data analysis, and contributed to the lack of difference in sedentary behaviour outcomes between groups [22]. More engagement of participants in the control group in some of the usual care services (e.g., contact with MS nurse and occupational therapist) compared to the intervention group [29], and not explicitly targeting reduction of sedentary behaviour may also contribute to the absence of difference between groups [29], Nevertheless, the effect size of the intervention on reducing daily sedentary time was 0.41 for the intervention group [22] which is similar to the magnitude of change that we report in this study. They reported a significant reduction in the level of fatigue between groups at post-intervention and follow-up and a significant decrease in the level of pain at follow-up [22].

In regards to interventions, Spence and colleagues [43] suggested that interventions with a focus on changing posture (e.g. sitting to standing) while maintaining the same activity (e.g. standing while watching TV) may increase daily light-intensity physical activity. These researchers further suggested that those interventions might have greater potential to reduce sedentary behaviour than interventions that focus on substitution of daily sedentary behaviour with another behaviour such as MVPA [43]. Accordingly, primarily targeting sedentary behaviour and focus on increasing light intensity activities with our intervention rather than asking for MVPA changes (i.e., occupy a small fraction of the day and may not substantially reduce sedentary time), may explain the significant reduction in sedentary behaviour outcomes we report. This type of intervention may be more feasible for people who have challenges with movement. However, to date, there is not enough research on this type of intervention in people with mobility disability such as individuals with MS. More research with larger samples including a control group is

needed to determine the effect of those interventions on reducing sedentary behaviour.

Fatigue, depression and anxiety are three of the most commonly reported symptoms in the MS population [44,45]. The observed effect sizes for those outcomes in the present study were moderate in magnitude (table 2-6), while we report small effects on pain, sleep quality, and QOL (table 2-6). Previous research allows comparison of the effect sizes reported from the "SitLess with MS" intervention with those reported in a trial that focused on increasing lifestyle physical activity, especially walking [46]. Researchers reported a significant improvement in the levels of fatigue, depression and anxiety at post-intervention [46], and no significant improvements in pain, sleep quality, and QOL with an intervention focusing only on lifestyle physical activity [46]. The effect sizes of the intervention were moderate to large (0.82, 0.64, 0.64) for fatigue, depression and anxiety, and small (0.45 and 0.42) for decrease in pain and improvement of sleep quality in the intervention group [46]. The effect sizes are comparable with the effect sizes in the present study thereby suggesting that an intervention targeting sedentary behaviour has a similar impact on MS-related symptoms as an intervention focusing on increasing lifestyle physical activity.

The finding of a similar effect from a sedentary behaviour intervention as compared to one focusing on increasing light intensity activity make sense. Sedentary behaviour and light-intensity physical activity are usually almost perfectly correlated [47] such that increasing light-intensity physical activity reduces sedentary time. A study by Kozey-Keadle et al. [48] tested the effect of a 12-week trial with obese participants in 4 intervention foci (exercise; reduction of sedentary time and increase non-exercise physical activity; exercise and reduce sedentary time; control) on sedentary behaviour and non-exercise physical activity. They reported no significant changes in sedentary time and non-exercise physical activity in the exercise group (exercised 5 days per week

at a moderate intensity) [48]. However, they reported a reduction in free-living sedentary time and an increase in non-exercise physical activity in the groups that included the reduction in sedentary behaviour component [48]. Their results demonstrated the importance of targeting intervention for the desired change. They concluded that Interventions targeting multiple behaviours (sedentary behaviour and non-exercise physical activity) may be able to successfully increase daily activity [48]. The results from the current and the above studies [46,48] indicate that clinicians might be able to recommend either for the management of symptoms in MS.

Participants made gains in physical performance outcomes and continued to make gains even after the intervention ended. Based on the obtained effect sizes, the greatest improvement amongst physical performance outcomes was observed for the SPPB-Chair sit-stand test which is an indicator of the lower-extremity strength. This improvement is in line with the focus of our intervention on sitting less (i.e., promoting the action of moving from sitting to standing), which is exactly what is tested with the chair sit to stand test. Our preliminary findings indicate that an intervention that focuses on sitting less and moving more can affect physical performance.

Cognition, as measured by the SDMT, was unchanged from baseline to post-intervention and 7-week post-intervention. Cognition is complex in nature and consists of different domains such as memory, attention and information processing [49,50]. The use of the SDMT which primarily measures information processing speed [51,52] may help to explain our findings related to cognition.

Based on the evidence, frequency, duration and intensity of activity over time are considered important factors when evaluating the effects of activity on cognition [53–55]. For instance, research shows that moderate-intensity exercise is related to improvement in working

memory and cognitive flexibility, while high-intensity exercise enhances the information processing speed [56]. Peripheral brain-derived neurotrophic factors significantly increase after high-intensity physical activity, but not after low-intensity activity [57] which might be responsible for improvement in cognition following activities with higher intensity. A recent 3-week exercise intervention that included 5 weekly moderate-to-vigorous training sessions reported a significant improvement in cognitive performance as measured by the SDMT in adults with MS [58]. Although shorter in duration (i.e., 3 weeks), the exercise intensity (working out for 30 minutes daily at lactate threshold) was higher than in the present study. Another study [59] which evaluated the effectiveness of a 6-month internet-based physical activity intervention on cognitive performance measured by oral SDMT also reported a clinically meaningful improvement in cognition in patients with mild disability, but not in persons with moderate disability [59]. Therefore, the intensity may play a role in the potential for impact of an intervention on cognition. Primarily targeting reduction in daily sitting time and increasing light-intensity activities such as slow walking following the "SitLess with MS" intervention may not have enough intensity to create a significant change in the level of cognition in a duration of 15 weeks [53–57]. Our results are congruent with a recent systematic review on healthy adults [13] that reported replacing seated with standing workstations (i.e. changing posture from sitting to standing as a light-intensity physical activity) does not lead to improvements in cognitive function. Our findings are also in agreement with another systematic review that showed interventions targeting reduction in sedentary behaviour in adults at the workplace are not associated with changes in cognitive performance [60].

2.5 Study Limitations

The lack of a control group allowed evaluation of preliminary efficacy of the intervention only. The follow-up period was 7 weeks and provides only an estimation of the long-term sustainability of the intervention effects. The effect on the primary outcome (sedentary behaviour) was not sustained over a short follow-up. Only patients with MS who had mild to moderate disability were included, and the findings are not generalizable among non-ambulatory persons with MS.

2.6 Conclusion

The present research provides support for a less intense whole-day activity behaviour intervention in MS. Further research including randomized controlled trials focusing on sitting less and moving more (i.e., changing behavioural topography from sitting to standing) in MS populations is required to replicate the effect under conditions of high internal validity. Future research may focus on the issue of adherence – is long term adherence actually better with a lower intensity focus? That possibility is hypothesized but requires testing. A strategy to facilitate improvement in light-intensity activities such as slow walking and a reduction in sitting time may be a first step towards promoting activity levels and increasing energy expenditure in persons with MS.

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Declaration of interest

The authors declare that there is no conflict of interest.

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CHAPTER 3. Validity of ActivPAL3™ and Fitbit One activity monitors in adults with multiple sclerosis in a laboratory setting

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ABSTRACT

Background: People with multiple sclerosis (MS[1]) sit more and are less active than peers, despite public health recommendations. Accurate measurement of physical activity behaviour helps patients to understand and change activity levels and can be used to evaluate activity interventions. We examined the validity of ActivPAL3™ for measuring sitting time, standing time, numbers of postural transitions and steps and the validity of Fitbit One for measuring steps in ambulatory patients with MS.

Methods: Thirty-two ambulatory patients with MS aged 18 to 65 years old wore ActivPAL3™ and Fitbit One (using both waist and ankle placement) monitors while performing a series of postural and walking tasks in a laboratory setting. Recorded data from the ActivPAL3™ and Fitbit Ones were compared against direct observation as the criterion measure.

Results: The ActivPAL3™ demonstrated validity evidence as a measurement tool for sedentary behaviour (sitting time), standing time and steps (ICC[2]: 0.98). The waist-worn (ICC: 0.88) and ankle-worn (ICC: 0.72) Fitbit Ones demonstrated validity evidence for measurement of steps. The ankle-worn Fitbit One performed better (ICC: 0.89) than the waist-worn Fitbit One (ICC: 0.76) in people with walking aids.

[1] Multiple Sclerosis

[2] Intraclass correlation coefficients

Conclusions: Both ActivPAL3^{TM} and Fitbit One can be used to accurately measure steps in the MS population.

Keywords: Validity, Accelerometers, Measurement, ActivPAL3^{TM}, Fitbit, Steps, Sedentary behaviour

3.1 Introduction

Multiple sclerosis (MS) is a chronic progressive disease of the central nervous system [1]. The consequences of MS include balance and walking disabilities [2,3] as well as comorbidities such as hypertension, coronary heart disease, and obesity [4]. Together the sequelae and co-occurring conditions related to MS may lead to physical inactivity [5] and large amounts of sedentary behaviour [6,7].

Accurate assessment of physical activity and sedentary behaviour is essential to identify current activity levels and to allow evaluation of the effectiveness of activity interventions. Activity behaviour can be measured by self-report and/or observation. Questionnaires, surveys, diaries and logbooks are self-reported tools that can be used to measure physical activity and sedentary behaviour [8,9]. Observed measurement relies on information generated through direct observation or from activity monitors [10]. Even though self-report assessment provides researchers useful information, observed measurement appears more accurate [11]. Accelerometry and pedometry are the most commonly used measurement tools, yielding outcomes such as activity counts, sitting time and steps taken [12]. Accelerometers are typically consumer-grade such as Fitbit (less expensive and accessible to the general public) [13,14] or research-grade such as ActivPAL3^{TM} (more expensive, shown to be more accurate, not used by the general public) [15,16].

When we are deciding on the selection of the appropriate activity measurement tools as part of an intervention, we need to consider that the most common way people with MS are active is through walking.[17] Many patients with MS use walking aids or

walk slowly [18]. Thus, a selected activity monitor must be accurate in people with MS who walk at different speeds or with variable gait patterns.

People with MS may especially benefit from the utilization of consumer-grade activity monitors since they provide an opportunity for individuals to monitor their daily physical activity. These monitors can be synchronized to smartphones and computers to generate immediate feedback and can encourage individuals to increase their activity levels by monitoring daily steps taken as a surrogate for physical activity.

Balto et al. [19] evaluated the precision and accuracy of different consumer-grade activity trackers for measuring steps in ambulatory adults with MS and reported the Fitbit One (Fitbit Inc, San Francisco, CA, USA) as the most accurate and precise device. However, there was no criterion measure used in their study. Activity trackers produced by Fitbit are popular and widely utilized. Fitbit activity trackers (e.g. Fitbit One) record steps, stairs climbed, distance travelled, sleep, and calories burned. The Fitbit One can be attached to the hip, bra, or ankle. Earlier studies in healthy adults [20], and community-dwelling elderly [21] showed the hip-worn Fitbit One accurately measured step counts. Treacy et al. [22] and Simpson et al. [23] found the Fitbit One worn on the ankle had excellent agreement with direct observation of steps in individuals who walk slowly such as patients with stroke [22] and the elderly [23]. However, poor agreement was observed at slower gait speeds when the Fitbit One was attached to the hip [22]. Patients with MS may have slow or altered gait [24] with frequent bilateral gait deficits, as compared to people with stroke who typically have hemiplegic gait patterns [25]. Use of walking aid (e.g., cane, or walker), which is also common in people with MS, is also likely to influence activity tracker accuracy. Therefore, the validity of the Fitbit One in both locations (i.e., hip and ankle) must be determined with persons with MS.

Measuring posture - a surrogate for sedentary behaviour - and distinguishing between standing and sitting is an important component of understanding and quantifying sedentary behaviour [26]. Accelerometers worn on the thigh, such as ActivPAL3™ (PAL Technologies Ltd, Glasgow, UK), have the ability to differentiate between standing (thigh vertical) and sitting (thigh horizontal) in comparison with the waist or the wrist-worn accelerometers such as ActiGraph [26]. The research-grade activity monitor, ActivPAL3™, measures sitting/lying and upright (standing and walking) times, numbers of sit-to-stand and stand-to-sit transitions and step counts. The ActivPAL3™ monitor has previously shown excellent ability to measure sitting and upright times, number of postural transitions and step counts in healthy adults [27], people with disability [28], and the elderly [28]. Although evidence suggests that the ActivPAL may be the gold standard for measuring sedentary time [11,29], to date, no study has examined the validity of the ActivPAL3™ in assessing sedentary behaviour in individuals with MS. Therefore, this study aimed to evaluate:

1) the concurrent criterion validity of the ActivPAL3™ activity monitor for measuring time spent in sitting and standing, and number of postural transitions against direct observation in ambulatory patients with MS;

2) the concurrent criterion validity of the ActivPAL3™ and the Fitbit One activity monitors for measuring step counts against direct observation in ambulatory patients with MS.

3.2 Methods

3.2.1 Study Design

This methodological study utilized a concurrent criterion validity design. Ethical approval was granted by the institutional Health Research Ethics committee of the University of Alberta (Pro00067657_AME2).

3.2.2 Participants

Participants were included if they met the following criteria: (1) aged ≥ 18 years old; (2) confirmed diagnosis of MS of at least one-year duration; (3) stable in terms of disease-modifying drugs and rehabilitation over the previous 6 months; and (4) able to walk 10 meters with or without a walking aid.

3.2.3 Recruitment

Thirty-two participants were recruited through the MS Clinic at the University of Alberta via posters and flyers, as well as website announcements at the MS Society of Alberta. Participants were screened on the phone to ensure they met the inclusion criteria and received the study information letter by email. Participants who met inclusion criteria and agreed to participate were enrolled.

3.2.4 Study Procedures and Data Collection

Prior to data collection, all included monitors were assessed for functionality by the researcher (GM). First, all ActivPALs3^{TM} and Fitbits were connected to the same computer to synchronize the time on the devices. Each ActivPAL3^{TM} was set up and worn

by the researcher (GM) as per the manufacturer's instructions (anterior mid-thigh). The researcher then performed different activities including sitting, standing, stepping, sit-to-stand, and stand-to-sit postural transitions for 30 minutes. Following that, all Fitbit activity trackers were attached to the researcher's waist for 30 minutes to record the number of steps. The start and end time for each activity were directly recorded from the computer by the researcher (direct observation). It was then compared with the ActivPAL3^{TM} and Fitbit monitors' recorded start and end times to assess the accuracy of each device against direct observation. The monitors were included in the study if the accuracy of the devices was ≥ 95 % (research-grade) [27] and ≥ 90 % (consumer-grade) [30] compared to direct observation by the researcher. This preliminary testing of the activity monitors was done once prior to the start of data collection.

Participants were invited to a 1.5-hour data collection session. The research study was explained to them and any questions and/or concerns were addressed. All participants signed the consent form prior to taking part in the study. Demographic data and physical characteristics of participants including age, sex, self-reported height and weight, and use of assistive devices were obtained. Participants were categorized into two different groups based on the use of walking aids.

The researcher examined the strength of participants' legs with a manual muscle test to determine the stronger leg. One ActivPAL3^{TM} monitor and two Fitbit One activity trackers were then initialized and positioned on the participant as follows. The ActivPAL3^{TM} monitor was attached to the midline of the anterior aspect of the participant's stronger thigh by waterproof non-allergic adhesive pads (Tegaderm, 3M Company, Canada). Two Fitbit Ones were attached to the participants' stronger side at the following locations: (i) on the waistband, just above the greater trochanter (Fitbit –

Waist) by a clip, and (ii) on the ankle, just above the lateral malleolus (Fitbit – Ankle) by an elastic band. Waist attachment was in accordance with the manufacturers' guidelines. A video camera was set up and connected to the same computer as the monitors, to synchronize the time on each of the devices. After synchronization, the video camera was placed appropriately to capture the different movement activities during the session.

Participants performed a series of tasks (Table 3-1) including sitting, standing, walking, sit-to-stand, and stand-to-sit transitions. Based on the ActivPAL3^{TM} manufacturer's settings, a minimum seated duration of 10 seconds and a minimum upright duration of 10 seconds is required to register a sitting or standing event by the ActivPAL3^{TM} [31]. Therefore, the participants were asked to perform the 5-repeated chair postural transition test, incorporating a hold of at least 10 seconds between transitions. Instructions and the starting cue such as "Are you ready? 3, 2, 1, start," was given before each task. Participants were given adequate rest between each test.

Finally, participants completed a 6-minute walk test using a standard protocol [32] on a 30-meter track. The researcher (GM) walked slightly behind and to the side of the participant. Participants were instructed to stand still for 1-minute prior to and after the 6-minute walk, to mark the start and stop times accurately. The start and end time of the walking test was also expressed verbally and recorded onto video.

Table 3-1: Tasks performed by participants

Posture/Movement	Activity and timing	Measurement
Sitting	Sitting on a chair for 5 minutes	ActivPAL3™; Direct observation
Standing	Standing still for 5 minutes	ActivPAL3™; Direct observation
Stepping	6-minute walk test	ActivPAL3™; Direct observation; Fitbit One
Sit-to-Stand and Stand-to-Sit Transitions	5 repetitions of postural transitions	ActivPAL3™; Direct observation

3.2.5 Instruments

ActivPAL3™ is a small (3.5 cm × 5.3 cm × 0.7 cm), light-weight (15 grams), triaxial, research-grade physical activity monitor. It measures accelerations of the thigh at a sampling frequency of 20 Hertz with signal generation related to thigh inclination [33]. The device summarizes data in 15-second intervals (epochs) over a 24-hour period [34] and provides output for body postures (lying/sitting, standing, and stepping) using a proprietary algorithm in the manufacturer-provided software. In general, the ActivPAL3™ measures time spent in sedentary behaviour (sitting or lying), and upright positions (standing and walking), numbers of sit-to-stand and stand-to-sit transitions, and step counts [33].

The Fitbit One activity tracker is a light-weight (8 grams) and small (4.8 x 1.9 cm x 1.0 cm), triaxial, consumer-grade accelerometer that records steps, stairs climbed, distance travelled, sleep, and calories burned. It is a relatively affordable device that can provide real time feedback on either the device itself, on a smartphone or via simple software accessed by the internet. The device summarizes data in 60-second intervals (epochs).

Direct observation derived from a digital video camera (HDR-PJ270, Sony Corporation, Japan) was used as a criterion measure for all the sedentary and physical activities. Procedures related to direct observation were as follows. Two researchers viewed the videos independently and timed sitting and standing, counted the number of postural transitions, and calculated the step counts during the 6-minute walk test. A hand-held step counter (H102-4, Keihoku Keiki Kogyo Co. Ltd., Tokyo, Japan) was used for counting steps. There was no difference in recorded sitting and standing times, and number of postural transitions between two researchers. The number of steps typically differed by one or two steps and was mainly due to the classification of when a step occurred at the end of the 6-minute walk test. The step counts were recounted until consensus was achieved for cases of dissimilar counts.

3.2.6 Data Analysis

Data from the ActivPAL3^{TM}, the Fitbits, and the video camera were downloaded to a computer for analysis using Professional Research Edition software (PAL Software Suite Version 8**),** Fitabase (Small Steps Labs LLC), and VLC Media Player (version 2.2.6), respectively. All data from the activity monitors were downloaded to Excel and exported to SPSS statistical package Version 24 (Armonk, New York, USA, IBM Corp).

Descriptive statistics were calculated including means and standard deviations for each continuous variable (sitting time, standing time and number of postural transitions) and percentage for categorical variables.

The ActivPAL3^{TM} reports transitions and postural information (unlike Fitbit) thus the validity of transitions and time in certain postures is only reported for the ActivPAL3^{TM}. Mean, standard deviation and proportion (percentage) were used to

determine validity of the ActivPAL3^{TM} for measuring sitting and standing times and number of postural transitions against direct observation. Validity of the ActivPAL3^{TM} and the Fitbit Ones (ankle and waist placement) for measuring step counts against direct observation was tested in several ways including Intraclass correlation coefficients (ICC), mean absolute percentage error (MAPE[3]), and Bland-Altman plots.

ICCs for continuous data were used to compare:

1) the total step counts recorded by the ActivPAL3^{TM} with the steps derived from direct observation during the 6-minute walk;

2) the total step counts recorded by the Fitbit Ones with the steps derived from direct observation during the 6-minute walk;

3) the total number of steps recorded by the ActivPAL3^{TM} with total step counts recorded by the Fitbit Ones during the 6-minute walk.

ICC estimates and their 95% confidence intervals were calculated based on a single rater (k = 1), absolute-agreement, 2-way mixed-effects model. An ICC value > 0.90 was defined as "excellent", an ICC value between 0.75 and 0.90 ($0.75 \leq ICC \leq 0.90$) was defined as "good", an ICC value between 0.50 and 0.74 ($0.50 \leq ICC \leq 0.74$) was defined as "moderate", and an ICC value less than 0.50 ($ICC < 0.50$) was defined as "poor" [35].

[3] Mean absolute percentage error

The mean absolute percentage error ([|activity monitor recorded steps - direct observation|/direct observation] × 100) was also calculated for the number of steps from the devices to show the magnitude of error for each device against direct observation. Bland–Altman plots were used to provide a visual illustration of agreement between the different measurements [36]. Small mean differences and narrow limits of agreement in Bland–Altman plots indicated greater agreement.

Measured variables from the devices were reported in three groups; the full sample, people who use walking aids and people without walking aids.

3.3 Results

Thirty-two (28 females and 4 males) ambulatory adults with MS participated. The data for one participant did not match the time frame of direct observation, thus data from thirty-one participants were analyzed. Participant characteristics are outlined in Table 3-2.

Table 3-2: Participants' characteristics (n = 31)

Characteristics	Mean (SD) or n (%)	Range
Age (years)	49 (9.6)	29-65
Sex (female)	28 (90.3 %)	
Weight (kg)	74.7 (15.3)	45-109
Height (m)	1.6 (0.1)	1.5-1.8
Body Mass Index (kg/m^2)	27.6 (5.1)	19-37
Uses Cane (unilateral or bilateral)	8 (25.8 %)	
Uses Walker	5 (16.1 %)	

n: Number of participants, SD: Standard Deviation; kg: Kilogram; m: Meter

The majority of participants (n = 25) were middle-aged and 22 out of 31 were classified as overweight or obese as defined by a body mass index ≥ 25. Eighteen participants (58%) used no walking aids.

Sitting and standing times were accurately recorded by the ActivPAL3^{TM} 100% of the time for all participants (Table 3-3). Sit-to-stand (Up) and stand-to-sit (Down) transitions were recorded accurately in 24 and 23 participants, respectively (Table 3-3).

Table 3-3: Averages for the duration of postures and number of transitions recorded by the ActivPAL3TM and direct observation

Variables	Direct observation (n=31) Mean ± (SD)	ActivPAL3^{TM} (n=31) Mean (SD) or n (%)	
Sitting time (seconds)	300 ± (0)	300 ± (0)	
Standing time (seconds)	300 ± (0)	299.9 ± (0.1)	
Number of sit-to-stand transitions	*5	5 out of 5	24 (77%)
		4 out of 5	4 (12.9%)
		2 out of 5	1 (3.2%)
		1 out of 5	2 (6.4%)
Number of stand-to-sit transitions	*5	5 out of 5	23 (74.1%)
		4 out of 5	4 (12.9%)
		3 out of 5	2 (6.4%)
		2 out of 5	1 (3.2%)
		0 out of 5	1 (3.2%)

n: Number of participants; SD: Standard Deviation.
*All participants performed 5 postural transitions.
The number of transitions recorded by the ActivPAL3^{TM} out of 5 directly observed transitions and the number of participants for each recorded number of transitions is shown above.

The number of steps recorded during the 6-minute walk by each of the measurement devices is summarized in Table 3-4. In comparison with direct observation, the ActivPAL3^{TM} underestimated the number of steps for all but 3 participants. The

ActivPAL3^{TM} underestimated steps by an average of 12 in people without walking aids and 18 steps in people with walking aids (Table 3-4). The Fitbit Ones, regardless of placement on the waist or ankle, underestimated the number of steps in all participants during the 6-minute walk. On average, the waist-worn Fitbit One underestimated the number of steps taken by 24 and 61 steps in individuals without and with walking aids, respectively (Table 3-4). The ankle-worn Fitbit One underestimated step counts by 41 steps in those who used walking aids and 61 steps in those without walking aids (Table 3-4).

Table 3-4: Step count during the 6-minute walk as measured by direct observation, the ActivPAL3TM and Fitbit One Locations

Variables	Full sample n=31		No Walking aids n=18		Use of Walking aids n=13	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
DO steps (Counts)	625.6 (117.5)	369-862	684.3 (86.0)	551-862	544.2 (108.2)	369-728
AP steps (Counts)	611.2 (121.2)	354-848	672.6 (81.6)	550-848	526.1 (117.6)	354-722
FBw steps (Counts)	586.2 (146.2)	248-848	660.7 (93.3)	513-848	483 (145.8)	248-721
FBa steps (Counts)	573.4 (105.1)	342-750	623.7 (80.2)	481-750	503.7 (97.4)	342-694

AP: ActivPAL3^{TM}; DO: Direct Observation; FBw: Waist-worn Fitbit; FBa: Ankle-worn Fitbit; SD: Standard Deviation; n: Number of participants

The mean absolute percentage error (MAPE) for the steps recorded by the ActivPAL3^{TM} and the Fitbit Ones against direct observation is shown in Figure 3-1. The ActivPAL had the smallest MAPE in all 3 groups (Figure 3-1). The waist-worn Fitbit One had smaller MAPE than the ankle-worn Fitbit One in persons who didn't use walking aids. A smaller MAPE for the ankle-worn Fitbit One in comparison with the waist-worn Fitbit One was observed in individuals with walking aids (Figure 3-1).

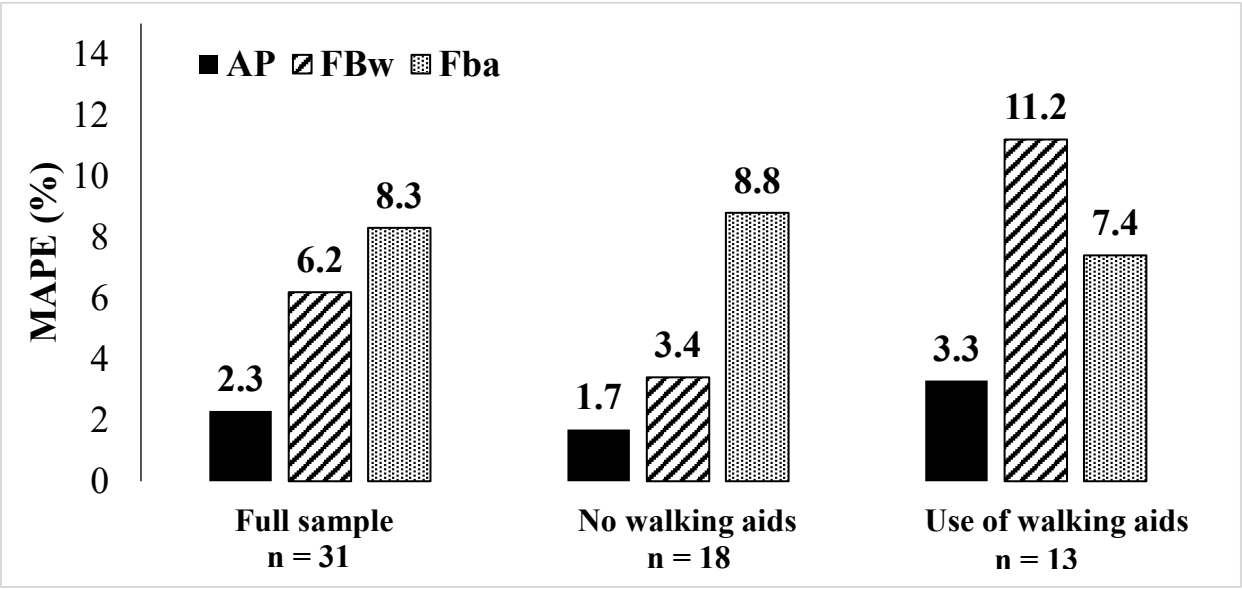


Figure 3-1: Mean absolute percentage error for the steps from the ActivPAL3™ and the two Fitbit locations against direct observation.

AP: ActivPAL; FBw: Waist-worn Fitbit; FBa: Ankle-worn Fitbit; MAPE: Mean Absolute Percentage Error; n: Number of participants

ICCs for the ActivPAL3™ and the Fitbit Ones against direct observation are shown in Table 3-5. There was good agreement (ICC: 0.90, CI: 0.78-0.95) between the ActivPAL3™ and the waist-worn Fitbit One and good agreement (ICC: 0.75, CI: 0.49-0.88) between the ActivPAL3™ and the ankle-worn Fitbit One for step counts. The waist-worn Fitbit One was also in good agreement (ICC: 0.76, CI: 0.56-0.87) with the ankle-worn Fitbit One for measurement of steps.

Table 3-5: ICC for the ActivPAL3TM and the Fitbits against direct observation

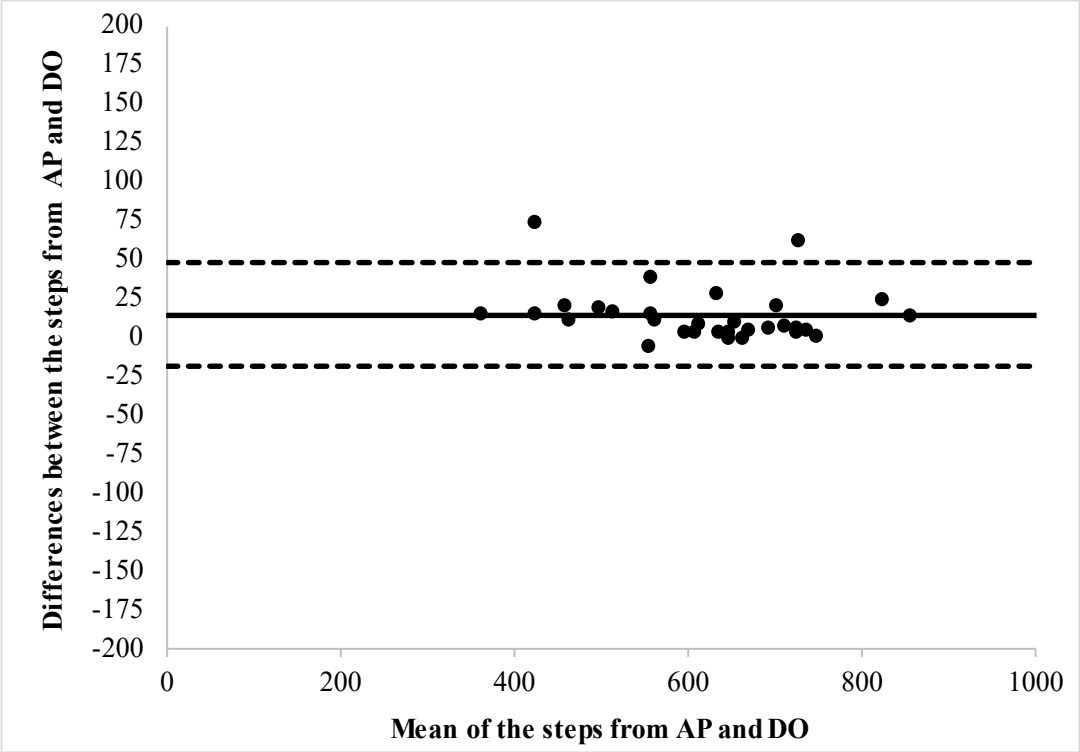
Step counts against direct observation	Whole sample (n = 31)		No walking aids (n = 18)		Use of walking aids (n = 13)	
	ICC	95% CI	ICC	95% CI	ICC	95% CI
ActivPAL	0.98	(0.90-0.99)	0.97	(0.87-0.99)	0.97	(0.79-0.99)
Fitbit-waist	0.88	(0.60-0.95)	0.94	(0.48-0.98)	0.76	(0.21-0.93)
Fitbit-ankle	0.72	(0.31-0.88)	0.33	(-0.07-0.66)	0.89	(0.08-0.97)

ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; n: Number of participants

Bland-Altman plots which provide a visual illustration of the agreement between the devices and direct observation for measuring steps in the whole sample are shown in Figure 3-2. The mean difference between the steps recorded by direct observation and the devices, as well as between devices, and their 95% limits of agreement are shown in Table 3-6. For the ActivPAL3^{TM}, the mean difference was smaller, and the limits of agreement narrower than those for the Fitbit Ones (Figure 3-2 and Table 3-6). The waist-worn Fitbit One had smaller mean difference and narrower limits of agreement than the ankle-worn Fitbit One (Figure 3-2 and Table 3-6). The Bland-Altman plots were in agreement with the ICCs and the MAPE for the full sample.

The mean difference between the ActivPAL3^{TM} and the waist-worn Fitbit One was smaller, and their limits of agreement were narrower than between the ActivPAL3^{TM} and the ankle-worn Fitbit One (Figure 3-2 and Table 3-6). These findings were in accordance with the ICC results.

A


Differences between the steps from AP and DO
200
175
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-125
-150
-175
-200
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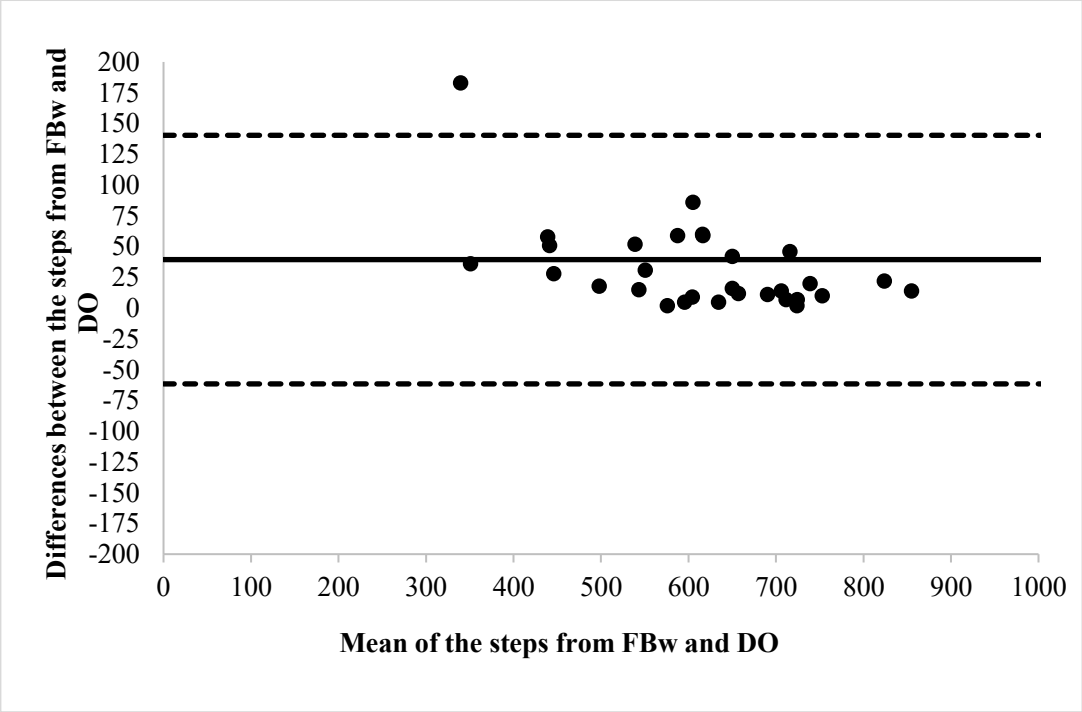
200
400
600
800
1000
Mean of the steps from AP and DO

B


Differences between the steps from FBw and DO
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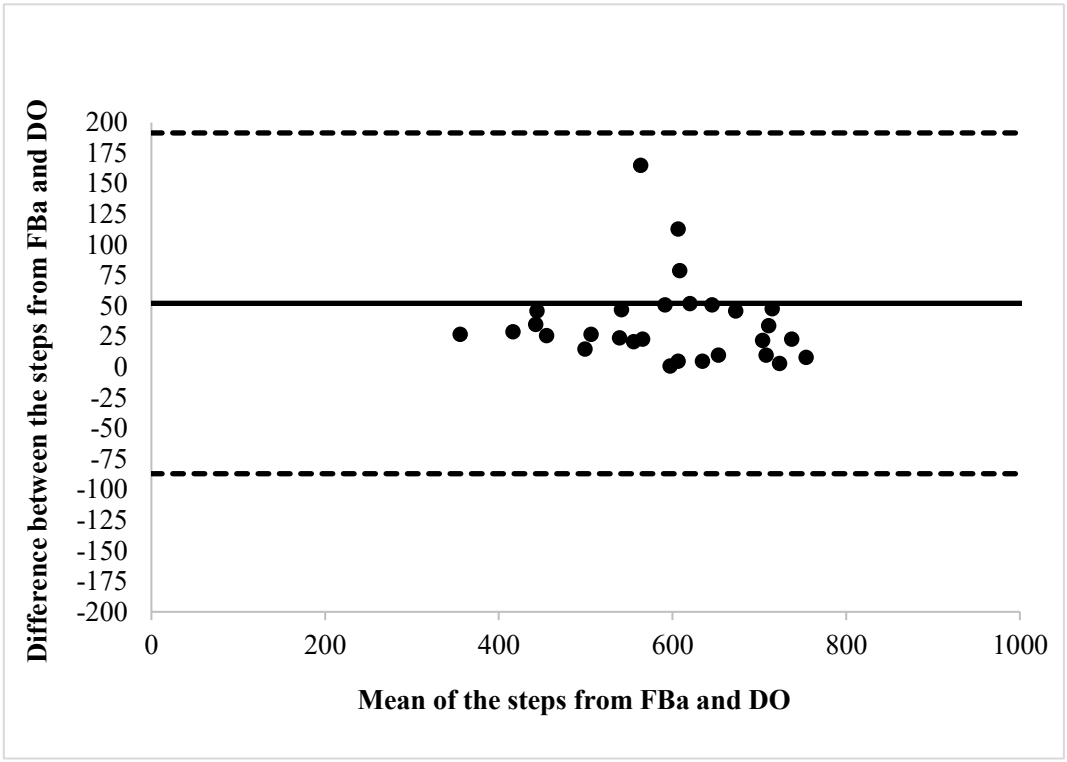
Mean of the steps from FBw and DO

C


Difference between the steps from FBa and DO
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400
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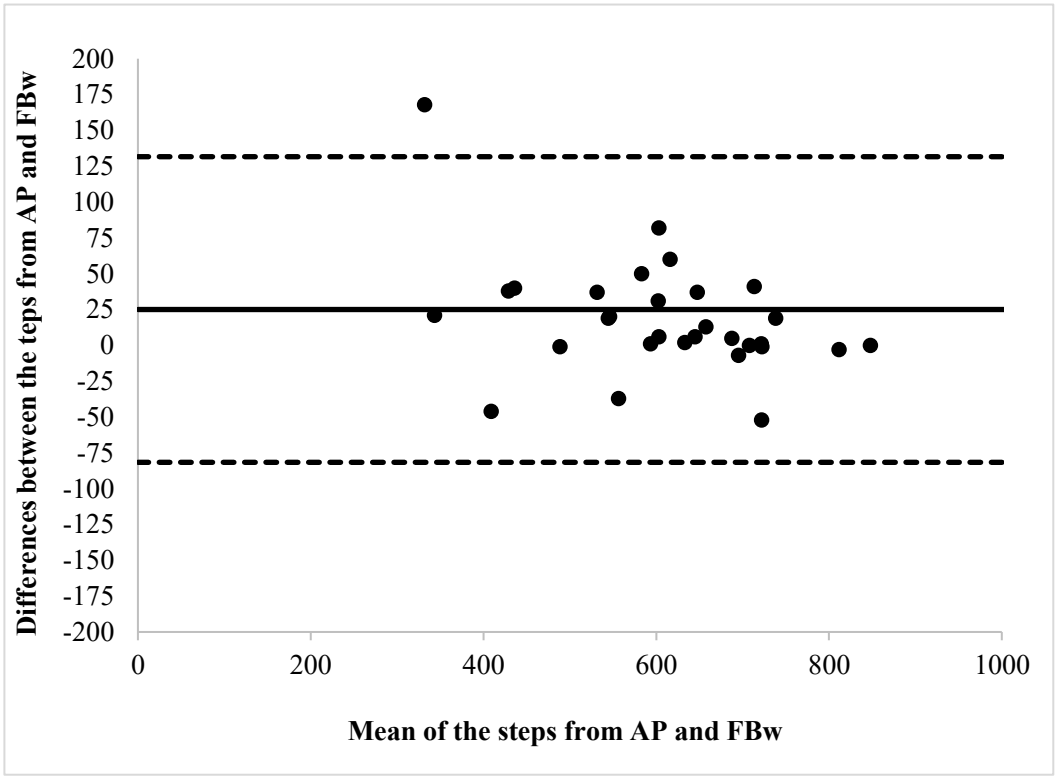
1000
Mean of the steps from FBa and DO

D


Differences between the teps from AP and FBw
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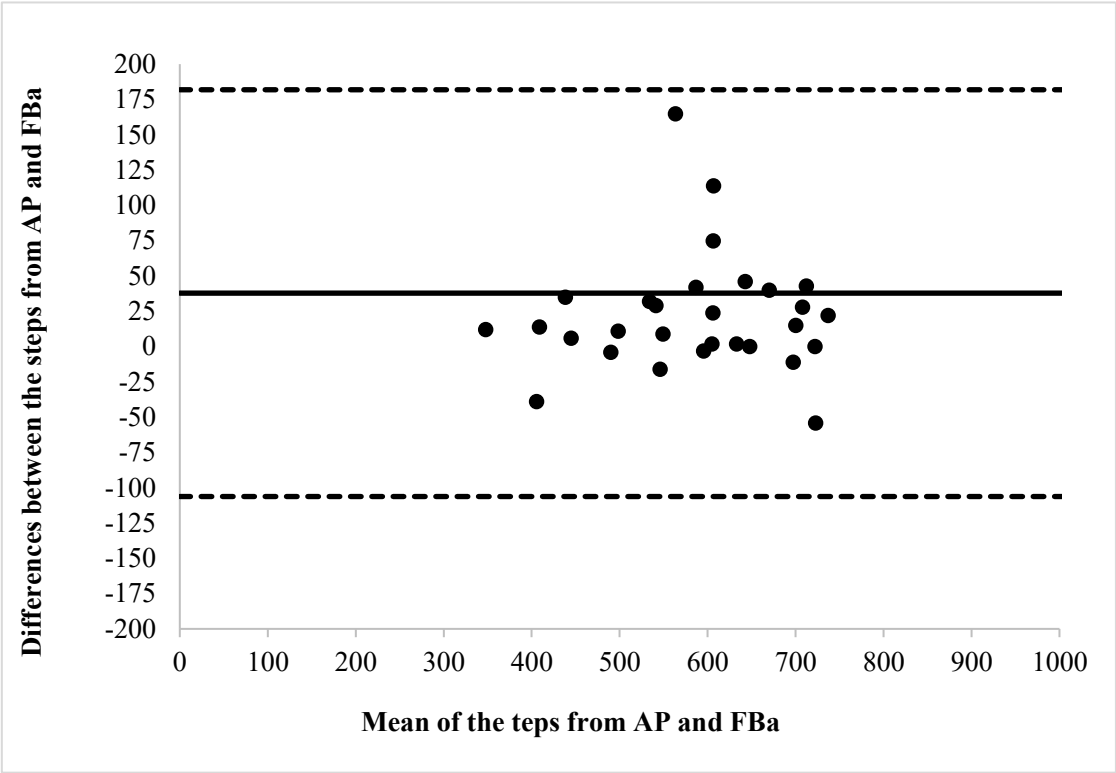
Mean of the steps from AP and FBw

E


Differences between the steps from AP and FBa
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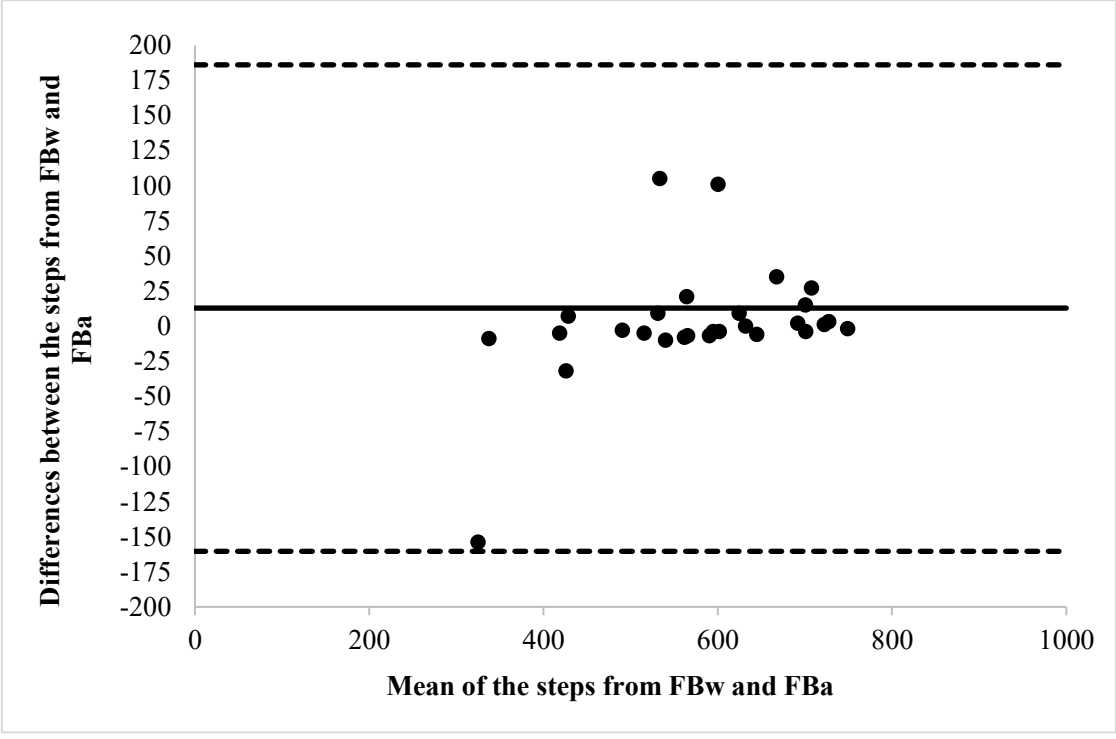
Mean of the teps from AP and FBa

F


Differences between the steps from FBw and FBa
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Mean of the steps from FBw and FBa

Figure 3-2: Bland-Altman plots comparing step counts over a 6-minute walk test for the ActivPAL3TM and the two Fitbit One Locations.

(A) Comparison between the ActivPAL3TM and direct observation, (B) Comparison between the waist-worn Fitbit One and direct observation, (C) Comparison between the ankle-worn Fitbit One and direct observation, (D) Comparison between the ActivPAL3™ and the waist-worn Fitbit One, (E) Comparison between the ActivPAL3™ and the ankle-worn Fitbit One, (F) Comparison between the waist-worn Fitbit One and the ankle-worn Fitbit One. The middle line indicates the mean difference between the two measures, upper and lower lines indicate the limits of agreement (±1.96 standard deviations of the mean difference).

AP: ActivPAL3™; FBw: Waist-worn Fitbit One; FBa: Ankle-worn Fitbit One

Table 3-6: Bland–Altman mean differences and limits of agreement from the devices against direct observation and the devices against each other for measuring step counts during the 6-minute walk

	ActivPAL3™		**Fitbit-waist**		**Fitbit-ankle**	
	MD	**95% LoA**	**MD**	**95% LoA**	**MD**	**95% LoA**
Direct observation	14.3	(-19.3, 48.0)	39.3	(-61.6, 140.3)	52.1	(-87.1, 191.4)
ActiVPAL3™			23.1	(-83.2, 129.4)	36.5	(-109.3, 182.4)
Fitbit-waist	25	(-81.6, 131.6)			12.8	(-160.4, 186)
Fitbit-ankle	37.8	(-106.2, 181.8)	12.8	(-160.4, 186)		

MD: Mean Difference; LoA: Limits of Agreement

3.4 Discussion

The results of this study provide concurrent validity evidence supporting the use of the ActivPAL3™ for measurement of sedentary behaviour (sitting time), standing time and step counts in ambulatory patients with MS. Moreover, results support the use of the waist- and the ankle-worn Fitbit Ones for the measurement of steps in the MS population. However, the waist-worn Fitbit One provided more accurate results in people who did not use walking aids while the ankle-worn Fitbit One performed better in individuals with walking impairment and consequently, the use of assistive devices such as cane or walker.

Results of our study regarding the recorded sitting and standing times by the ActivPAL are similar to Taraldsen et al. [28] who found that the ActivPAL accurately recorded both sedentary and standing times in all participants (i.e. patients with stroke and the elderly). The results were also in agreement with the results of Larkin et al. [37] and Sellers et al. [27] who reported the ActivPAL as a valid measure of sedentary and standing times in patients with rheumatoid arthritis (MAPE: 1.4% and 8.4% for sitting and standing times, respectively) and adults and young people (percentage error within ± 5% of direct observation), respectively.

The ActivPAL accurately recorded the number of postural transitions (5 out of 5) in approximately 75% of the participants in the current study which is less than Taraldsen et al. [28] who reported that the device accurately recorded postural transitions 100% of the time. The accuracy of the ActivPAL for measurement of postural transitions we observed was more similar to Larkin et al. [37] who reported the device underestimated transition counts by 36%. The variability in the reported rates of postural transitions across the studies may be related to the differences in the range of motion of leg joints which can be caused by many factors such as muscle weakness, stiffness or spasticity and reduced dynamic stability in patients with MS and rheumatoid arthritis. These factors may influence the proper thigh inclination and therefore, the ability of the ActivPAL to differentiate sitting from standing accurately leading to underestimation of the number of postural transitions.

In regard to step counts, the MAPE for the ActivPAL3^{TM} in our study was 2.3%. This means that for 1000 steps the device misses approximately 23 steps on average, which indicates high accuracy of the ActivPAL3^{TM} for the measurement of steps in the MS population. The magnitude of error for the ActivPAL3^{TM} was higher in people who

used walking aids. Our results are similar to the findings of Coulter et al. [38] who reported that the ActivPAL3^{TM} was valid for the measurement of upright time and step count in patients with MS. However, our study extends the findings by Coulter and colleagues [38] by the assessment of the validity of the ActivPAL3^{TM} for all the recorded parameters including sedentary time, standing time, numbers of postural transitions as well as steps in patients with MS. Our results were also in agreement with the findings of Seller et al. [27] who reported the MAPE of 3.4% in adults and 5.4% in young people.

Impaired knee and ankle control and reduced movements and range of motion in both joints that affect gait are common in patients with MS [18,39]. Previous studies with assessment of gait patterns in individuals with MS showed reduced step length and gait speed [24,40–42]. This may contribute to the underestimation of step counts by the ActivPAL and the Fitbit Ones in the majority of the participants in the current study.

In general, the MAPE for the waist-worn Fitbit One (6.2%) was smaller than the ankle-worn Fitbit One (8.3%) which indicated higher accuracy of the waist-worn Fitbit One in measuring steps in our sample. The results of our study regarding the ankle-worn Fitbit One are similar to findings by Simpson et al. [23], Treacy et al. [22] and Klassen et al. [43] who reported that the ankle-worn Fitbit One had significantly less error than the waist-worn Fitbit One in measuring steps in slow-walking older adults [23], slow-walking patients admitted to rehabilitation setting [22] and patients with stroke [43]. These findings may be explained by the ability of the ankle-worn device to record small accelerations compared to the waist-worn device. Accelerations at the ankle are perhaps greater than the accelerations at the hip during leg swing in slow-walking individuals and therefore, the ankle-worn device is more likely to record steps than the waist-worn Fitbit One in people who walk slowly. On the other hand, our findings regarding the waist-worn

Fitbit One were in agreement with the results reported by Takacs et al. [44], Paul et al. [21], and Floegel et al. [45] who found that the waist-worn Fitbit One was valid for measuring the number of steps in healthy adults, older adults without walking impairment, and the elderly with varied ambulatory abilities who don't use assistive devices. Our results are also similar to a systematic review of all Fitbit devices [46] that indicated a trend of underestimating steps in Fitbit studies in controlled settings. The study [46] demonstrated a greater tendency of the Fitbit activity trackers to accurately measure steps during normal walking speed with torso placement, and during slow walking with ankle placement.

Based on our results, the ActivPAL3^{TM} had the highest agreement for steps taken compared with direct observation. In addition, the mean difference in Bland-Altman plots for the ActivPAL3^{TM} was smaller and the limits of agreement were narrower than the plots for the Fitbit Ones. Treacy et al. [22] found a higher level of agreement between direct observation and an ankle-worn Fitbit One than between the ActivPAL and directly-observed steps in patients admitted in general and stroke rehabilitation wards, which is in contrast with our findings. This could be due to the fact that patients with MS have different walking patterns compared with the patients with stroke, which could affect the accuracy of the ankle-worn Fitbit One and the ActivPAL for capturing steps. Storm et al. [47] also reported higher agreement between the waist-worn Fitbit One and visually counted steps than between the ActivPAL and steps counted by the researcher. These different findings could be potentially explained by differences in the populations under study which may be a function of walking speed, walking pattern, or device placement and, therefore, the accuracy of the devices for recording steps. The results of our study

cannot be generalized to other populations due to individual differences and characteristics.

3.5 Limitations

There are limitations to this study. Our sample size was relatively small and most of our participants were females with MS, therefore, the validity of the devices could be different in a male-dominant sample [48]. However, the majority of the MS population is female [49]. Our study was performed in a laboratory setting in which participants walked through a straight line in a hall-way. Greater errors may have been observed if walking had been assessed in a free-living environment. Additionally, our protocol encompassed a short walking test, therefore it is possible that smaller errors would have been observed over a longer walking distance. Lastly, we did not measure gait speed and cadence so in the future validity of the Fitbit One in individuals with MS with various gait speeds should be examined.

3.6 Conclusion

The ActivPAL3^{TM} demonstrated adequate concurrent validity for the measurement of sedentary behaviour in patients with MS. The device also appears accurate for measuring step count, which is the main form of physical activity performed by people with MS. The waist- and the ankle-worn Fitbit One positions were accurate for measuring step count. However, the ankle-worn Fitbit One is recommended for patients with MS who experience difficulty walking or use assistive devices as this placement performed better in people who walk slowly. Furthermore, the waist-worn Fitbit One may provide a more accurate daily record of steps in people with MS without the use of

walking aids. Future studies are recommended within free-living environments with larger samples of patients with MS, especially those with mobility impairments.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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CHAPTER 4. Comparison of Fitbit One and ActivPAL3^{TM} in adults with multiple sclerosis in a free-living environment

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Abstract

Walking is the most common and preferred way for people with multiple sclerosis (MS) to be active. Consumer-grade wearable activity monitors may be used as a tool to assist people with MS to track their walking by counting the number of steps. We evaluated the validity of Fitbit One activity tracker in individuals with MS by comparing step counts measured over a 7-day period against ActivPAL3^{TM}. Twenty-five ambulatory adults with MS with an average age 51.7 (10.2) years and gait speed 0.98 (0.47) metres/seconds, median EDSS 5.5 (2.5-6.5), and 15 years post-MS diagnosis wore Fitbit One (using both waist and ankle placement) and ActivPAL3^{TM} for 7 consecutive days. Validity of Fitbit One for measuring step counts against ActivPAL3^{TM} was assessed using Intraclass correlation coefficients (ICC), Bland-Altman plots and t-tests. Regardless of wearing location (waist or ankle), there was good agreement between steps recorded by Fitbit One and ActivPAL3^{TM} [ICC: 0.86 (0.82, 0.90)]. The ankle-worn Fitbit measured steps more accurately [ICC: 0.91 (0.81, 0.95)] than the waist-worn Fitbit [ICC: 0.81 (0.62, 0.85)] especially in individuals (n = 12) who walked slowly (gait speed = 0.74 m/s). Fitbit One as a user-friendly, inexpensive, consumer-grade activity tracker can accurately record steps in persons with MS in a free-living environment.

Keywords: Validity, Step counts, Physical activity, Activity monitor

4.1 Introduction

Regular physical activity leads to decreased risk of more than 25 chronic health conditions including obesity, cancers and hypertension (Warburton & Bredin, 2017). In people with multiple sclerosis (MS), physical activity is associated with reduction in rates of MS relapses, improvement of MS symptoms, and slowed disability progression over time (Dalgas & Stenager, 2012; Doring et al., 2011; Motl et al., 2008; Sandroff et al., 2012). However, physical activity levels are significantly reduced in persons with MS (Beckerman et al., 2010; Motl et al., 2005). The symptoms of MS such as fatigue, pain or depression in addition to disability accumulation represent the primary explanation for low levels of physical activity in the MS population (Crayton et al., 2004). These manifestations make it difficult for patients with MS to achieve or maintain the recommended amount of moderate-to-vigorous intensity physical activity (Motl, 2008; Motl et al., 2011; Motl et al., 2010).

Precise measurement of physical activity is essential to identify current activity levels, to assess changes in populations over time, and to evaluate the effectiveness of interventions aimed at increasing activity levels. When considering the measurement of physical activity in a population, it is important to identify the context in which the majority of activity takes place. Walking is the most common mode of activity in the context of a free-living environment and the preferred way to achieve physical activity throughout the day in individuals with MS (Weikert et al., 2011). Thus, consumer-grade wearable activity monitors may be an effective way of assisting individuals with MS to track their walking activities by counting the number of steps, a surrogate for physical activity levels (Balto et al., 2016). A valid consumer-grade activity tracker in a free-living

condition has the potential to provide valuable information as it is easy to use and may be beneficial for documenting individuals' status in clinical care over time (Arvidsson et al., 2019).

There are numerous consumer-grade wearable activity monitors on the market. Many have been tested in people with disabilities, including those with MS. Fitbit devices (Fitbit Inc, San Francisco, CA, USA) are amongst the most popular and user-friendly ones. Balto et al. (2016) conducted a study in a laboratory-setting and reported the Fitbit One as the most accurate and precise device in comparison with other consumer-grade activity monitors for measuring steps in ambulatory adults with MS. Earlier studies demonstrated the validity of the Fitbit One for measuring step counts in laboratory settings in healthy adults (Diaz et al., 2015), the elderly (Paul et al., 2015; L. A. Simpson et al., 2015) and patients admitted to rehabilitation wards (Treacy et al., 2017). Furthermore, there is evidence regarding the validity of the Fitbit One for measurement of steps in free-living environments in healthy adults (Ferguson et al., 2015; Middelweerd et al., 2017), female adults (Reid et al., 2017), men with prostate cancer (Van Blarigan et al., 2017), and stroke survivors (Hui et al., 2018). However, different gait patterns including frequent bilateral gait deficits and/or slower walking (Filli et al., 2018) in individuals with MS can impact activity tracker accuracy in a free-living environment. Moreover, use of walking aids (e.g., cane or walker) which is also prevalent in people with MS may influence the accuracy of the activity tracker.

Research-grade activity monitors provide more accurate activity data in comparison to consumer-grade devices (Napolitano et al., 2010). However, they are more expensive, less user-friendly and not accessible to the general public (Ferguson et al., 2015; Napolitano et al., 2010), which limits their daily use outside the research context.

Some of the research-grade monitors such as ActivPAL3^{TM} (PAL Technologies Ltd, Glasgow, UK) are considered accurate for measuring the daily number of steps and have been previously validated in adults (Sellers et al., 2016), young people (Sellers et al., 2016), the elderly with impaired function (Taraldsen et al., 2011) and patients with stroke (Taraldsen et al., 2011). There is also evidence regarding the validity of the ActivPAL3^{TM} for measuring step counts in patients with MS with moderate disability in a laboratory-setting depending on cadence and EDSS levels. (Coulter et al., 2017) It is unknown whether the Fitbit One provides similar information to that gained from a research-based monitor such as ActivPAL3^{TM}. Therefore, this study assessed the validity of the Fitbit One activity tracker in persons with MS within a free-living environment by comparing step counts measured over a 7-day period against ActivPAL3^{TM}.

4.2 Material and Methods

4.2.1 Study Design

We used a convergent validity design to compare step count measurement of a consumer-grade activity monitor (i.e., Fitbit One) to a previously validated research-grade accelerometer (i.e., ActivPAL3^{TM}). This study was part of a larger study called the "SitLess with MS" intervention program, which focused on interrupting prolonged sitting and replacing it with light-intensity physical activity during the day in ambulatory adults with MS (Aminian et al., 2019). This project was approved by the Health Research Ethics Board of the University of Alberta (# Pro000667657), the Northern Alberta Clinical Trials and Research Centre, and the Alberta Health Services Edmonton Zone (operational approval for recruitment through the Northern Alberta MS Clinic).

4.2.2 Study Context

This study used data collected during the interim time point (Week 8) of the "SitLess with MS" intervention. This was a 15-week activity promotion program where individual weekly coaching sessions were provided to participants with MS (excluding Weeks 0 and 15) to facilitate activity behaviour change and increase accountability and compliance with the program. The intervention was 15 weeks in length and included activity measurement (with a research-grade monitor) at baseline (Week 0), intervention mid-point (Week 8) and post-intervention (Week 15) (Aminian et al., 2019). The activity measurement at the interim time point, when the ActivPAL3^{TM} and the Fitbit One were worn simultaneously for a 7-day period, is the focus of this study. The 7-day interim activity measurement period started at midnight after the first coaching session of the "MoveMore" stage of the program and lasted until midnight before the second coaching session of the "MoveMore" stage, which included 7 consecutive days (Week 8) (Aminian et al., 2019).

4.2.3 Participants and Recruitment

Participants in the "SitLess with MS" program were recruited through community programs and the Northern Alberta MS Clinic at the University of Alberta as detailed in the protocol paper (Aminian et al., 2019). Participants were eligible for inclusion if they were: 1) diagnosed with MS by a neurologist for at least one year; 2) aged 18 years or over; 3) mild or moderately disabled (defined by Expanded Disability Status Scale (EDSS) score of 1-6.5) (Kurtzke, 1983); 4) relapse-free within the previous 3 months; and 5) able to walk 10 meters with or without a walking aid. Recruitment was done through community programs and the Northern Alberta MS Clinic at the University of

Alberta as described in the protocol paper (Aminian et al., 2019). All participants provided written informed consent for participation in the “SitLess with MS” program.

4.2.4 Study Procedures and Data Collection

4.2.4.1 Procedure for activity data collection at baseline time point

Participant characteristics including age, sex, body mass index (BMI), MS-related characteristics (i.e., type and duration), and disability status (defined by EDSS score) were collected at the baseline measurement session of the “SitLess with MS” intervention.

The Fitbit One was provided to each participant at the baseline measurement session of the program. At that time, the Fitbit application was installed on their phone, iPad, or laptop. The monitor was configured based on age, sex, height, and weight. Participants received basic instructions at this baseline session including log-in information as well as information about how to use the device and synchronize the Fitbit to the computer. Written instructions were provided to supplement the teaching at the baseline measurement session. Participants were asked to wear the Fitbit during all waking hours throughout the full intervention (15 weeks) and to remove it during water-based activities such as showering or swimming. A Fitbit log was given to each participant and they were asked to record wake and bedtimes and any time they removed the device for any reason. The intervention coach was able to view the participants' Fitbit data and reminded them to wear it (if needed) during their weekly sessions. Participants retained the Fitbit after intervention completion.

The Fitbit was worn either on the waist or the ankle, and placement was recorded. Evidence indicates that the Fitbit One performs better when worn on the ankle if walking

more slowly (Hui et al., 2018; Klassen et al., 2017; Treacy et al., 2017). Gait speed 0.80 meters/seconds appears to be the threshold where the accuracy of the Fitbit starts to decrease. Thus, participants who walked at a gait speed < 0.80 meters/ seconds during the 10-meter walk test at the baseline measurement session of the "SitLess with MS" program were directed to wear the device on a band around their ankle.

4.2.4.2 Procedure for activity data collection at interim time point

Participants wore the Fitbit, as described above, during the 7 days of data collection at the interim time point. They also wore the ActivPAL3^{TM}, which was initialized and mailed to them. An ActivPAL log was given to each participant to record wake and bedtimes, and any instances that they removed the device for any reason. They were instructed to attach the ActivPAL3^{TM} to the midline of the anterior aspect of the stronger thigh by waterproof non-allergic adhesive pads (Tegaderm, 3M Company, Canada) and wear it at all times during the 7-day period. After completion of 7 full days of activity monitoring, participants mailed the ActivPAL monitor along with the ActivPAL log to the research team. The Fitbit was worn on the same side as the ActivPAL (on either the waist or ankle).

4.2.5 Instruments

Fitbit One activity tracker is a small (4.8 x 1.9 cm x 1.0 cm) and lightweight (8 g) triaxial accelerometer that uses proprietary algorithms to count steps, distance travelled, stairs climbed, sleep, and calories burned. The Fitbit One can provide real-time feedback on either the device itself, on a smartphone or through simple software accessed by the internet (Fitbit website). The device collects data in 60-second intervals (epochs) and can be attached to the hip, bra, or ankle.

ActivPAL3^{TM} activity monitor is a small (3.5 cm × 5.3 cm × 0.7 cm) and lightweight (15 grams) triaxial accelerometer. The device measures thigh accelerations at a sampling frequency of 20 Hertz (Kim et al., 2015). It summarizes data in 15-second intervals (epochs) over a 24-hour period with the battery capacity allowing continuous recording for 7-10 days (Ryan et al., 2006). The monitor uses proprietary analysis algorithms in the manufacturer-provided software to determine posture (sitting time and upright time) and stepping (stepping time and step counts).

4.2.6 Data Management and Analysis

Steps data from the Fitbit One and the ActivPAL3^{TM} activity monitors were downloaded to a computer for analysis, using Fitabase (Small Steps Labs LLC) and Professional Research Edition software (PAL Software Suite Version 8**)**, respectively.

The number of valid days for the Fitbit One and the ActivPAL3^{TM} activity monitors throughout the 7 day-period were determined for each participant with the main goal of determining the number of days where valid days from the two monitors matched. A valid day for the Fitbit One was defined as one in which the Fitbit was worn for at least 10 hours (Gomersall et al., 2016; Middelweerd et al., 2017; Van Blarigan et al., 2017; Wang et al., 2015) during the 24-hour period from 12 AM to 12 AM. We considered a measurement day as "valid" when there was at least a 10-hour window between the time when the first two steps were taken in the morning (wake time) and the time when the last few steps were taken at night (bedtime). The participant's log was reviewed after preliminary analysis for confirmation of findings from the excel output.

A valid day for the ActivPAL3^{TM} was defined as a day where the device reported movement (standing or stepping) for at least 6 hours during wake time (Winkler et al.,

2016). The Chastin method (Chastin et al., 2014) with a few adjustments was used to determine wake and bedtimes. Wake time was defined as the first standing event after a long continuous period ≥ 2.5 hours of non-upright posture. Bedtime was defined by the last standing event before a long continuous period ≥ 3 hours of non-upright posture. Standing or stepping with a duration of ≥ 15 minutes occurring before 1:00 AM and after a sedentary bout of ≥ 2.5 hours was classified as waking time (van der Berg et al., 2016). To verify wake and bedtimes, the log was also checked. The R package version 3.6.1. (PAactivpal) (Lyden et al., 2017) was used to determine total daily step counts.

Participants who wore the Fitbit One for at least 3 valid days throughout the 7-day period with 3 matching valid days for the ActivPAL were included in the analysis. Valid days did not have to be consecutive. All analyzed data from the devices in the Excel spreadsheets were exported to SPSS statistical package Version 24 (Armonk, New York, USA, IBM Corp).

The total number of steps from the Fitbit One and the ActivPAL3^{TM} during each valid day was calculated for each participant. Descriptive statistics were presented as mean per day and standard deviation for the number of steps recorded by the Fitbit One activity tracker and the ActivPAL3^{TM} during the 7-day free-living condition.

Validity of the Fitbit One for measuring step counts against the ActivPAL3^{TM} was examined in several ways including Intraclass correlation coefficients (ICC), Bland-Altman plots and paired sample t-test. Intraclass correlation coefficients (ICC) for continuous data and their 95% confidence intervals (95% CI) were used to determine the level of correlation and agreement between the Fitbit One and the ActivPAL3^{TM}. A 2-way mixed-effects model, absolute-agreement definition, and single rater type (k = 1)

were used to determine convergent validity between the Fitbit One and the ActivPAL3^{TM} for matched valid days of the 7-day time period. An ICC value > 0.90 was defined as excellent, an ICC value between 0.75 and 0.90 ($0.75 \leq ICC \leq 0.90$) was defined as good, an ICC value between 0.50 and 0.74 ($0.50 \leq ICC \leq 0.74$) was defined as moderate, and an ICC value less than 0.50 ($ICC < 0.50$) was defined as poor (Koo & Li, 2016).

Bland–Altman plots were used to provide a visual representation of the differences between the steps recorded by the Fitbit and the ActivPAL against the means of the differences between the steps recorded by two devices in order to identify systematic differences between the devices (Bland & Altman, 1986). A paired sample t-test was also used to determine whether there is a statistically non-significant difference between the number of steps recorded by the two devices.

The number of steps on matched valid days was compared. Then, the average number of steps per valid day was calculated for each participant for the two devices and was compared. All analyses were conducted in SPSS software version 24 at a significance level of $P < 0.05$.

As discussed in the methods section, participants wore the Fitbit on either the waist or the ankle, allowing a sub-group analysis according to monitor placement. In addition, participants were divided into two groups based on their gait-speed: 1) Higher gait-speed group (≥ 0.80 m/s) and 2) Lower gait-speed group (< 0.80 m/s) (Bohannon & Williams Andrews, 2011). All analyses described above were repeated for both monitor placement and both gait-speed groups.

4.3 Results

Twenty-five participants (23 females and 2 males) out of the 41 ambulatory adults with MS who participated in the "SitLess with MS" program had at least 3 matching valid days between the two monitors. The other 16 participants in the "SitLess with MS" program either didn't have ActivPAL data (ActivPAL3^{TM} didn't record any data due to malfunction) or 3 matching valid days between the two devices. Participant characteristics are provided in Table 4-1.

Table 4-1: Participants' characteristics (N = 25)

Characteristics	Mean (SD) or n (%) Values	Min/Max
Age (years)	51.7 (10.2)	33-72
Sex (female)	23 (92%)	
Weight (kilogram)	76.9 (16.5)	45-109
Height (metre)	1.6 (0.06)	1.5-1.8
Body Mass Index (kilograms /metre^2)	28.6 (6.2)	17.2-44.3
Type of MS		
Relapsing-remitting	16 (64%)	
Secondary progressive	6 (24%)	
Primary progressive	3 (12%)	
MS Duration (years)	15.4 (12.4)	2-50
EDSS		
Mild disability (EDSS < 4)	12 (48%)	2-3.5
Moderate disability (4 ≤ EDSS≤ 6.5)	13 (52%)	5.5-6.5
Median (IQR)	5.5 (2.5-6.5)	
Uses Cane (unilateral, bilateral, or quad)	8 (32%)	
Uses Walker	5 (20%)	
Gait Speed (metres/second) *	0.98 (0.47)	0.03-1.71
Higher gait-speed group (n = 16)	1.28 (0.24)	0.83-1.71
Lower gait-speed group (n = 9)	0.44 (0.25)	0.03-0.72

Note. N: Number; SD: Standard Deviation; IQR: Interquartile Range.
* The gait speed that was measured at the baseline session of the "SitLess with MS" program is reported.

The majority of participants (n = 22) were middle-aged, diagnosed with relapsing-remitting MS (n = 16) and had reported moderate levels of disability (n = 13). Sixteen out of 25 were classified as overweight or obese as defined by a body mass index ≥ 25. Twelve participants (48%) used no walking aids.

The average number of steps recorded by the Fitbit One and the ActivPAL3^{TM} for participants with matched valid data and the average number of steps during valid days are summarized in Table 4-2. The overall mean (SD), minimum and maximum absolute differences between the ActivPAL3^{TM} and the Fitbit One were 1237.3 (1182.4), 3, and 7002 steps, respectively (Table 4-2).

Table 4-2: Daily and average step counts for each device and absolute differences between the devices during valid days

	ActivPAL3™ step counts			Fitbit One step counts			Absolute Difference between the devices		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Day 1 (n = 21)*	5005.3 (3141.6)	82	11708	4707.9 (3461.6)	72	11586	1301.1 (1221.8)	4	3747
Day 2 (n = 24)*	4969.1 (2918.2)	60	10884	4770 (3051.7)	225	11116	1358.8 (1453.4)	105	7002
Day 3 (n = 23)*	4746 (3057.2)	58	11778	4510.7 (3142.2)	160	10717	1115.1 (1044.3)	87	3891
Day 4 (n = 23)*	4326.1 (2671.7)	36	11674	4181.8 (3146.3)	83	10311	1197.2 (1097.7)	23	4323
Day 5 (n = 25)*	4991.6 (4087)	28	13718	4880.8 (4365.5)	65	13864	1260.2 (1272.3)	3	4465
Day 6 (n = 21)*	4711.9 (3049)	34	12394	4331.7 (3578.1)	126	12211	1333.6 (1190.5)	19	3972
Day 7 (n = 18)*	4437.6 (2996.9)	66	11936	4194 (3316.4)	146	11593	1082 (1029.8)	8	3409
Average over valid days (n = 25)	4752.5 (3126.5)	28	13718	4527.4 (3418.7)	65	13864	1237.3 (1182.4)	3	7002

Note. n: Number of participants with valid data, SD: Standard Deviation

*The number of individuals who participated in the study was 25. However, the number of individuals with valid Fitbit data on each day was different from the number of individuals with valid ActivPAL data on the same day. Therefore, n reflects the number of participants with both valid ActivPAL and Fitbit data on each day of the 7-day period and is thus less than 25.

The comparison (ICCs and t-test results) between the Fitbit One and the ActivPAL3^{TM} is shown in Table 4-3. In general, there was good agreement between the Fitbit One and the ActivPAL3^{TM} [overall average ICC = 0.86 (95% CI: 0.82, 0.90)] (Table 4-3). T-test results showed a statistically non-significant difference between the devices (Table 4-3).

Table 4-3: Intraclass Correlation Coefficients and paired sample t-test between the devices for daily stepcounts and the average step counts during valid days

Association between AP and FB	ICC (95% CI)	p-value	t value	p-value
Day1 (n = 21)*	0.85 (0.68, 0.93)	< 0.001	-0.76	0.45
Day 2 (n = 24)*	0.78 (0.55, 0.89)	< 0.001	-0.48	0.63
Day 3 (n = 23)*	0.88 (0.74, 0.94)	< 0.001	-0.73	0.46
Day 4 (n = 23)*	0.84 (0.67, 0.93)	< 0.001	-0.42	0.67
Day 5 (n = 25)*	0.91 (0.85, 0.96)	< 0.001	-0.32	0.75
Day 6 (n = 21)*	0.86 (0.69, 0.94)	< 0.001	0.99	0.33
Day 7 (n = 18)*	0.89 (0.73, 0.95)	< 0.001	-0.69	0.49
Average over valid days	0.86 (0.82, 0.90)	< 0.001	-1.65	0.10

Note. AP: ActivPAL3^{TM}; FB: Fitbit One; n: Number of participants with valid Fitbit and ActivPAL data; ICC: Intraclass Correlation Coefficients; CI: Confidence Interval, P: level of significance (< 0.05)

*The number of individuals who participated in the study was 25. However, the number of individuals with valid Fitbit data on each day was different from the number of individuals with valid ActivPAL data on the same day. Therefore, n reflects the number of participants with both valid ActivPAL and Fitbit data on each day of the 7-day period.

Bland-Altman plots providing a visual representation of the systematic differences and agreement between the devices for measuring steps are shown in Figure 4-1. The difference between the average step counts over valid days for the two devices was plotted against the mean of the average recorded steps over valid days for those devices for all 25 participants. For the majority of participants (n = 23), data (black round points) are placed around the mean and between the lower and upper limits of agreement. The outliers (black triangles) are related to only 2 participants with waist-worn Fitbits.

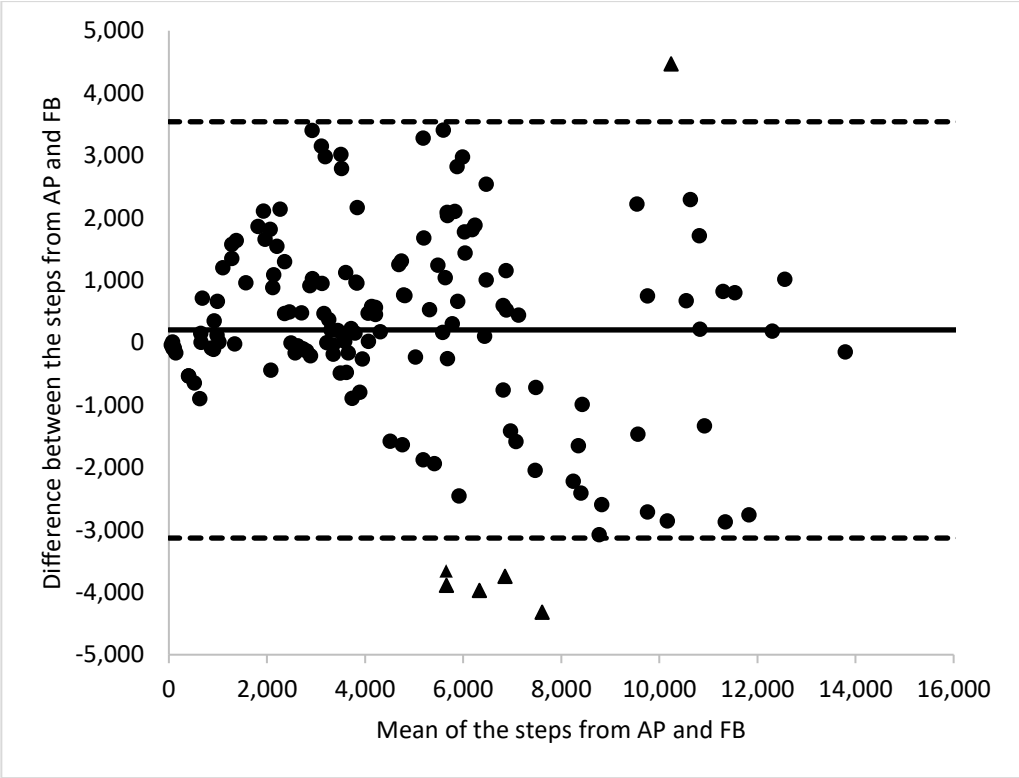

Figure 4-1: Bland-Altman plot comparing the average step counts over valid days from the Fitbit One and the ActivPAL3TM for all participants

Note. The solid line indicates the mean difference (205.4) between the two measures. The dashed lines indicate the upper (3541.33) and lower (-3130.53) limits of agreement (±1.96 standard deviations of the mean difference).
Each black point is the difference between the average step counts over valid days by two devices against the mean of the average recorded steps over valid days for those devices for each participant. The outliers are shown with triangles.

After analysis of the data for all participants, data were examined using stratified groups according to Fitbit placement and gait speed. Seventy-five % of those who chose to wear the Fitbit on their ankle (n = 9) used walking aids such as a cane or walker, whereas 70% of participants with the waist-worn Fitbit (n = 9) did not use any walking aids. The average gait speed in those who chose to wear the Fitbit on their ankle was 0.74 m/s while it was 1.20 m/s in those who wore the Fitbit on their waist. The average number of steps for participants for both Fitbit locations (waist and ankle), for the matched ActivPAL, the absolute difference between each Fitbit location and the matched ActivPAL, and the association between the Fitbit One and the ActivPAL (ICC) are shown

in Table 4-4. In general, there was good to excellent agreement between steps as recorded by the waist- and the ankle-worn Fitbit Ones and the ActivPAL3^{TM} (Table 4-4).

Table 4-4: Average step counts, absolute differences, and Intraclass Correlation Coefficients for two Fitbit locations

	Waist-worn Fitbit (n = 13)	**ActivPAL3^{TM} (n = 13)**	**Ankle-worn Fitbit (n = 12)**	**ActivPAL3^{TM} (n = 12)**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
	Min-Max	**Min-Max**	**Min-Max**	**Min-Max**
Average step counts during valid days	4800.7 (3130.2)	5742.2 (2956.3)	4415.2 (3726.1)	3745.8 (2995.5)
	491-13864	1098-13718	65-13205	28-10444
Absolute difference between the devices over valid days*	Mean (SD)	Min	Max	Mean (SD)	Min	Max
	1524.8 (1139.3)	51	4465	895.6 (1148.7)	3	7002
ICC (95% CI)	0.81 (0.62-0.89)**			0.91 (0.81-0.95) ***		

Note. n: Number of participants with valid data; SD: Standard Deviation; ICC: Intraclass Correlation Coefficients; CI: Confidence Interval

*The mean (SD), minimum and maximum absolute differences between the Waist-worn Fitbit and the ActivPAL3^{TM} and between the Ankle-worn Fitbit and the ActivPAL3^{TM}.

**The ICC between the waist-worn Fitbit One and the ActivPAL3^{TM}; ***The ICC between the Ankle-worn Fitbit One and the ActivPAL3^{TM}.

The average step counts for two activity monitors, the absolute differences between the devices, and the association between the two devices (ICC) at each gait-speed group are shown in Table 4-5. Overall, there was moderate to good agreement between steps recorded by the Fitbit One and the ActivPAL3^{TM} at both gait-speed groups (Table 4-5).

Table 4-5: Average step counts, absolute differences, and Intraclass Correlation Coefficients for both gait-speed groups

	Gait speed ≥ 0.80 metres/second			Gait speed < 0.80 metres/second		
	Fitbit One (n = 16) Mean (SD) Min/Max	ActivPAL3™ (n = 16) Mean (SD) Min/Max		Fitbit One (n = 9) Mean (SD) Min/Max	ActivPAL3™ (n = 9) Mean (SD) Min/Max	
Average step counts during valid days	5924 (3223.8) 749-13864	6170 (2802.7) 1098-13718		1999.7 (1964) 65-7198	2123.1 (1654.9) 28-6434	
Absolute Difference between the devices over valid days	Mean (SD) 1392.4 (1155.6)	Min 4	Max 4465	Mean (SD) 924 (1185.2)	Min 3	Max 7002
ICC (95% CI)	0.82 (0.74-0.87)			0.66 (0.47-0.79)		

Note. n: Number of participants with valid data; SD: Standard Deviation; ICC: Intraclass Correlation Coefficients; CI: Confidence Interval

4.4 Discussion

To our knowledge, this is the first study testing the convergent validity of the Fitbit One in ambulatory adults with MS through comparison with a research-grade activity monitor (ActivPAL3™) in a free-living environment. In general, we found a good agreement between steps recorded by the commercially available Fitbit One and the research-grade ActivPAL3™. The devices were comparable for quantifying the number of daily steps, however, the ICC confidence intervals for each day of the 7-day period were wide (Table 3) and the Bland Altman plot had wide limits of agreement with some outliers (Figure 1). Therefore, although the Fitbit One might be an accurate device for reporting steps in individuals with MS in a free-living environment over multiple days, the results should be interpreted with caution.

The level of agreement between the Ankle-worn Fitbit and the ActivPAL3^{TM} was higher (ICC = 0.91) and the 95% CI was narrower (CI: 0.81, 0.95) than between the waist-worn Fitbit and the ActivPAL3^{TM}. This indicates that the ankle-placement may be more accurate in slow-walking individuals such as patients with MS.

Coulter et al. (2017) demonstrated the ability of the ActivPAL3^{TM} to accurately measure walking activity in patients with MS with moderate disability (EDSS scores 4 - 6.5) within a laboratory setting. They found that the validity of the device for measuring the number of steps varied depending on cadence and EDSS levels with underestimating steps in those with slow cadences and higher EDSS levels (Coulter et al., 2017). They reported that steps measured by the ActivPAL3^{TM} in people moderately affected with MS with slow cadences should be interpreted with caution (Coulter et al., 2017). Misclassifying walking periods as standing by the ActivPAL3^{TM} and the lower acceleration of the thigh during the swing phase of gait in people with slow cadences which does not exceed the required threshold by the ActivPAL3^{TM} to record a step taken were mentioned as the main factors for underestimating steps (Coulter et al., 2017). Since the median EDSS in our sample was 5.5 which indicates moderate level of disability, the ActivPAL3^{TM} likely underestimated step counts especially in those with slower gait speed. Therefore, ActivPAL3^{TM} is not valid in measuring steps for everyone with MS as slow walking in those with a greater disability is where it starts to fail. Even though the Fitbit was comparable with the ActivPAL3^{TM} for recording the number of daily steps, the ActivPAL3^{TM} is not the gold standard as it underestimates steps in those with slow cadences.

Although there are no studies to allow direct comparison of our findings (i.e., Fitbit vs ActivPAL), several researchers have tested the validity of the waist-worn Fitbit One against the ActiGraph (ActiGraph, Pensacola, FL, USA) in different populations.

Our results are similar to the results of Reid et al., (2017), Middelweerd et al. (2017) and Van Blarigan et al. (2017) who reported the Fitbit One as a valid tool for measurement of steps in comparison with the ActiGraph GT3X in a free-living environment in women, healthy young adults and men with prostate cancer, respectively. In these studies, the Fitbit One slightly overestimated daily step counts by an average of 1100 (Reid et al., 2017), 677 (Middelweerd et al., 2017), and 700 (Van Blarigan et al., 2017) steps compared to the ActiGraph GT3X while we observed the Fitbit One to slightly underestimate daily steps counts by an average 1273 steps in comparison to the ActivPAL3^{TM}. Although the ActiGraph GT3X and the ActivPAL3^{TM} are both triaxial accelerometers, the differences in the device structure, placement, and algorithm for measuring steps might be responsible for the underestimation or overestimation of steps in comparison with the Fitbit One. Our findings are also in agreement with the findings of Hui et al. (2018) who found that the ankle-worn Fitbit One was in agreement with the ankle-worn Actical (Philips Respironics, Baltimore, MD, USA) for measuring the number of steps in adults with stroke in a free-living environment. They found that the Fitbit One underestimated step counts by an average of 220 steps per day (Hui et al., 2018) which is less than the current study. Accelerations at the ankle recorded by the Actical are possibly greater than the accelerations at the thigh throughout leg swing particularly in people who walk slowly and as a result, the ankle-worn device is more likely to capture more steps in slow-walking individuals such as patients with stroke and/or MS. It might be the reason that in our study, the waist-worn Fitbit slightly underestimated the number of steps compared to the thigh-worn ActivPAL3^{TM} while the ankle-worn Fitbit slightly overestimated steps. Considering research conducted to date, it appears the Fitbit One is comparable to some of the most accurate research-grade devices

for measurement of steps in a free-living environment. It may be a good choice in clinical practice and everyday wear.

Our findings regarding the ankle placement of the Fitbit One are in agreement with the results of Simpson et al. (2015), Treacy et al. (2017) and Klassen et al. (2017), who found that an ankle-worn device could accurately measure steps in slow-walking older adults (Simpson et al., 2015), slow-walking patients admitted to rehabilitation settings (Treacy et al., 2017), and patients with stroke (Klassen et al., 2017), respectively. The results of our study are also similar to the findings of Feehan et al. (2018) who reported that the step count accuracy was higher when the Fitbit Device was worn on the waist during normal-speed walking and when it was worn on the ankle during slow walking activities.

Even though we had more participants with bilateral gait deficits (as would be expected with MS) than previous studies in persons with stroke, gait speed continues to be one of the central determinants of accuracy. Regardless of the Fitbit placement, when participants were split into 2 groups based on their gait speed the ICC between the Fitbit One and the ActivPAL3^{TM} was less (ICC = 0.66 (0.47-0.79)) in the lower gait-speed group (< 0.80 m/s) which indicated a lower accuracy of the Fitbit One in individuals with very slow walking speed. This finding is in agreement with the results of Treacy et al. (2017) and Hui et al. (2018) who reported less accuracy of the Fitbit One in lower gait speeds in slow-walking patients admitted to rehabilitation settings and patients with stroke, respectively.

4.5 Limitations

The study involved a modestly sized sample of adults with MS with mild to moderate disability, reducing statistical power for some of the subgroup analyses undertaken. The number of participants for both the waist- and the ankle- placement and high and low gait-speed groups is relatively small and the majority of our sample were females and the association between the devices could be different in a male-dominant sample. Studies including more participants for each wearing location with various gait speeds (e.g., at least 30 participants at each group) and incorporating more male participants should be conducted in the future. Since only the validity of the Fitbit One device was assessed in the current study, the findings should not be generalized to other Fitbit devices.

4.6 Conclusion

Commercially available, relatively inexpensive devices, such as the Fitbit One, have the ability to measure step count reasonably well in a free-living environment. The device can encourage users to set specific activity goals (e.g., daily step counts) and to monitor progress throughout the day, week or month. In clinical situations, when the use of a research-grade activity monitor is not feasible and/or when patients with MS are keen to monitor their daily steps, the Fitbit One is an appropriate choice to be recommended by clinicians.

The ability of wearing the Fitbit One in different locations allows for a more comfortable wearing experience. Although the waist placement appears to be accurate in healthy populations, the ankle placement seems to capture steps more accurately in slow-

walking individuals such as patients with MS. Our findings of the ankle placement of the Fitbit activity tracker were novel in the MS population which highlights the importance of activity monitor placement on the validity of the measurements by the activity monitor in research settings or/and clinical practice.

Overall, the Fitbit One appears to be a useful and attractive tool for measuring step counts in the MS population given its user-friendly interface, low price, and ability to provide real-time monitoring. However, there are errors in using the Fitbit One in people with MS and data should be interpreted with caution.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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CHAPTER 5. Feasibility of use of a Fitbit activity tracker in adults with multiple sclerosis over 15 weeks

This chapter has not been submitted yet and the format is similar to Chapter 1.

5.1 Introduction

According to the According to the Canadian physical activity guidelines for special populations, adults with multiple sclerosis (MS) should engage in a minimum of 30 minutes of moderate-intensity aerobic activity twice a week and resistance training activities including all major muscle groups 2 days per week to gain optimal health benefits.[1] This is in line with the current evidence that exercise (physical activity) is a symptomatic and disease-modifying treatment in MS[2,3] and it is considered "medicine" for 26 chronic health conditions including MS.[4] Despite the benefits, physical activity levels are significantly reduced in persons with MS.[5,6] Less than 20% of patients with MS meet recommended physical activity guidelines[7] and there is a linear decline in their physical activity levels over time.[8] Inactivity increases the risk of comorbidities (e.g., hypercholesterolemia, hypertension, obesity, and type 2 diabetes)[9] and has detrimental effects on mobility, balance, muscle strength, disability progression and quality of life.[9,10]

A study by Ronda et al. with 2,600 men showed that inactive people are frequently not aware they are insufficiently active.[11] The use of an activity monitor that constantly records and displays the real-time physical activity level and provides instant feedback may increase awareness and help to reduce inactivity.[12,13] Hultquist et al.[14] reported that sedentary women who were given a pedometer and were instructed to walk 10,000 steps a day, took approximately 2,000 more steps per day than women who were only instructed to walk briskly for 30 minutes every day. Two systematic reviews also found that consistent use of wearable activity trackers is associated with higher levels of physical activity over time.[15,16]

Walking is the most common way to achieve physical activity in patients with MS and can be considered an ideal behaviour to target since both intensity and frequency can be gradually increased over time. Based on the evidence, the number of steps per day represents a reliable and valid measure of daily walking behaviour in MS.[17,18] Consumer-grade wearable activity monitors may be used as a beneficial tool to help individuals with MS track their walking activities by counting the daily number of steps, a surrogate for daily physical activity levels.[19] However, adherence to wearing an activity tracker is important in order to reap the potential benefits of increasing awareness of activity behaviour through monitoring. For instance, a study on 248 ambulatory adults with MS who were asked to wear the Fitbit One (Fitbit, Inc., San Francisco, CA, USA) over a 23-day study period showed an average of 20 days of wearing the device and a mean of 4,393 steps per day.[20] At the end of the study, the adherence rate of the participants for using the Fitbit One was 87%, and 68% of participants reported the device useful for self-management of activity behaviour.[20] Therefore, their results[20] showed that it is feasible to integrate these technologies with the everyday life of individuals with MS in order to measure and increase physical activity levels and improve MS-related symptoms and health-related quality of life. Nevertheless, it is unknown whether it is feasible to use a consumer-grade activity monitor such as the Fitbit One over a longer period such as a few months. Therefore, we assessed the feasibility of the use of a consumer-grade activity monitor (i.e. Fitbit One) over 15 weeks in ambulatory adults with MS.

The efficacy of the "SitLess with MS" intervention, a behaviour change intervention focused on sitting less and moving more,[21] on the step counts recorded by the Fitbit One and by the research-grade activity monitor (i.e. ActivPAL3™ (PAL Technologies Ltd, Glasgow, UK)) will also be evaluated.

5.2 Material and Methods

5.2.1 Study Design

This study was part of a larger study called the "SitLess with MS" program, which used a single group repeated measures design. The "SitLess with MS program" focused on interrupting prolonged sitting and replacing it with light-intensity physical activity in ambulatory adults with MS. The intervention and study methods are described in detail in the protocol paper [21]. This project was approved by the Health Research Ethics Board of the University of Alberta (# Pro000667657), the Northern Alberta Clinical Trials and Research Centre, and the Alberta Health Services Edmonton Zone (operational approval for recruitment through the Northern Alberta MS Clinic).

5.2.2 Study Context

This study reports on the physical activity data (from Fitbit and ActivPAL monitors) collected during the "SitLess with MS" intervention. The intervention was a 15-week activity promotion program including two stages: SitLess stage (Weeks 1-7) and MoveMore stage (Weeks 8-15). Weekly coaching sessions (excluding Weeks 0 and 15) between an intervention coach and a participant were used to facilitate activity behaviour change and enhance accountability and compliance with the program. There were 4 measurement points including pre-intervention or baseline (Week 0), intervention mid-point or interim (Week 8), post-intervention (Week 15) and follow-up (Week 22) (see figure 1 for the timeline of study activities).

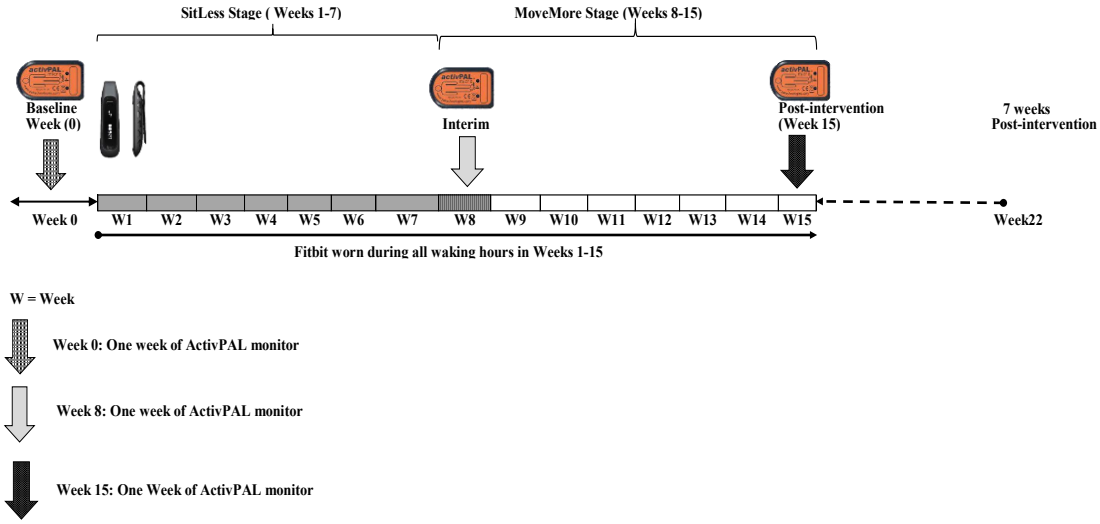

Figure 5-1: Timeline of the "SitLess with MS" intervention program.

The figure is redrawn based on the figure from Aminian S, Motl RW, Rowley J, Manns PJ. Management of multiple sclerosis symptoms through reductions in sedentary behaviour: protocol for a feasibility study. *BMJ Open*. 2019;9(4):e026622. Participants were seen in person at baseline, post-intervention, and 7 weeks post-intervention only. Participants wore the Fitbit during the 15-week intervention. They wore the ActivPAL for 7 consecutive days at baseline (Week 0), interim (Week 8), Post-intervention (week 15) and 7-weeks post-intervention (Week 22) for measurement of activity behaviour change over time.

5.2.3 Participants and Recruitment

Inclusion criteria for this study were as follows: 1) diagnosis of MS by a neurologist for at least one year; 2) age 18 years or over; 3) mild or moderately disability (defined by Expanded Disability Status Scale (EDSS)[22] score of 1-6.5); 4) relapse-free within the previous 3 months; 5) able to walk 10 meters with or without a walking aid; 6) physically inactive (defined as insufficiently active by a score of less than 14 on the Godin-Shephard Leisure-Time Physical Activity Questionnaire)[23]; and 7) mobile phone access. Recruitment was done through community programs and the Northern Alberta MS Clinic at the University of Alberta as explained in the protocol paper.[21] All

participants provided a written consent form before the baseline measurement.

5.2.4 Study Procedures and Data Collection

Participant demographic and clinical characteristics including age, sex, body mass index (BMI), MS-related characteristics (i.e., type and duration), and disability status (defined by EDSS score) were collected at the baseline assessment of the "SitLess with MS" intervention.

Participants attended the baseline measurement session and were set up with an ActivPAL3^{TM} activity monitor to wear for 7 days (Week 0) (See Figure 5-1). They were also instructed how to attach the ActivPAL3^{TM} to the midline of the anterior aspect of the stronger thigh by waterproof non-allergic adhesive pads (Tegaderm, 3M Company, Canada) in case they had to remove it for any reason and wear it again. Participants were given a log to write down any time they removed the device for any reason.

A Fitbit One was given to each participant by researcher as a self-monitoring tool at the baseline measurement session. The Fitbit application was installed on their phone, iPad or laptop and was initialized based on age, sex, height, and weight. Written instructions were provided to supplement the teaching at the baseline measurement session.

On day 1 of the intervention, participants had the first one-on-one coaching session of the SitLess stage. At that time, they removed the ActivPAL3^{TM} and started wearing the Fitbit One activity tracker (Week 1) (See Figure 5-1). They were instructed to wear the Fitbit during all waking hours throughout the 15-week intervention period and to only remove it during water-based activities such as showering or swimming. Participants attached the Fitbit One to the same side as the ActivPAL3^{TM} on one of the

following locations: (i) on the waistband, just above the greater trochanter by a clip, or (ii) on the ankle, just above the lateral malleolus by an elastic band. Based on the research evidence, the Fitbit One performs better for people who walk slowly, when worn on the ankle.[24–26] For the most part participants who walked more slowly wore the device on a band around their ankle, but Fitbit placement was the choice of participants. Participants received a Fitbit log (i.e., different from the ActivPAL log) at the baseline measurement session to write down any time they removed the device for any reason.

During the weekly coaching sessions (excluding Weeks 0 and 15), the participants and coaches reviewed and discussed the Fitbit activity graphs together to interpret participants' activity behaviours. The following strategies were used to facilitate Fitbit wear for the participants. A researcher (GM) viewed the participants' Fitbit data on a weekly basis, and if participants were not wearing the monitor, the intervention coach was alerted. In the next coaching session, the intervention coach discussed Fitbit wear with the participant and encouraged them to wear it daily. Participants were contacted directly if there were apparent or reported technical issues with the Fitbit. Participants received a new Fitbit if the technical difficulties were not solvable, or if the monitor was lost.

The follow-up time point (Week 22) is not the focus of the current study as we didn't follow the participants' Fitbit wear after the post-intervention measurement session.

On the day of the first one-on-one coaching session of the MoveMore stage (First day of Week 8), participants put on the ActivPAL3^{TM}, which was initialized and mailed to them. Participants wore the ActivPAL3^{TM} for 7 days (see Figure 5-1). The

ActivPAL3^{TM} was worn for the assessment of activity-related behaviour change at the end of the SitLess stage compared to pre-intervention. The ActivPAL3^{TM} was removed on the day of the second one-on-one coaching session of the MoveMore stage (The first day of Week 9). An ActivPAL3^{TM} was again initialized and given to each participant to wear at the post-intervention measurement session, extending for the 7 days after intervention completion (See Figure 5-1). The ActivPAL3^{TM} was worn for the assessment of activity-related behaviour change at the end of the MoveMore stage compared to pre-intervention and the end of the SitLess stage. The ActivPAL3^{TM} was mailed to the research team by each participant after completion of the 7-full day monitoring at each measurement time point.

5.2.5 Instruments

ActivPAL3^{TM} is a small (3.5 cm × 5.3 cm × 0.7 cm), light-weight (15 grams), triaxial, research-grade physical activity monitor. It measures accelerations of the thigh at a sampling frequency of 20 Hertz with signal generation related to thigh inclination [27]. The device summarizes data in 15-second intervals (epochs) over a 24-hour period [28] and provides output for body postures (lying/sitting, standing, and stepping) using a proprietary algorithm in the manufacturer-provided software. In general, the ActivPAL3^{TM} measures time spent in sedentary behaviour (sitting or lying), and upright positions (standing and walking), numbers of sit-to-stand and stand-to-sit transitions, and step counts. [27] For this study, we focus on the measurement of stepping. Sedentary behaviour outcomes have been reported previously.[29]

The Fitbit One activity tracker is a light-weight (8 grams) and small (4.8 cm x 1.9 cm x 1.0 cm), triaxial consumer-grade accelerometer that records steps, stairs climbed,

distance travelled, sleep, and calories burned. It is a relatively affordable device that can provide real-time feedback on either the device itself, on a smartphone or via simple software accessed by the internet. The device summarizes data in 60-second intervals (epochs). A study in ambulatory adults with MS reported the Fitbit One as the most accurate and precise device in comparison with other consumer-grade activity monitors for measuring steps in a laboratory-setting.[19] The evidence indicates validity of the Fitbit One for measurement of steps in free-living environments in healthy adults,[30,31] female adults,[32] men with prostate cancer[33] and stroke survivors.[26] Therefore, the Fitbit One was selected to be used in the "SitLess with MS" program.

A Fitbit Zip (Fitbit, Inc., San Francisco, CA, USA) was given to participants if they lost their Fitbit One during the 15-week intervention and the Fitbit One was not available. The Fitbit Zip is a small (3.5 cm× 2.9 cm× 0.9 cm) and light-weight (8 g) tri-axial consumer-grade accelerometer. The device records step count, distance, and energy expenditure (kcal) with 4 to 6 months of battery life. Evidence indicates high accuracy of the Fitbit Zip for measuring step counts in healthy adults[31,34,35] and patients with Stroke[36]. In addition, it can be attached to either the hip or ankle as with the Fitbit One.

5.2.6 Data Management and Analysis

Steps data from the Fitbit One for each participant were downloaded weekly to an Excel spreadsheet, using Fitabase (Small Steps Labs LLC). Steps data from the ActivPAL3^{TM} for each participant were downloaded to a computer for analysis, using Professional Research Edition software (PAL Software Suite Version 8**)**. The ActivPAL3^{TM} data were downloaded in the Excel spreadsheet as the number of steps taken every 15-seconds during a 24-hour day.

Fitbit feasibility

The total number of Fitbit valid days during 15 weeks of the intervention was calculated for each participant, using the rules below:

A valid day for the Fitbit One was defined as one in which the Fitbit was worn for at least 10 hours[30,33,37,38] during the 24-hour period from 12 AM to 12 AM. We considered a measurement day as 'valid' when there was at least a 10-hour window between the time when the first two steps were taken in the morning (wake time) and the time when the last few steps were taken at night (bedtime). The participant's log was reviewed after preliminary analysis for confirmation of findings from the excel output.

The mean number of valid days over the 15-week intervention was computed for the full sample. The number of valid days the Fitbit was worn during each of the SitLess and the MoveMore stages for each participant were also calculated, allowing determination of any differences in valid days between stages. The percentage of the total number of valid days at each stage in relation to the total number of valid days for the full intervention was calculated for each participant.

Preliminary efficacy of the "SitLess with MS" intervention on steps data recorded by the activity monitors

The preliminary efficacy of the "SitLess with MS" intervention on the number of steps recorded by the Fitbit and the ActivPAL were evaluated at 3 different time points. The Fitbit time points were different from the ActivPAL time points. Each time point is defined below (See Table 5-1).

Table 5-1: Three-time points for the measurement of activity behaviour by Fitbit and ActivPAL

Timeline	Start	End	Timeline duration
Baseline ActivPAL time point (Week 0)	Midnight after the baseline measurement session	Midnight before the first coaching session of the SitLess stage	Seven consecutive days
Baseline Fitbit time point (Week 1)	Midnight after the first coaching session of the SitLess stage	Midnight before the second coaching session of the Sit-Less stage	Seven consecutive days
Interim Fitbit and ActivPAL time point (Week 8)	Midnight after the first coaching session of the MoveMore stage	Midnight before the second coaching session of the MoveMore stage	Seven consecutive days*
Post-Intervention Fitbit time point (Week 14)	Midnight after the final coaching session of the MoveMore stage	Midnight before the day of post-intervention assessment	Seven consecutive days
Post-Intervention ActivPAL time point (Week 15)	Midnight after the post-intervention measurement session		Seven consecutive days

*As Week 8 is the end of the SitLess stage and the beginning of the MoveMore stage, it was considered as the interim time point and was included in the analysis.

Participants who wore the Fitbit for at least 3 valid days throughout the three 7-day time points (Week 1, Week 8, and Week 14) and the ActivPAL3^{TM} for at least 3 valid days throughout the three 7-day time points (Week 0, Week 8 and Week 15) were included in the analysis. Valid days did not have to be consecutive.[38]

A valid day for the ActivPAL3^{TM} was defined as a day where the device reported movement (standing or stepping) for at least 6 hours during wake time.[39] The Chastin method[40] with a few adjustments was used to determine wake and bedtimes. Wake time was defined as the first standing event after a long continuous period ≥ 2.5 hours of non-upright posture. Bedtime was defined by the last standing event before a long continuous

period ≥ 3 hours of non-upright posture. Standing or stepping with a duration of ≥ 15 minutes occurring before 1:00 AM and after a sedentary bout of ≥ 2.5 hours was classified as waking time.[41] To verify wake and bedtimes, the log was also checked. The R package version 3.6.1. (PAactivpal)[42] was used to determine total daily step counts.

As the preliminary efficacy of the "SitLess with MS" intervention program on the number of steps recorded by the Fitbit One and the ActivPAL3^{TM} were evaluated separately, the valid days for the Fitbit One were not necessarily the same as the valid days for the ActivPAL3^{TM}. The total number of steps from the Fitbit One during each valid day throughout the three 7-day time points (Week 1, Week 8 and Week 14) and the total number of steps from the ActivPAL during each valid day throughout the three 7-day time points (Week 0, Week 8 and Week 15) were determined for each participant. Then, the total number of steps per the number of valid days and the average step counts during those valid days were computed at each time point for each participant.

All data from the Fitbits and the ActivPAL3^{TM} activity monitors in the excel spreadsheets were exported to SPSS software version 24 (IBM SPSS Statistics for Windows, Version 24.0; Armonk, NY: IBM Corp). Descriptive statistics were presented as mean and standard deviation (SD) and percentage to describe the study participants, daily step counts from the Fitbit and the ActivPAL^{3TM}, and the Fitbit feasibility outcomes. A linear mixed effect model respecting the independence of measures over time was used to determine whether the average number of steps from the Fitbit and the ActivPAL changed over time from Week 0 or 1 vs Week 8 vs Week 14 or 15. The effect size was calculated using Cohen's d for the average number of steps at Week 8 and Week 14 or 15 for both devices and was interpreted as small, medium, or large. All the analyses were conducted in SPSS software version 24 (IBM SPSS Statistics for Windows, Version 24.0;

Armonk, NY: IBM Corp) at a significance level of $p < 0.05$.

5.3 Results

Forty-one participants were enrolled in the "SitLess with MS" program at baseline and 41 and 39 participants completed the interim and post-intervention assessments, respectively. Participants were primarily female (n = 37) and had moderate levels of disability (n=23) as demonstrated by the EDSS scores. The majority of participants (n = 31) were middle-aged, diagnosed with relapsing-remitting MS (n=26) and classified as overweight or obese as defined by a body mass index ≥ 25 (n=24). Twenty-three out of 41 participants used walking aids. Participants' characteristics are presented in Table 5-2.

Table 5-2: Participants' characteristics (n = 41)

Characteristics	Mean (SD) or n (%) Values	Min/Max
Age (years)	50.5 (10.2)	31-72
Sex (female)	37 (90 %)	
Weight (kilograms)	77.5 (19.1)	45-122
Height (metres)	1.6 (0.07)	1.5-1.8
Body Mass Index (kilograms /metre^2)	28.4 (6.2)	17.2-44.3
Type of MS		
Relapsing-remitting	26 (63%)	
Secondary progressive	11 (27%)	
Primary progressive	4 (10%)	
MS Duration (years)	14.3 (11.2)	1-50
EDSS		
Mild disability (EDSS < 4)	18 (44%)	1.5-3.5
Moderate disability (4≤ EDSS≤ 6.5)	23 (56%)	4-6.5
Median (IQR)	5.5 (2.5-6.5)	
Walking Aids		
Cane (unilateral, bilateral, or quad)	14 (34%)	
Walker	9 (22%)	
Education		
High school or less	10 (24%)	
College/Diploma	15 (37%)	
Bachelors	11 (27%)	
Masters	5 (12%)	

MS: Multiple sclerosis; n: Number; SD: Standard Deviation; IQR: Interquartile Range.

For 2 participants, the Fitbit Zip was used to replace a lost Fitbit One and 3 participants also started the intervention with the Fitbit Zip, because the Fitbit One was no longer available.

Feasibility of Fitbit Use

According to the rules for determination of a Fitbit valid day (i.e., the Fitbit was worn for at least 10 hours during the 24-hour period from 12 AM to 12 AM), 34, 33 and 34 participants met the Fitbit wear criteria at baseline, interim and post-intervention,

respectively. These participants were included in the feasibility analysis. The average number of Fitbit steps per valid day during each week of the "SitLess with MS" program is summarised in Table 5-3. The last weekly coaching session between a participant and an intervention coach was done on Week 14 and there was no coaching session at Week 15. Some participants therefore might forget to wear the Fitbit from the time they woke up in the morning at Week 15 since there was no reminder and as a result, the number of participants with valid Fitbit data at Week 15 was fewer (Table 5-3).

Table 5-3: Number of Fitbit steps per valid day at each week of the "SitLess with MS" Intervention

Week	Number of participants with valid Fitbit data	Number of steps per valid day	
		Mean (Standard Deviation)	Min-Max
Week 1	34	4767.5 (4021)	231-15705
Week 2	35	4148 (3378)	98-12052
Week 3	36	4219.4 (3633.2)	130-14035
Week 4	35	4312.9 (3250.4)	153-11691
Week 5	34	4251.1 (3228.1)	215-11187
Week 6	35	4203.3 (2887.7)	59-9983
Week 7	35	4745.7 (3347.3)	139-12091
Week 8	33	5103.6 (3592.4)	317-16460
Week 9	33	4866.5 (3657)	213-16326
Week 10	34	4900.6 (3231.5)	144-11376
Week 11	34	5092 (3361.7)	184-12667
Week 12	34	4963.3 (3482)	306-12394
Week 13	34	5199.3 (3347.6)	203-12666
Week 14	34	5291.2 (3553.6)	171-14544
Week 15	26	4479.7 (3036)	152-13366

The average number of Fitbit valid days during the SitLess stage, the MoveMore stage and the Full intervention are shown in Table 5-4. In general, the average length of the intervention was 100.2 (7.7) days and on average there were 85 Fitbit valid days

(85%) throughout the full intervention period (Table 5-4). The average number of Fitbit valid days at the SitLess stage composes 49.6% of the Full intervention valid days, which is almost similar to the MoveMore stage.

Table 5-4: Number of Fitbit valid days at each stage and full intervention

Intervention	Number of Fitbit valid days	
	Mean (Standard Deviation)	Min-Max
SitLess stage	42.5 (8.8)	6-49
MoveMore stage	42.8 (11.7)	0-49
Full intervention	85.6 (19.7)	6-98

Preliminary efficacy of the intervention on Fitbit and ActivPAL recorded steps

Analysis of the preliminary efficacy of the "SitLess with MS" intervention on Fitbit steps data was limited to 33 and 34 participants at interim and post-intervention time points, respectively. This was due to the number of participants with valid Fitbit data at those time points. (Table 5-5). There was no significant change in the average number of Fitbit steps per valid day from baseline to interim and post-intervention (See Table 5-5).

Analysis of the preliminary efficacy of the "SitLess with MS" intervention on ActivPAL steps data was limited to 27 and 37 participants at interim and post-intervention time points, respectively. This was the number of participants with valid ActivPAL data at those time points. (See Table 5-5). There was a significant increase in average step counts per valid day recorded by the ActivPAL from baseline to post-intervention (see

Table 5-5). However, no significant change from baseline to the interim time point was observed (See Table 5-5).

Table 5-5: Change in number of steps per valid days across three-time points

Time points		n	Steps per valid days from Fitbit		n	Steps per valid days from ActivPAl3™	
Baseline							
Mean	SD	34	4767.5	4021	40	4668.9	2993.6
Interim							
Mean	SD	33	4925	3317.7	27	4405.3	2935.7
Post-intervention							
Mean	SD	34	5291.2	3553.6	37	5563.6	3239.3
Interim-Baseline							
Mean difference	p		291.6	1.00		304	0.29
(95% CI)			(-648, 1231.4)			(-148.7, 756.8)	
Postintervention-Baseline							
Mean difference	p		523.7	0.59		639	0.02
(95% CI)			(-484.5, 1532.1)			(77.7, 1200.3)	
Postintervention-interim							
Mean difference	p		232	0.90		335	0.69
(95% CI)			(-327.2, 791.4)			(-356.5, 1026.5)	

SD: Standard Deviation; p: Level of significance, n: Number of participants; CI: Confidence interval

The effect size of the intervention on the number of steps recorded by the activity monitors is shown in Table 5-6. The ActivPAL showed larger effect sizes at all 3-time points.

Table 5-6: Effect size of the intervention on the number of steps recorded by the activity monitors

	Cohen's d Effect size		
	PI-B	**interim-B**	**PI-interim**
Steps from Fitbit One	0.14	0.04	0.10
Steps from ActivPAl3™	0.29	0.08	0.37

B: Baseline; PI: Post-intervention

5.4 Discussion

To our knowledge, this is the first study testing the feasibility of using a consumer-grade activity tracker such as the Fitbit over a few months (i.e., 15 weeks) in adults with MS. The current study expands the published literature on the feasibility of the use of a consumer-grade activity monitor to record free-living activity behaviour over a longer period in individuals with MS. The average number of Fitbit valid days was 85 (i.e., 85% of the full intervention period) showing that participants were willing to monitor their activity behaviour over a long period of time. The number of Fitbit valid days (i.e., days with wearing the Fitbit for at least 10 hours) was not different during both the SitLess and the MoveMore stages which means that the focus of the stage did not affect wear. Although the Fitbit application only provides real-time feedback on the number of daily steps (i.e., the primary focus of the MoveMore stage), it didn't make any difference in Fitbit wear at both stages. The results, therefore, indicate the feasibility of wearing the Fitbit activity tracker in interventions that focus on sedentary behaviour and/or physical activity in the MS population.

No significant change was observed in the average number of Fitbit steps per valid day from baseline to interim and post-intervention time points. The intervention showed a non-significant small effect on the steps recorded by the Fitbit (d: 0.14). However, measurements from the ActivPAL showed a statistically significant increase in average step counts per valid day from baseline to post-intervention (Table 5-5). The effect of the intervention on recorded steps from the ActivPAL was also small (effect size of d: 0.29, see Table 5-6) but statistically significant.

The ActivPAL3^{TM} is a research-grade accelerometer and is more accurate[43] than a consumer-grade activity tracker such as the Fitbit One for measuring daily step counts. Therefore, it might be able to record more steps especially at slower gait speeds than the Fitbit activity tracker. Moreover, participants were asked to wear the ActivPAL for 24 hours while they were instructed to only wear the Fitbit during waking hours and to remove it before going to bed (maximum 16 hours per day). Sometimes participants might not have worn the Fitbit from the time they woke up in the morning and as a result, the Fitbit was worn for fewer hours. All the above reasons may cause the Fitbit to miss recording some activity (i.e., fewer steps) comparing to the ActivPAL and as a result, the interventions didn't show a non-significant effect on the number of steps recorded by the Fitbit.

The average number of Fitbit steps per valid day at baseline (Week 1), interim (Week 8) and post-intervention (Week 14) time points were 4,767.5, 5,103.6, and 5,291.2, respectively which demonstrates a greater change from baseline to interim than from interim (beginning of the MoveMore Stage) to post-intervention. The results show that although participants took more steps in the MoveMore stage as the main focus of the MoveMore stage was on increasing daily step counts, the magnitude of change from

interim to post-intervention was less. It is possible that the participants were more motivated at the beginning of the "Sitless with MS" intervention to change their activity behaviour or/and wore the Fitbit for more hours daily. Furthermore, although the program had separated focusing on the reduction of sedentary behaviour and increasing light-intensity physical activity in 2 different stages, our intervention might be more suitable for motivating people to decrease sedentary time than encouraging them to take more steps. Therefore, more change in the number of steps from baseline to interim than interim to post-intervention might be a result of the overall reduction in total daily sedentary time rather than trying to take more steps. In addition, seasonality may play a role in the non-significant change in the average number of steps from baseline to interim and to post-intervention time points since our data were collected from 2017 to 2019 and data collection was done in Fall and Winter for some participants when physical activity is lower.[44] The variability in the course of the disease may also contribute to less change in the step counts for some participants as their symptoms are worse sometimes and they take probably fewer steps on those days.

The average number of daily steps at the SitLess stage (i.e., average of steps from Weeks 1-7) was 4,378.2 ± 3,392.2 which is less than the average daily steps at the MoveMore stage (i.e., average of steps from Weeks 8-14) (5,059 ± 3,460.8). This is likely explained by the fact the main focus of the SitLess stage was interrupting prolonged sitting while the MoveMore stage primarily focused on increasing the daily number of steps, an overall increase in daily light-intensity physical activity and maintaining reduction in total daily sedentary time.

The average daily number of steps during 15 weeks was 4,702.94 (3,400.5) which is similar to a study using the Fitbit One for measurement of daily steps over 23 days (i.e.,

4,393 ± 2,603) in 114 ambulatory adults with MS.[20] They reported an average of 20 days of wearing the device over the 23-day study period (i.e. 86% of the full intervention period)[20] which is the same as the current study. The mean age of participants in the current study was 50 years old with a mean disease duration of 14 years and the majority were females with relapsing-remitting MS, which is very similar to the aforementioned study.[20] Furthermore, participants in our study received weekly coaching sessions to accelerate accountability and compliance with the program and participants in that study also received regular email reminders throughout the study period containing information on how to use the activity monitor and contact information for study personnel.[20] It demonstrates the effect of coaching and being in contact with participants on facilitating wear and adherence and compliance with wearing the activity tracker. Thus, adherence with wear might be different in a study with no coaching or communication with participants (e.g., sending email reminders). The reported step counts in our study at baseline are less than another study measuring 7-day activity behaviour of 645 adults with MS using either Yamax SW-200a pedometers or ActiGraph accelerometers.[45] They reported an average of 5,903 ± 3,185 daily steps in their sample.[45] The majority of their participants had mild disability (PDDS score ≤ 2) and shorter disease duration (i.e., 9.3 ± 7.8 years).[45] The average age of the sample was 46.3 years, which is younger than our sample.[45] In addition, the steps were measured by ActiGraph accelerometer for 58% of participants[45,] which is more accurate than a consumer-grade activity tracker[43] and might be able to record more daily steps. All those differences might explain the higher number of daily steps in their study comparing to the current study.

The average daily step count (i.e., the average of steps during the entire 15-week intervention) for persons with MS from the current sample (4,702.94 ± 3,400.5) is less

than the mean daily step count observed in persons with other neuromuscular diseases (i.e., 5,769 steps).[46] It is also significantly less than the average step counts from previous studies of 3,744 healthy adults in the United States (9,676 ± 1,079)[47] and 1,853 healthy adults in Finland (7,499 ± 2,908).[48] These findings indicate that individuals with MS are less physically active than the general population.[5,49] Nevertheless, different physical activity monitors were used in both studies and the duration of wearing the activity monitors was 7 days. Thus, the difference in daily steps might be due to differences in the study population or/and measurement devices.

The results of our study regarding the step count recorded by the ActivPAL are different from a randomized controlled trial by Ryan et. al. which evaluated the effectiveness of a 3-month behaviour change intervention on the levels of objectively measured activity behaviour immediately and 6-months post-intervention in adults with MS.[50] The average number of steps recorded by the ActiGraph GT3X in the intervention group at baseline, post-intervention and follow-up were 3,334.7 ± 2,384.7, 3,560.1 ± 2,506.1 and 3,798.2 ± 2,988.8,[50] respectively. This indicates less change from baseline to 3 months and 9 months in comparison to our study from baseline to interim and post-intervention. Even though they primarily focused on increasing daily physical activity levels and less focus was on reduction of sedentary behaviour[51] in the intervention group, the magnitude of change in average step counts from baseline to post-intervention and follow-up was less than our study. The differences in study design and type of research-grade activity monitor and the longer period of the follow-up (9 months) might be responsible for the lower change in average number of steps in Ryan's study.

5.5 Limitations

A limitation of this study was the small sample size; however, the "SitLess with MS" intervention was a pilot feasibility study and the number of participants was in line with other feasibility studies. [51–54] The majority of our sample were White females with relapsing-remitting MS, and the results may be different in a sample including persons with progressive MS and various ethnicities. The lack of a control group didn't allow the evaluation of the effectiveness of the intervention and the preliminary efficacy was thus tested. Only patients with MS who had mild to moderate disability were included, and the findings are not generalizable among non-ambulatory persons with MS. Since the Fitbit One and the Fitbit Zip have been used in the current study and they are mainly worn on the waist (54%), the findings should not be generalized to other Fitbit devices.

5.6 Conclusion

The present research provides evidence that participants with MS will wear a Fitbit over the 15-week period of an intervention. In general, wearing a Fitbit activity monitor is convenient and is compatible with most daily activities, making it a practical choice for everyday use. The device encourages users to set specific activity goals (e.g., daily step counts) and to monitor progress throughout the day, week or month. It also provides instant feedback on goal achievement, either on the device or through a user-friendly web-based interface, which may make it a useful tool for documenting persons' activity status in clinical care over time.[55] In regard to evaluating the efficacy of an intervention on the step counts recorded by activity monitors, the research-grade devices might be a better choice as they are more accurate. Nevertheless, if a consumer-grade activity tracker is worn 24 hours, the findings from the study may be more accurate and

the chance of missing activity data and lack of intervention effect may be less. Lastly, testing activity behaviour interventions with randomized controlled trial design in individuals with MS is suggested to compare the effectiveness of the intervention on activity behaviour outcomes with other research in the MS population.

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CHAPTER 6. GENERAL DISCUSSION AND CONCLUSIONS

6.1 Discussion of research findings

The main purpose of this project was to test the preliminary efficacy of the "SitLess with MS" program- a new activity behaviour change intervention- on reducing daily sedentary behaviour and improving symptoms and physical performance outcomes in adults with MS. My work complements and enhances the work related to the "SitLess with MS" program, which included the publication of the protocol,[1] and the feasibility findings.[2] Prior to this thesis, no intervention with the primary focus on reduction of daily sedentary time in adults with MS and comprehensive assessment of MS symptoms and physical performance outcomes was conducted. We used validated activity and symptom measures and reported that the 15-week intervention led to a 38-min reduction in daily sedentary behaviour on average, increased step counts by 639 as measured by ActivPAL, and an improvement in most of the common symptoms experienced by those with MS.

The first step began with a review of the literature for the prevalence of sedentary behaviour and existing interventions on reducing sedentary behaviour in the MS population. The evidence from the literature indicates that adults with MS spend over 60% of their daily waking hours in sedentary behaviours.[3,4] In addition, replacing sedentary behaviour with standing and/or stepping (light-intensity physical activities) is associated with beneficial health outcomes in community dwelling adults.[5] Every 2-hour spent standing and/or stepping per day is beneficially associated with lower fasting blood glucose, cholesterol, triglycerides, body mass index and waist

circumference.[5] A gap in the literature regarding the interventions with the main focus on reducing daily sedentary behaviour in MS was identified. The first study in this thesis (Chapter 2) entitled, "Preliminary efficacy of the SitLess with MS intervention for changing sedentary behaviour, symptoms, and physical performance in multiple sclerosis" addressed that gap.

The "SitLess with MS" program was a 15-week telerehabilitation intervention (i.e., internet based intervention) which included objective monitoring of activity behaviour by ActivPAL3^{TM} and Fitbit One activity monitors.[1] The validity of the activity monitors used in the intervention was tested in both laboratory-setting and free-living environments. The validity work enhanced confidence in the results of the "SitLess with MS" intervention on activity behaviour outcomes and was presented in Chapters 3 and 4. As this research program progressed, it also became clear that an additional gap in the literature was related to the feasibility of the long-term use of the consumer-grade activity trackers for daily monitoring of activity behaviour in adults with MS. Therefore, the fourth study (chapter 5) entitled "Feasibility of the use of Fitbit One activity tracker over 15 weeks in adults with multiple sclerosis" was performed.

The findings from these interrelated studies demonstrated support for a less intense whole-day activity behaviour intervention in individuals with MS in order to maximize health benefits, particularly in those with mobility impairments. A strategy to expedite reduction in daily sitting time and increase in light-intensity activities such as slow walking may be more feasible, acceptable, less challenging, and a first step towards promoting activity levels and increasing energy expenditure in people with MS especially those with mobility disability. The findings from the validity studies confirmed that the monitors were providing valid information in the "SitLess with MS" intervention. We found that the validity of the ActivPAL3^{TM} for measuring sedentary behaviour was not different from what has been reported in other populations with disabilities[6–8]

It showed that using the device in a different population (i.e., patients with MS) did not change the validity of the ActivPAL3^{TM}. Our results were also similar to the findings of Coulter et al.[9] who reported that the ActivPAL3^{TM} was valid for the measurement of upright time and step counts in patients with MS. Moreover, our findings demonstrated that wearing the Fitbit One over a long period in real life and/or research settings is feasible and acceptable by individuals with MS.

6.2 Strengths and limitations of the thesis

The "SitLess with MS" intervention was a novel activity behaviour change program in adults with MS that focused on whole day activity behaviour rather than targeting moderate to vigorous-intensity physical activity only and primarily targeted reduction in daily sedentary behaviour. The intervention was accessible as it was delivered within the home environment and included strategies such as breaking up sitting with standing up or/and walking around at frequent intervals throughout the day which makes it possible and easy for most to do in any setting. In addition, the intervention program involved objective monitoring of total daily activity behaviour which provided more accurate data than self-report measures.

Weekly coaching sessions between an intervention coach and a participant were a key strength of the "SitLess with MS" program. The individual coaching sessions were used to expedite knowledge translation and strategies for activity behaviour change and to help accountability and compliance with the intervention. Weekly coaching sessions helped participants to understand that some physical activity even at light-intensity is better than none and they should not necessarily perform moderate-to-vigorous intensity physical activities in order to gain health benefits. Participants also learnt about the detrimental effects of sedentary behaviour on their health and the possible ways to reduce daily sedentary time and to increase total activity

levels and energy expenditure during the day. The sample size (n = 41) was adequate and acceptable for a feasibility study, in accordance with previous activity behaviour interventions with persons with MS and stroke populations. [10–13]

The findings of the free-living validity study added more evidence to the findings of the laboratory-setting validity study and strengthened the evidence regarding the accuracy of the consumer-grade Fitbit One for measuring steps in the MS population. Our findings of the ankle placement of the Fitbit activity tracker were novel in the MS population which highlights the importance of activity monitor placement on the validity of the measurements by the activity monitor in research settings or/and clinical practice. The findings from the validity studies also help clinicians and researchers in the selection of an appropriate tool for measurement of activity behaviour in clinical practice or/and research interventions in patients with MS.

The main limitation of the "SitLess with MS" intervention was the single-group design and lack of a control group which allowed evaluation of preliminary efficacy of the intervention only. Patients with MS who were physically inactive and had mild to moderate disability were only included, and the findings are not generalizable among non-ambulatory persons with MS. The follow-up period was 7 weeks and provided only an estimation of the long-term sustainability of the intervention effects. In addition, the laboratory-setting validity study included a small sample size (n = 32) and patients with mild to moderate disability only, which limits the generalization of the findings to a free-living environment and non-ambulatory individuals with MS. Moreover, many commercially available activity monitors such as the Fitbit One activity tracker do not report sedentary time and we could not examine the convergent validity of the Fitbit One against the research-grade ActivPAL3^{TM} for measurement of sedentary behaviour in the MS population.

6.3 Practical implications and recommendations

Our research suggests that ambulatory people with MS spent approximately 10 hours on sedentary behaviour every day. There should be a good balance between total daily physical activity, rest period or sitting and sleep (7-8 hours per day is normal). A gradual reduction in daily sedentary time might be the first step for reducing daily sedentary behaviour and indirectly increasing the daily light-intensity physical activity levels such as moving around the house. For individuals with MS, an initial target might be no more than 7-8 hours of sitting or/and lying down in order to make a balance between 24-hour activity behaviour components (i.e., physical activity, sleep and sedentary behaviour). It is a reasonable goal and may be more feasible and sustainable over time to increase total daily activity levels. If they could achieve the goal of no more than 7 hours of sedentary time per day, they could be more encouraged to set new goals and work towards more reduction in sedentary time throughout the day which is in accordance with principals of social cognitive theory.[14] In addition to the total sedentary time per day, the number of breaks in sedentary time and step counts during the day are also important. Persons with MS can gradually increase the number of daily steps by moving more often around the house, in the backyard or neighborhood and may use an activity tracker for encouragement and monitor of their daily levels.

Furthermore, it may be important for clinicians to provide information and education on the health consequences of prolonged sedentary behaviour for patients with MS. This recommendation is in line with recent activity guidelines for general population and people with disability.[15,16] They can describe that a reduction in sedentary behaviour may improve patients' physical and mental health, which is supported by the findings from this thesis. When patients

understand how their behaviours might influence their health, they may be more motivated to change such detrimental habits.

Clinicians can also educate patients on strategies to break up sitting regularly at home or/and workplace and to avoid prolonged periods of uninterrupted sitting. Evidence indicates that interrupting sedentary time every 30 minutes could decrease the negative health risks associated with prolonged sedentary behaviour.[17] When the patients experience improvements in their physical and mental health by sitting less and moving more (taking more steps), it increases confidence and motivation to engage in more activities.

There are a few practical strategies for reducing daily sedentary behaviour that was discussed by intervention coaches in the coaching sessions and can be recommended by health care professionals:

- Planning to regularly stand or take steps after 30 minutes of uninterrupted sitting for at least one minute at home or/and workplace
- Standing or walking around during TV advertisements, working with a computer or reading
- Using a high table or counter for support in standing while talking on the phone or reading
- Doing light-intensity activities such as washing the dishes or sweeping more often
- Setting an alarm on the phone or an activity tracker as a reminder to frequently break up sitting with standing or walking
- Using an activity tracker to monitor changes in the number of daily steps and total activity levels over time
- Lifestyle changes such as walking instead of using a car, bus or train, parking farther from a shopping center, workplace or grocery store to increase the walking distance, use of stairs instead of elevators, standing in the bus or train, moving on the chair while sitting

- Environmental changes such as height-adjustable desks for sit-to-stand transitions, standing computer desks at home and/or workplace, removing chairs from the TV area and use of kitchen counter in order to eat meals in a standing position

In clinical situations, when the use of a research-grade activity monitor is not feasible and/or when patients with MS are keen to monitor their daily steps, the Fitbit One is an appropriate choice to be recommended by clinicians.

6.4 Future research directions

The final section of this thesis identifies future research directions that may improve our knowledge of sedentary behaviour, and the importance of changing it, in those with MS.

There is limited research on the psychometric properties of measurement tools used to measure sedentary behaviour in the MS population. Inadequate research on the psychometrics of sedentary behaviour measures might explain less research on sedentary behaviour in MS. In addition, the majority of small research on the rate of sedentary behaviour in patients with MS (7.5 to 8 hours per day)[18,19] has come from the self-report measures. Therefore, more research on sedentary behaviour using objective measures (i.e., activity monitors) and evaluation of the psychometric properties of those measures are needed in the MS population. Validity studies with a larger sample size, including adults with mild, moderate and severe mobility impairments (i.e., wheelchair users) and in a free-living environment are required to strengthen the evidence regarding the validity of the objective measures of sedentary behaviour in the MS population.

In addition, as it is not possible to use a research-grade activity monitor (e.g., ActivPAL) out of a research context and during daily life in healthy population and people with disability, a

valid consumer-grade activity tracker will be a useful tool for monitoring total daily sedentary time or the number of breaks in sedentary time per day. Two recent studies examined the concurrent validity of two consumer-grade activity trackers (i.e., Fitbit Flex and Fitbit Charge 2) for measuring sedentary behaviour against the ActiGraph GT3X in healthy adults.[20,21] The results demonstrated a strong correlation between the Fitbits and the research-grade ActiGraph GT3X for measuring sedentary behaviour[20,21] and indicated that a wrist-worn consumer-grade activity tracker might be a useful tool for measurement of daily sedentary behaviour in healthy individuals. However, the accuracy of waist-worn and/or ankle-worn commercially available activity trackers for measurement of sedentary behaviour might be different in healthy adults and/or individuals with disability such as people with MS which might underscore the importance of wearing location for more accuracy of sedentary behaviour measurement. Therefore, more studies evaluating the validity of the user-friendly popular consumer-grade activity trackers worn at different locations (e.g., wrist, waist and ankle) for measurement of sedentary behaviour against the valid research-grade activity monitors (e.g., ActivPAL3^{TM}) must be conducted in the MS population.

Moreover, our findings regarding the ankle placement of the Fitbit One for measuring step count was novel in people with MS. Nevertheless, the Fitbit One is not available in the market anymore which demonstrates the necessity of future research on ankle placement of the currently existing consumer-grade activity trackers such as Fitbit Inspire and/or Fitbit Charge 4 for measurement of steps in people with higher levels of disability who walk slowly (gait speed < 0.80 m/s) such as persons with MS with moderate disability.

In addition, no study has assessed the correlation between the recorded activity outcomes by a consumer-grade activity tracker (e.g., daily sedentary time or step counts) and common MS-

related symptoms and/or physical performance outcomes over a few weeks or a few months in the MS population. It could provide a better understanding of the association between activity level and accumulation patten with clinical features of the disease. Such research is also needed to be conducted in the future.

Most activity behaviour interventions in MS have merely focused on increasing moderate-to-vigorous physical activities and very few[22,23] targeted reductions in sedentary behaviour as the main or secondary outcome of the intervention that was explained in detail in chapter 1. Future research on interventions targeting reduction in sedentary behaviour as the main outcome with accurate measurement of sedentary behaviour with valid activity monitors, a randomized controlled design, a larger sample size, a longer follow-up period and evaluating the effect of the intervention on most common MS symptoms and physical function outcomes in adults with different levels of disability is needed.

A systematic review and meta-analysis evaluated the effectiveness of using computer, mobile or/and wearable technology in interventions with randomized controlled design aimed at reducing sedentary behaviour in healthy adults.[24] They reported that use of computer, mobile and wearable technology tools is effective for reducing total daily sedentary time as it led to an average 41.28 minutes per day reduction in sitting time in favour of the intervention group.[24] The pooled effects indicated mean reductions of 42.42 minutes/day, 37.23 minutes/day and1.65 minutes/day at short (≤ 3 months), medium (>3 to 6 months), and long-term follow-up (>6 months), respectively.[24] Thus, more research on effectiveness of utilisation of such technologies on reducing daily sedentary time in interventions with main focus on decreasing sedentary behaviour is required in people with disability such as individuals with MS.

There is also a lack of research on the consequences of high sedentary time on the risk of cardiovascular diseases, cancers, diabetes and mortality in the MS population. Furthermore, it is unknown whether the rates or patterns of sedentary behaviour predict the physical or mental health outcomes and/or quality of life in the MS population. The effect of a sedentary behaviour intervention on health outcomes such as biomarkers of cardiovascular disease in the MS population has not been examined yet. Therefore, future research on the effects of sedentary behaviour and its reduction on health outcomes such as cardiometabolic risk biomarkers are needed in the MS population. More research on the independent or cumulative role of physical activity and sedentary behaviour on the health and function of people with MS is also required.

Furthermore, no research regarding the adherence of people with MS to sedentary behaviour interventions and/or whether it is more feasible to reduce sedentary behaviour than to engaging in moderate-to-vigorous intensity physical activity exists. Future research comparing the effectiveness of interventions with focus on only moderate-to-vigorous intensity physical activity with interventions with main focus on reducing daily sedentary time and comparison of the adherence of people to those interventions in the MS population is needed.

6.5 Conclusions

Accurate measurement of volume and pattern of accumulation of sedentary time in MS is essential to determine current levels and to design interventions and strategies to decrease daily sedentary behaviour in order to maximize health and quality of life. Research on the validity of the research-grade activity monitors and the commercially available activity trackers measuring sedentary behaviour and physical activity is required as it helps researchers, clinicians and patients with MS to make decisions on how best to monitor and modify activity behaviour.

Using research-grade activity monitor to measure sedentary behaviour, the findings of this thesis showed that patients with MS spend approximately 62% of their daily waking hours on sedentary behaviour. Breaking up sedentary behaviour with short periods of standing or slow walking at home and/or workplace and increasing the daily number of steps is a feasible way to modify activity behaviour during the day. This strategy can also improve MS symptoms and physical performance over time. It is probably the time for a paradigm shift from moderate-to-vigorous intensity physical activity to sitting less and moving more in order to promote activity in the MS population and the message "sit less and move more" may be more acceptable for the majority of patients with MS.

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APPENDICES

Appendix A: Northern Alberta Clinical Trial Research Centre

Suite 507, 8215 112 Street NW
Edmonton, AB T6G 2C8
EM: NACTRC@NACTRC.CA
www.nactrc.ca

EDMONTON ZONE
ADMINISTRATIVE APPROVAL FOR CLINICAL RESEARCH
All clinical research being conducted within the Edmonton Zone requires operational approval to access AHS areas and ethics approval by a recognized Alberta Research Ethics Board.
Other related documents may be required depending on the scope of the study.
Research in the Edmonton Zone cannot begin until Administrative Approval has been issued.

Protocol Title: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS? Phase II

Principal Investigator:
Patricia Manns
Rehabilitation Medicine

Funding Agency: Alberta Innovates - Health Solutions (AIHS)
Funding Type: Investigator-Initiated/Grant
Overhead Rate: 0%

Related Documents:	ID#	Submitted	Status	Effective
Research Ethics:	Pro00067657		Approved	Apr 06, 2017
AHS HIA Research Agreement:	RA83775	May 15, 2017	Not Required	

AHS Operational Approval: The following AHS areas have agreed to support your research. To gain access, you must have Edmonton Zone Administrative Approval.

35876: Kaye Edmonton Clinic - Multiple Sclerosis Clinic

Edmonton Zone Administrative Approval for Project (PRJ) #34545

Approved: May 15, 2017
Approved By: Ron Welch
Director of Operations, NACTRC

Appendix B: Application for Operational Approval

Alberta Health Services

APPLICATION FOR
OPERATIONAL APPROVAL
to Conduct Research at Alberta Health Services
KAYE EDMONTON CLINIC
MULTIPLE SCLEROSIS CLINIC

NACTRC Northern Alberta Clinical Trials + Research Centre

RESEARCH TITLE:
Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?

Expected Start Date:	2017-05-01
Expected End Date:	2018-12-31
Expected Number of Research Subjects:	45
Research Category:	Interventional
Research Type:	Procedure
REB / REB #:	HREB / Pro00067657

PI INFORMATION:

Name:	Trish Manns
Zone:	Edmonton
Faculty:	Rehabilitation Medicine
Phone:	780-492-7274
Email:	trish.manns@ualberta.ca

STUDY COORDINATOR: Study Coordinator

Name:	Saeideh Aminian
Zone:	Edmonton
Phone:	587-936-1180
Email:	saeideh@ualberta.ca

AREA IMPACT:

1) Will AHS staff from this area be expected to participate and/or carry out any duties related to this study??

YES 2 -3 Neurologists - After the study is briefly introduced to potential participants by the neurologists, those who express interest will be asked to provide consent to be contacted by the research team (It will be one-time; 5 minutes for each potential participant).

2) Will AHS staff from this area require any training or education??

NO

3) Are you expecting this AHS area to provide you with supplies and/or equipment? ?

NO

4) Funding Type: Investigator-Initiated Grant

NOTE: If the area being impacted determines that there are costs associated with your research, they will contact you prior to issuing Operational Approval.

QUESTIONS SPECIFIC TO THE AREA:

SUBMITTED BY / ASSESSORS / APPROVERS:

Requested By:	Saeideh Aminian	Date Requested:	2017-04-21
Assessed By:	Susan Larson	Date Assessed:	2017-05-01
Assessed By:	Elizabeth Seib	Date Assessed:	2017-05-04

Page 1 of 1 O/A #35876 Status: Approved

Appendix C: Approval From

Approval Form

Date:	April 6, 2017
Study ID:	Pro00067657
Principal Investigator:	Patricia Manns
Study Title:	Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?
Approval Expiry Date:	Thursday, April 5, 2018

Approved Consent Form:	Approval Date	Approved Document
	4/6/2017	Phase II-Information Letter Updated
	4/6/2017	Phase III-Information Letter Updated
	4/6/2017	Phases II & III-Consent Form Updated

Sponsor/Funding Agency:	Alberta Innovates Health Solutions		AIHS	Canada

RSO-Managed Funding:		Project ID	Project Title	Speed Code	Other Information
	View	RES0027829	Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?		

Thank you for submitting the above study to the Health Research Ethics Board - Health Panel . Your application, including the following, has been reviewed and approved on behalf of the committee;

- Consent to Contact Information (3/10/2017)
- Phases II & II Participant Data Sheet (3/10/2017)
- Phase III Recruitment Poster (3/10/2017)
- Phase II Quick Reference Guide Study Information and Inclusion Criteria (3/10/2017)
- Phase III Quick Reference Guide Study Information and Inclusion Criteria (3/10/2017)
- Phase III Recruitment Poster Updated (4/4/20147)
- Post-Intervention Interview Indicative Questions (3/10/2017)
- Fatigue Severity Scale Guide & Scoring (3/10/2017)
- Functional Capacity (6 Min Walk) Score Sheets (3/10/2017)
- Gait Speed (10m Walk) Score Sheets (3/10/2017)
- Godin Leisure-Time Questionnaire (3/10/2017)
- Hospital Anxiety and Depression Scale (3/10/2017)
- Kurtzke EDSS & FSS (3/10/2017)
- Pittsburgh Sleep Quality Index & Scoring (3/10/2017)
- Modified Fatigue Impact Scale (3/10/2017)
- PDDS Performance Scales (3/10/2017)
- Quality of Life (SF-36) Questionnaire (3/10/2017)
- Short Physical Performance Battery Guide & Scoring (3/10/2017)
- Symbol Digit Modality Test (3/10/2017)
- Pittsburgh Sleep Quality Questionnaire (3/10/2017)
- Short Form McGill Pain Questionnaire Guide & Scoring (3/10/2017)
- Phase II Post Intervention Interview Indicative Questions (4/4/2017)

- Phases II & III Ethics Research Proposal (3/10/2017)
- ActivPAL Instruction and Compliance Log (3/10/2017)
- Sit Less with MS Program Manual Mar 9 (3/10/2017)
- Stage I Newsletter 1 (3/10/2017)
- Stage II Newsletter 1 (3/10/2017)
- Skype Chat 1 Script (3/10/2017)
- Skype Chat 2 Script (3/10/2017)

The Health Research Ethics Board assessed all matters required by section 50(1)(a) of the Health Information Act. Subject consent for access to identifiable health information is required for the research described in the ethics application, and appropriate procedures for such consent have been approved by the HREB Health Panel. In order to comply with the Health Information Act, a copy of the approval form is being sent to the Office of the Information and Privacy Commissioner.

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date (Thursday, April 5, 2018), you will have to re-submit an ethics application.

Approval by the Health Research Ethics Board does not encompass authorization to access the patients, staff or resources of Alberta Health Services or other local health care institutions for the purposes of the research. Enquiries regarding Alberta Health approval should be directed to (780) 407-6041. Enquiries regarding Covenant Health approvals should be directed to (780) 735-2274.

Sincerely,

Anthony S. Joyce, PhD.
Chair, Health Research Ethics Board - Health Panel

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Appendix D: Notification of Approval – Amendment

Notification of Approval - Amendment

Date:	June 14, 2017
Amendment ID:	Pro00067657_AME2
Principal Investigator:	Patricia Manns
Study ID:	MS1_Pro00067657
Study Title:	Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?
Sponsor/Funding Agency:	Alberta Innovates Health Solutions AIHS Canada

RSO-Managed Funding:

	Project ID	Project Title	Speed Code	Other Information
View	RES0027829	Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?		

Approved Consent Form:	Approval Date	Approved Document
	6/7/2017	Phases III-Consent Form Updated
	6/7/2017	Phase III-Information Letter Updated

Approval Expiry Date: Thursday, April 5, 2018

Thank you for submitting an amendment request to the Health Research Ethics Board - Health Panel . The following has been reviewed and approved on behalf of the committee:

- Additional baseline testing of the validity of the ActivePAL3 and Fitbit activity tracker against video observation.
- Validity Study Protocol (5/29/2017)

Note: Approval for an amendment does not change the original approval date.

Sincerely,

Anthony S. Joyce, PhD.
Chair, Health Research Ethics Board - Health Panel

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Appendix E: Sit Less with MS Poster

DEPARTMENT OF PHYSICAL THERAPY
FACULTY OF REHABILITATION MEDICINE

2-50 Corbett Hall
Edmonton, Alberta, Canada T6G 2G4
Tel: 780.492.5983
Fax: 780.492.4429
pt@rehabmed.ualberta.ca

Sit Less with MS:

We want to test a program to help you manage the symptoms of MS

- **Who:** People who have MS for one year or more.
- **Where:** University of Alberta campus - Corbett Hall.
- **When:** By appointment – we can accommodate most schedules including weekends.
- **Cost:** There is NO COST. We'll give you a gift as a sign of our appreciation at the end of the project.

If you are interested or would like more information about this project, titled **'Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?'** please contact:

Saeideh Aminian at (780) 492-8968 or by email: saeideh@ualberta.ca
Or Trish Manns @ trish.manns@ualberta.ca

Follow us on Twitter **@SitLesswithMS**
Find us on Facebook **SitLesswithMS**

Appendix F: Information Letter (I)

Title: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?

Research Investigator:
Trish Manns
ADDRESS 3-48 Corbett Hall
Department of Physical Therapy
University of Alberta
Edmonton, AB, T6G 2G4
EMAIL trish.manns@ualberta
PHONE NUMBER 780-492-7274

Co-Investigator
Robert Motl
1705 University Blvd. SHPB 336
Department of Physical Therapy
University of Alabama at Birmingham
Urbana Alabama 35233-1212
EMAIL robmotl@uab.edu
PHONE NUMBER 205-934-7787

Background

We invite you to participate in a research project. We are developing and testing a program for adults with multiple sclerosis (MS). The program is designed to help you to interrupt and reduce your sitting time and replace it with light activities. Increasing activity may help you to manage your MS symptoms such as fatigue or pain.

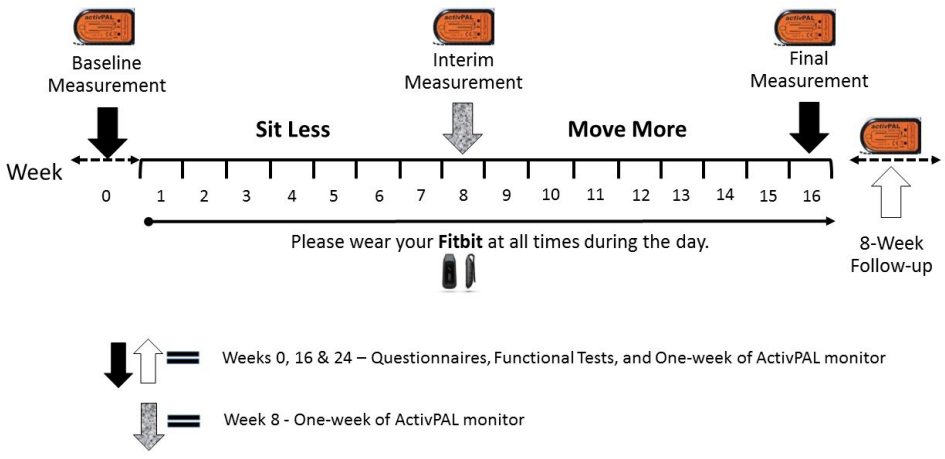
Purpose

The purpose of this project is to determine the feasibility of a sedentary behaviour program for improving sedentary behaviour outcomes and co-morbidities such as walking disability and fatigue.

Program Procedures

If you decide to participate, we will ask you to come to the University of Alberta campus (Corbett Hall, 8205 114 Street) four times. If you come with your car we will provide you a parking pass. Your involvement in this project will be 24 weeks in total. The diagram below provides information about what we'll be doing.

Diagram



The actual intervention duration will be 16 weeks which is divided into two stages: Stage I (Sit Less), and Stage II (Move more). The first time we'll see you is called baseline measurement (called Week 0 on the diagram). Before we start, you will be asked to sign a consent form. After that, we will measure your weight and height and ask you to answer a few questions about yourself (e.g., age), your MS (e.g., how long since you were diagnosed), and your medications. You will then complete several questionnaires including ones about fatigue, pain and reasoning, sleep, and physical activity. There are also some functional walking tests. These measurements will take about two hours. We repeat all these measurements two more times; at final (Week 16), and follow-up (Week 24).

You will also wear the small device below (ActivPAL monitor) at four measurement points: baseline (Week 0), interim (Week 8), final (Week 16), and follow-up (Week 24). At each measurement point, it should be worn at all times for **7 days.** The ActivPAL (see picture below) will be worn on your right thigh with non-allergenic tape and it measures your sitting, standing and walking time, and step counts. At the end of the baseline measurement period, we will attach the ActivPAL on your thigh and will collect it from you after 7 days at either your home or Corbett Hall. After that, a Fitbit (see picture below) will be worn on your waist, and we will teach you how to use it. This is the device you'll be using to track your activity during 16 weeks. We will ask you to complete a log book to record your bed-time and sleep-time and any times when you didn't wear the Fitbit.

ActivPAL3^{TM} monitor

Fitbit

In addition, every week from Week 2 to Week 16, we will send you a 2-page newsletter to read and then we will discuss it with you on Skype at the end of each week. At the end of the program, we will conduct an informal interview with you to get your feedback about the whole program. We may audio record the interview, and transcribe it word for word.

Benefits

- The information we collect from this research will be used to refine the internet-based program to reduce sedentary behaviour. By participating, you will help to ensure that the program is fully applicable to you and others with MS. There are NO COSTS to participation. At the end of the program, you will be asked to keep the Fitbit as our appreciation.

Risk

- There is minimal risk associated with participating. If you feel uncomfortable with any stage of the program, you can choose not to participate or answer the question and ask the assessor to move onto the next stage. During all assessments, you can take a rest at any time you wish.

Voluntary Participation

- You are under no obligation to participate in this program. The participation is completely voluntary.
- You can opt out of the program without penalty. Even if you agree to be in the program, you can change your mind and withdraw at any time. In the event of opting out in the middle of the interview, we will erase your interview.

Confidentiality & Anonymity

- Information we collect from you will be anonymous. Participants will not be identified in the dissemination of the research.
- The data (including audio files and transcripts) will be kept confidential. Only the primary researchers (Manns, Motl) and selected staff or graduate students they supervise will have access to the data.

- Data will be kept in a secure place for a minimum of 5 years following completion of the research project. Electronic data is password protected.
- If you would like to receive a copy of the final report from this research project, please make us aware of that by leaving your email address.

Further Information

- If you have any further questions regarding this project, please do not hesitate to contact Trish Manns (trish.manns@ualberta.ca) or Saeideh Aminian at 780-492-8968, saeideh@ualberta.ca
- The plan for this project has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Saeideh Aminian, PhD
Post-Doctoral Fellow
Faculty of Rehabilitation Medicine
University of Alberta
Phone: 780-492-8968
Email: **saeideh@ualberta.ca**

Appendix G: Information Letter (II)

Title: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?

Research Investigator:
Trish Manns
ADDRESS 3-48 Corbett Hall
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PHONE NUMBER 780-492-7274

Co-Investigator
Robert Motl
1705 University Blvd. SHPB 336
Department of Physical Therapy
University of Alabama at Birmingham
Urbana Alabama 35233-1212
EMAIL robmotl@uab.edu
PHONE NUMBER 205-934-7787

Background

We invite you to participate in a research project. We are developing and testing a program for adults with multiple sclerosis (MS). The program is designed to help you to interrupt and reduce your sitting time and replace it with light activities. Increasing activity may help you to manage your MS symptoms such as fatigue or pain.

Purpose

The purpose of this project is to determine the feasibility of a sedentary behaviour program for improving sedentary behaviour outcomes and co-morbidities such as walking disability and fatigue.

Program Procedures

If you decide to participate, we will ask you to come to the University of Alberta campus (Corbett Hall, 8205 114 Street) four times. If you come with your car we will provide you a parking pass. Your involvement in this project will be 24 weeks in total. The diagram below provides information about what we'll be doing.

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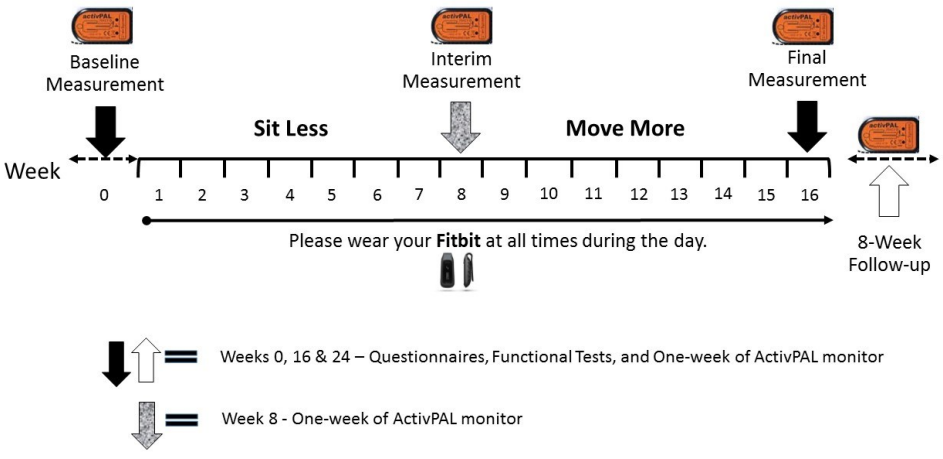

The actual intervention duration will be 16 weeks which is divided into two stages: Stage I (Sit Less), and Stage II (Move more). Before you enter the lab to perform the tests, one video camera will be set with an elevated view of the lab with a wide shot of the room to capture your sitting and standing activities. Another camera will be set in a hallway to record the numbers of your postural transitions and steps. The first time we'll see you is called baseline measurement (called Week 0 on the diagram). Before we start, you will be asked to sign a consent form. After that, we will measure your weight and height and ask you to answer a few questions about yourself (e.g., age), your MS (e.g., how long since you were diagnosed), and your medications. You will then complete several questionnaires including ones about fatigue, pain and reasoning, sleep, and physical activity. There are also some functional walking tests. These measurements will take about two hours. We repeat all these measurements two more times; at final (Week 16), and follow-up (Week 24).

You will also wear the small device below (ActivPAL monitor) at four measurement points: baseline (Week 0), interim (Week 8), final (Week 16), and follow-up (Week 24). At each measurement point, it should be worn at all times for **7 days.** The ActivPAL (see picture below) will be worn on your right thigh with non-allergenic tape and it measures your sitting, standing and walking time, and step counts. At the end of the baseline measurement period, we will attach the ActivPAL on your thigh and will collect it from you after 7 days at either your home or Corbett Hall. After that, a Fitbit (see picture below) will be worn on your waist, and we will teach you how to use it. This is the device you'll be using to track your activity during 16 weeks. We will ask you to complete a log book to record your bed-time and sleep-time and any times when you didn't wear the Fitbit.

ActivPAL3^{TM} monitor

Fitbit

In addition, every week from Week 2 to Week 16, we will send you a 2-page newsletter to read and then we will discuss it with you on Skype at the end of each week. At the end of the program, we will conduct an informal interview with you to get your feedback about the whole program. We may audio record the interview, and transcribe it word for word.

Benefits

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program is fully applicable to you and others with MS. There are NO COSTS to participation. At the end of the program, you will be asked to keep the Fitbit as our appreciation.

Risk

- There is minimal risk associated with participating. If you feel uncomfortable with any stage of the program, you can choose not to participate or answer the question and ask the assessor to move onto the next stage. During all assessments, you can take a rest at any time you wish.

Voluntary Participation

- You are under no obligation to participate in this program. The participation is completely voluntary.
- You can opt out of the program without penalty. Even if you agree to be in the program, you can change your mind and withdraw at any time. In the event of opting out in the middle of the interview, we will erase your interview.

Confidentiality & Anonymity

- Information we collect from you will be anonymous. Participants will not be identified in the dissemination of the research.
- The data (including audio and video files and transcripts) will be kept confidential. Only the primary researchers (Manns, Motl) and selected staff or graduate students they supervise will have access to the data.
- Data will be kept in a secure place for a minimum of 5 years following completion of the research project. Electronic data is password protected.
- If you would like to receive a copy of the final report from this research project, please make us aware of that by leaving your email address.

Further Information

- If you have any further questions regarding this project, please do not hesitate to contact Trish Manns (trish.manns@ualberta.ca) or Golnoush Mehrabani at (golnoush@ualberta.ca).
- The plan for this project has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Golnoush Mehrabani, MD
PhD student
Faculty of Rehabilitation Medicine
University of Alberta
Phone: 780-492-8968
Email: golnoush@ualberta.ca

Appendix H: Consent Form

Department of Physical Therapy
2-50 Corbett Hall
Edmonton, Alberta, Canada T6G 2G4

Tel: 780.492.5983
Fax: 780.492.4429

Participant ID:

CONSENT

Title: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?

Principal Investigator(s): Dr. Patricia Manns **Phone Number(s): 780.492.7274**
Co-Principal Investigator: Dr. Robert Motl **Phone Number(s): 205.934.7787**

	Yes	No
Do you understand that you have been asked to be in a research study?	☐	☐
Have you read and received a copy of the attached Information Sheet?	☐	☐
Do you understand the benefits and risks involved in taking part in this research study?	☐	☐
Do you understand the post-intervention interview will be audio recorded?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Do you understand that you are free to leave the study at any time, without having to give a reason and without any penalty?	☐	☐
Has the issue of confidentiality been explained to you?	☐	☐
Do you understand who will have access to your study records?	☐	☐

Who explained this study to you? _____

I agree to take part in this study:

Signature of Research Participant _____

(Printed Name) _____

Date:_____

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

Signature of Investigator or Designee _____ Date _____

THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH PARTICIPANT

Saeideh Aminian, PhD
Post-Doctoral Fellow
Faculty of Rehabilitation Medicine
University of Alberta
Phone: 780-492-8968
Email: saeideh@ualberta.ca

Appendix I: Consent to Release Contact Information

Consent to Release Contact Information

I, _____, give my permission to _____, to give my name and contact information to Dr. Trish Manns. The information (name, contact information) provided to Dr. Manns (or her Post-doc) indicates my willingness to be contacted to discuss participation in a research study (Titled: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?). I know that signing this form does not mean that I consent to participate in the study, only that I consent to be contacted.

This consent is effective today _____.

I know that I can revoke my consent at any time.

Signed _____

Date _____

Contact information of person consenting to be contacted:

- Name:
- Phone: _____
- Email (if you prefer):_____

Department of Physical Therapy
3-48 Corbett Hall • University of Alberta • Edmonton • Canada • T6G 2G4
Telephone: (780) 492-7274 • Fax: (780) 492-4429

Appendix J: Consent Form

Department of Physical Therapy
2-50 Corbett Hall
Edmonton, Alberta, Canada T6G 2G4

Tel: 780.492.5983
Fax: 780.492.4429

Participant ID:

CONSENT

Title: Reducing sedentary behaviour: A novel opportunity for managing comorbidity in MS?

Principal Investigator(s): Dr. Patricia Manns **Phone Number(s): 780.492.7274**
Co-Principal Investigator: Dr. Robert Motl **Phone Number(s): 205.934.7787**

	Yes	No
Do you understand that you have been asked to be in a research study?	☐	☐
Have you read and received a copy of the attached Information Sheet?	☐	☐
Do you understand the benefits and risks involved in taking part in this research study?	☐	☐
Do you understand all the activities that you are performing in the lab will be video recorded?	☐	☐
Do you understand the video recordings will be used for academic purposes only and will not be published in any form outside of this project without your written permission?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Has the issue of confidentiality been explained to you?	☐	☐
Do you understand who will have access to your study records?	☐	☐

Who explained this study to you? _____

I agree to take part in this study:

Signature of Research Participant _____

(Printed Name) _____

_____

Date: _____

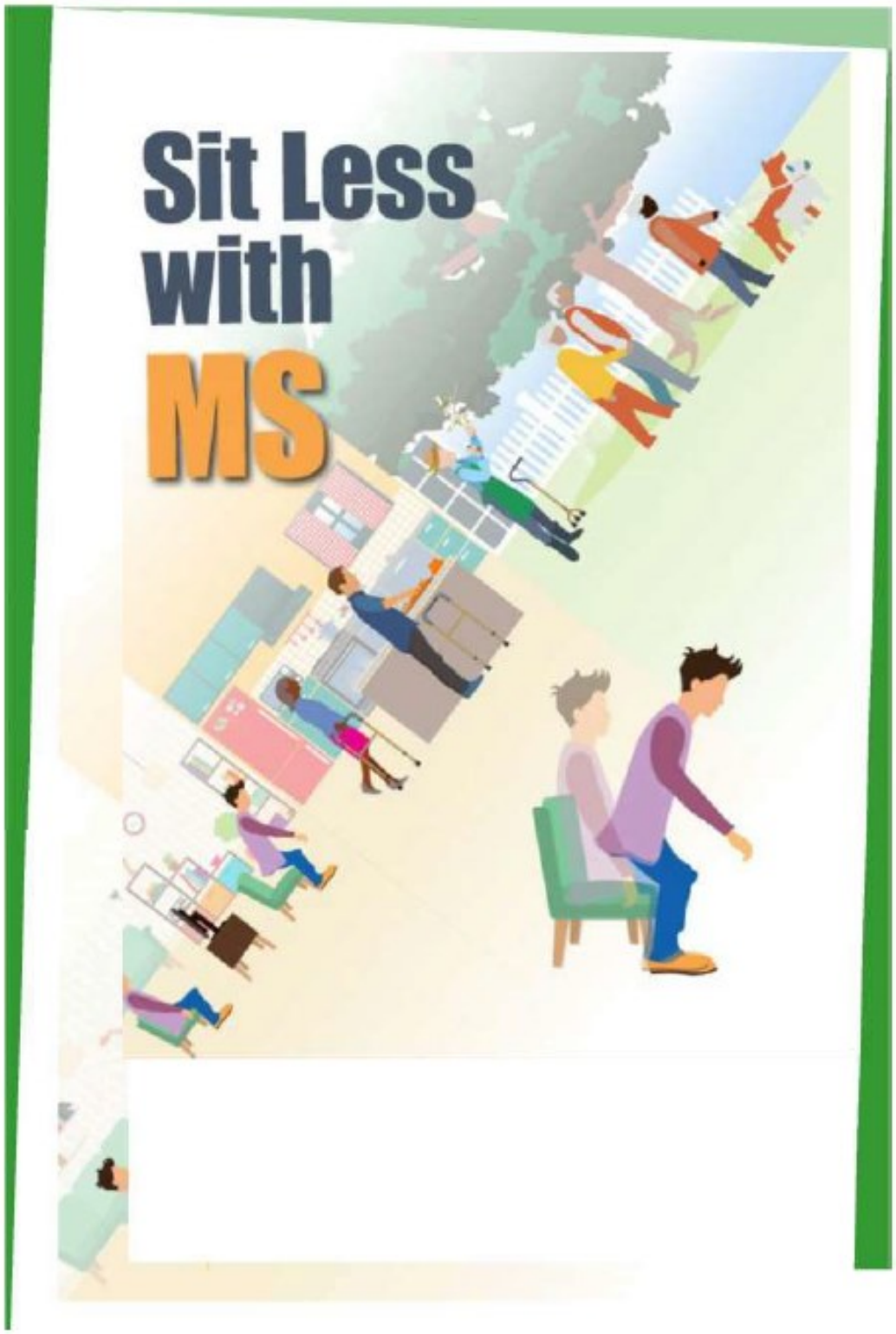
I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

Signature of Investigator or Designee _____ Date _____

THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH PARTICIPANT

Golnoush Mehrabani, MD
PhD student
Phone: 780-492-8968
Email: golnoush@ualberta.ca

Appendix K: “Sit Less with MS” Manual



Sit Less with MS

Table of Contents **Page**

Welcome to the Sit Less Program!

On behalf of everyone at the Laboratory, Faculty of Rehabilitation Medicine, at the University of Alberta, Edmonton, Canada, we would like to welcome you to the Sit Less with MS Program!

What is the Sit Less with MS Program?

The **Sit Less with MS** program is designed to help you reduce prolonged sitting and move more frequently throughout the day.

By participating in this program, you will improve your overall activity level and reduce prolonged sitting.

People with MS are in **danger of sitting disease!** Indeed, **sitting is the new smoking** and is associated with conditions like **obesity, heart disease, diabetes, early death, depression, anxiety, and even sleep problems** (see the next page for an illustration of the danger of prolonged sitting). These conditions **make MS symptoms worse!**

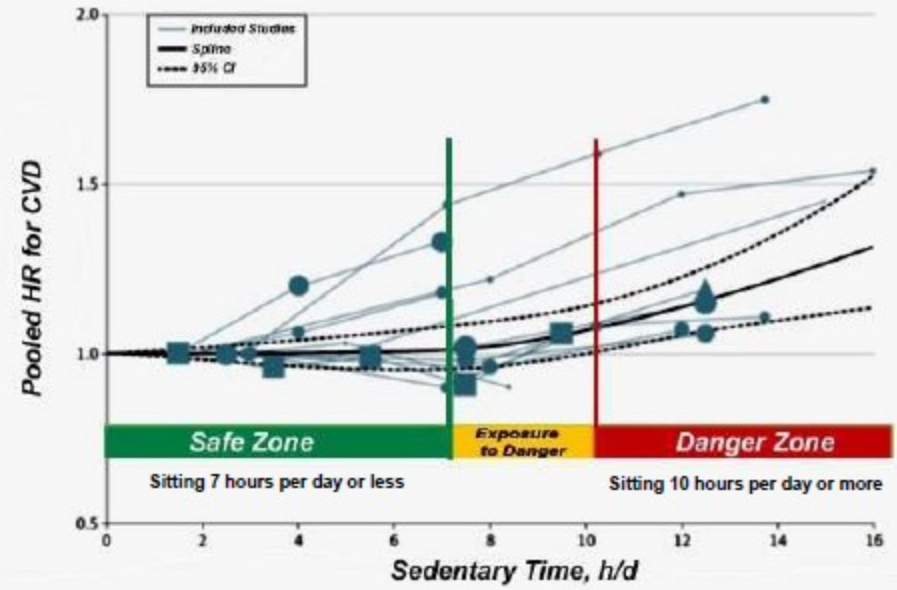
This program is designed as a new approach for **optimizing life with MS.** We will help you to **sit less, move more, and live the best life!**

- Sit Less with MS is not another exercise program.
- Sit Less with MS will give you the skills and resources to sit less and move more with a focus on creating a long-term habit.

Sit Less with MS

Danger of [illegible]

> 10 hours/day of sedentary time = DANGER ZONE for Cardiovascular Risk



Source: Pandey et al., (2016). JAMA Cardiology; 1: 575-583

Being sedentary for 7 or more hours per day increases the risk of cardiovascular disease. But being sedentary for 10 or more hours per day is an absolute **DANGER!**

Sit Less with MS

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What will I get from the Sit Less with MS program?

The Sit Less with MS program will provide you with:

- A manual to give you a road-map of how to successfully interrupt prolonged sitting and move more.
- Newsletters to guide you along the road to success, featuring inspiring topics such as setting goals and maintaining your ability to sit less and move more in the long-term (see page 16).
- Exclusive one-on-one mentorship with our Sit Less with MS team over Skype™ or the phone. The days and times of these calls will be determined between you and your designated specialist.
- A Fitbit for self-monitoring your daily activity including number of steps per day.

How does Sit Less with MS

- All of the program materials you will receive have an important role in helping you to frequently interrupt your sitting, to reduce your overall sitting time, and to move more.
- Take the time to read and look through the program materials, and remember to wear your Fitbit whenever you are awake to monitor and improve your activity level.
- Throughout the program you will receive newsletters and calls from the **Sit Less with MS** team to teach you the skills you need to be successful. Remember to ask our team questions, we are here to help you to be successful!

Sit Less with MS

The Sit Less with MS Team

(Top from left)

Trish Manns (Professor & Principal Investigator) - **University of Alberta**

Saeideh Aminian (Post-Doctoral Fellow & Program Manager) - **University of Alberta**

Robert W. Motl (Professor & Co-Principal Investigator) - **University of Alabama**

(Down from left)

Jacqueline Rowley (Interventionist & MSc Student) - **University of Alberta**

Victor Ezeugwu (PhD Student) - **University of Alberta**

Golnoush Mehrabani (PhD Student) - **University of Alberta**

Contact Information

Phone Number: 780-492-8968

Skype ID: SitLesswithMS

Email: SitLesswithMS@ualberta.ca

Like us on Facebook: SitLesswithMS

Follow Us on Twitter: @SitLesswithMS

Sit Less with MS

What is the Sit With MS Program?

The Sit Less with MS program consists of simple and easy steps that will help you sit less and move more. The Sit Less with MS program will last for a total of **24 weeks** and is divided into two stages and a follow-up period (illustrated on the next page):

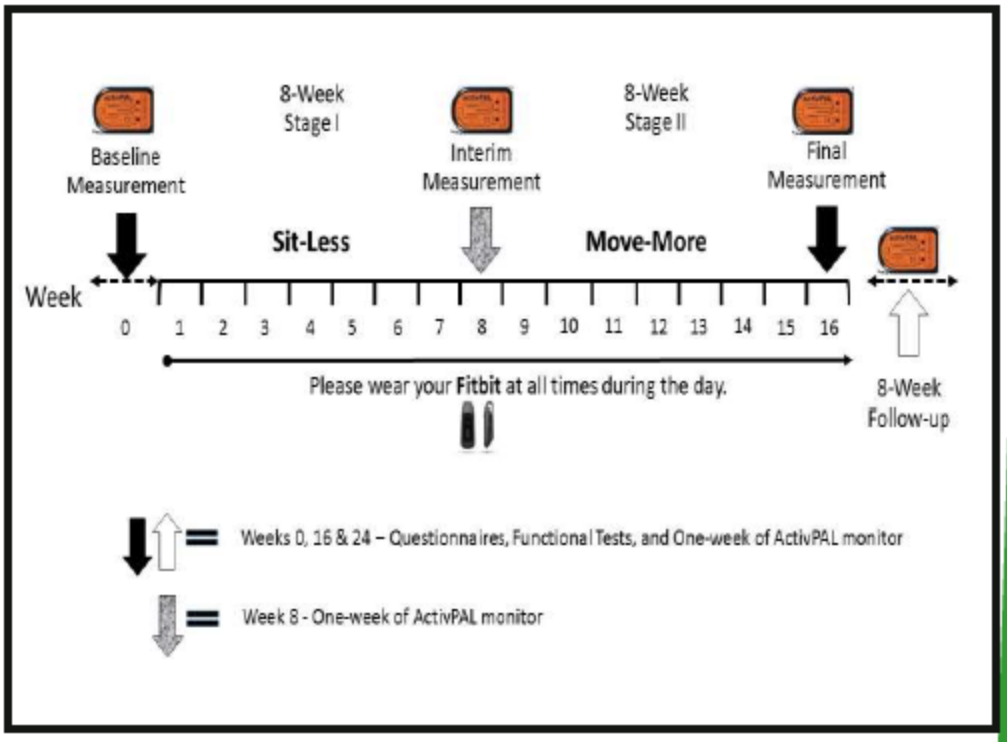
Stage I: SIT-LESS (8 weeks). The goal during this stage is to interrupt prolonged periods of sitting throughout the day. For example, getting up twice every hour or half-hour.

Stage II: MOVE-MORE (8 weeks). The aim of stage II is to replace prolonged sitting or lying with taking steps. For example, walking 5000 steps per day, in addition to interrupting your sitting.

Follow-Up (8 weeks). The follow-up stage is 8 weeks long. During those 8 weeks, we will leave you on your own, but we will do one more assessment at the end.

Sit Less with MS

An Overview OF The Whole Program



Note: The ActivPAL is a physical activity monitor that is worn for only one week during baseline, interim, post-intervention and follow-up time points.

Sit Less with MS

Sit-Less Stage

We are individualizing the programs for the needs and capacity of each of you based on three levels (White, Yellow, Green).

Table of Sit-Less Programs

With your help, we will choose a Sit-Less program (White, Yellow, or Green) that is the best for you!

Frequency	Week	Programs		
		White	Yellow	Green
		Number of interruptions		
During 30 minutes	1,2	1	2	4
	3,4	2	3	5
	5,6	3	4	6

Sit Less with MS

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Move-More Stage

We are individualizing the programs for the needs and capacity of each of you based on three levels (White, Yellow, Green).

Table of Move-More Programs

With your help, we will choose a Move-More program (White, Yellow, or Green) that is the best for you!

Frequency	Week	Programs		
		White	Yellow	Green
		Number of Steps		
Daily	1,2	1000	3000	5000
	3,4	2000	4000	6000
	5,6	3000	5000	7000

Sit Less with MS

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Safety

This program is designed with your safety in mind.

- We recommend that you let your health professional know that you are taking part in the **Sit Less with MS** Program.
- If you have trouble balancing, please interrupt your sitting by staying close to a large piece of stable furniture, a wall or another safe surface.
- Perform your sit-less, and move-more programs in a safe place; avoid slippery floors, poor lighting, throw rugs, and other potential tripping hazards.
- Remember to use your usual walking aid while walking or moving more.
- If at any time you feel lightheaded, overheated, or you begin to feel sharp or intense pain, STOP. It is important that you do not over-exert yourself.
- Record in a diary or log book any trouble or pain you have above what you normally experience during your activities, and bring your concerns up with the program team. Do not stress if you have a bad day and cannot complete your program, it's OK.
  Muscle soreness, and some fatigue are normal responses to moving more. However, if soreness or fatigue persist and interfere with your daily life, please let the **Sit Less with MS** team know.

Sit Less with MS

Fitbit

What is Fitbit?

- Fitbit is a wireless activity tracker that monitors daily activity levels, including number of interruptions in your sitting, number of steps, distance walked, and number of active minutes per day.

Why use a Fitbit activity tracker?

- Research has shown that monitoring your activity level provides motivation to sit less and move more and helps you to keep track your progress over time.

What is the wireless sync dongle?

- You do not need the wireless dongle for this study **BUT** it is in the Fitbit box. The wireless sync dongle is a small USB device used to wirelessly connect your Fitbit to a computer (Laptop or Desktop).

- In the **Sit Less with MS** program, we ask you to regularly synchronize (sync) your Fitbit with your mobile phone. You don't need the dongle to do that but your mobile's Bluetooth must be on. Please continue reading to learn how to use a Fitbit.

Sit Less with MS

How to use a Fitbit

What is inside the Fitbit box?

1. Fitbit One wireless activity tracker
2. Clip
3. Wireless sync dongle
4. Sleep wristband
5. Charging cable

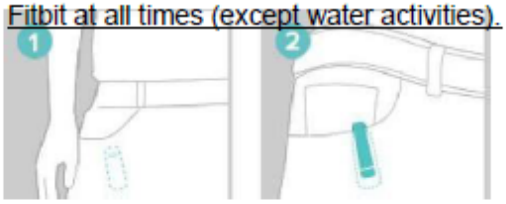
How to turn on your Fitbit?
You will turn on your Fitbit by holding down the button **for 10-12 seconds.**

How to charge your Fitbit?
You will charge your Fitbit by plugging the charging cable into a USB port on a computer (Laptop or Desktop). Make sure to align the gold contacts on your Fitbit with the gold contacts on the inside of the charging cable, then plug it into the computer's USB port. Charging typically takes about an hour or two. A fully charged Fitbit will last about 5 days before another charge is needed.

How to set up your Fitbit on your mobile phone so you can see your activity information?
We will help you to download the Fitbit application on your phone. The Fitbit application is compatible with mobile devices that support iOS and Android. **We will do this with you when we meet you at Corbett Hall.** We are able to remotely log into your web-based Fitbit account to see your activity data and chat with you about your progress.

How to synchronize your Fitbit information on your mobile phone?
To update your Fitbit activity information, we ask you regularly synchronize (sync) your Fitbit. To do this, turn on your mobile's Bluetooth, then open the Fitbit application, click "**sync**" on your Fitbit application. Your Fitbit must be within 20 feet of your mobile to be synchronized and let it to upload new information.

How to wear your Fitbit?
The Fitbit tracker should be attached on your waist-band clipped to your pocket or attached to a belt **OR** in your ankle-band (You will choose the placement of your Fitbit at the baseline assessment). The Fitbit is not waterproof and should be taken off showering, swimming or other water-based events. During the day, we would like you to wear the Fitbit at all times (except water activities).



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How to use a Fitbit

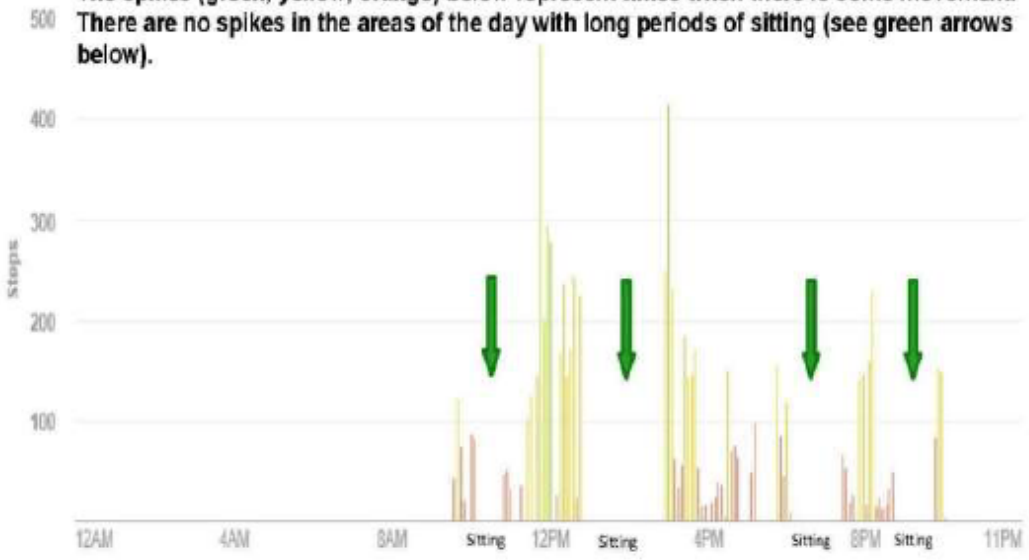
What information can you get by just looking at your Fitbit?

1. Steps taken
2. Floors climbed
3. Recent activity levels(represented by an expanding flower)
4. Distance traveled
5. Calories burned

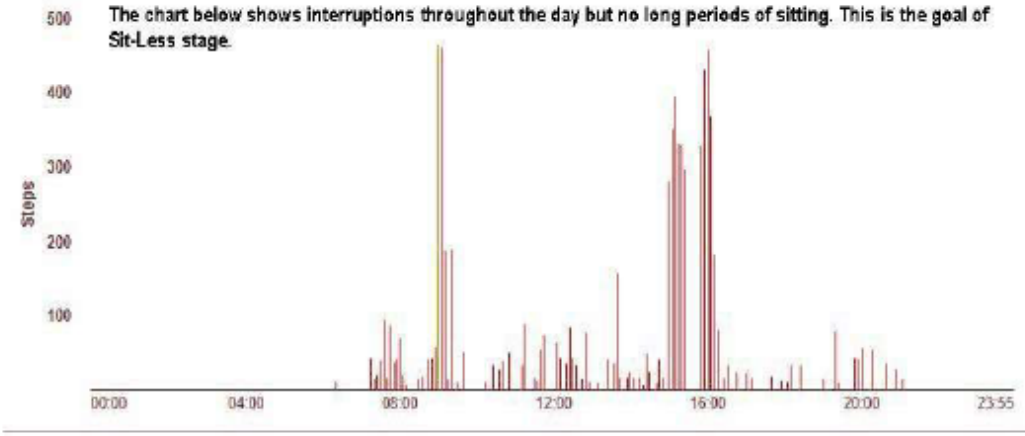
What are we looking at SIT-LESS stage?

At this stage, monitoring is designed to increase your understanding of how much you are interrupting sitting. This information is found only when you log in to the Fitbit website (http://www.fitbit.com); using the username MSSitLessStudy @gmail.com, and the password rehab2017. You will not find it on the dashboard on your mobile. Once you log in, go to "log", and then go to "activities" for that day (see the charts below). We will do this with you at the first Skype chat (coaching session).

The spikes (green, yellow, orange) below represent times when there is some movement. There are no spikes in the areas of the day with long periods of sitting (see green arrows below).



How to use a Fitbit



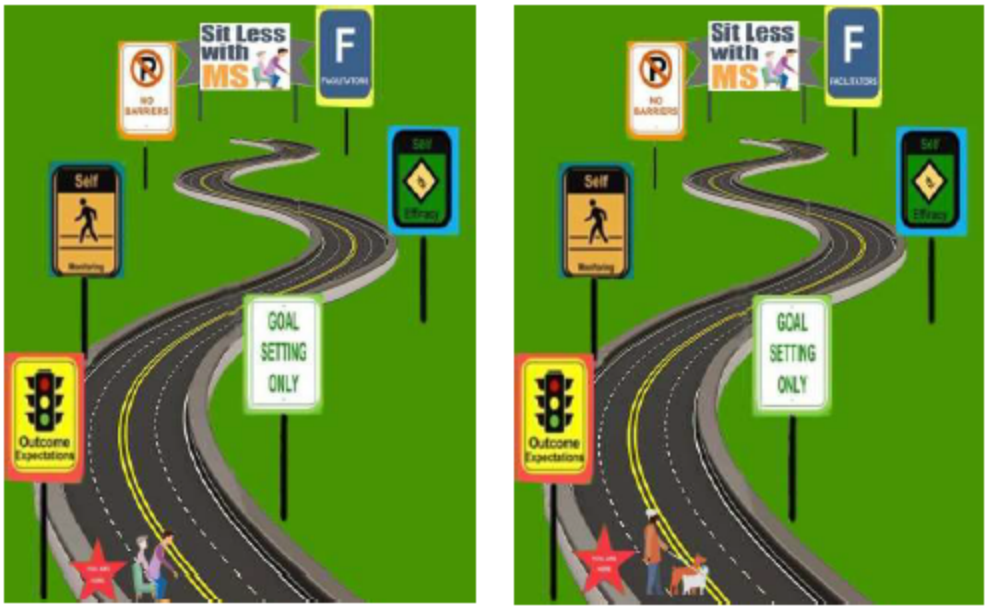
What are we looking at MOVE-MORE stage?
At this stage, the message is Move More – thus, the focus is on number of steps per day, as displayed on the Fitbit dashboard on your phone (see below). During the coaching sessions, we'll touch base about this.

Note: Please contact the **Sit Less with MS team** if you have any questions or trouble with the Fitbit. Phone Number: 780-492-8968

Newsletters

Every week, you will receive a newsletter to guide you along the road to success, featuring inspiring topics such as setting goals and maintaining your ability to sit less and move more in the long-term.

What kind of information will I find in the newsletters?



The road-map you see on the newsletters outlines the sequence of newsletters that you will receive. You will see the little Sit Less with MS mascot moves along the path to the destination where you are frequently interrupting your sitting ( ) and moving more ( ).

Sit Less with MS

What participants saying?

Kristine

"I've been living with MS for almost 23 years now. I had become less confident in my walking and balance, because I get so tired all the time. I was feeling more sluggish and depressed when I was not doing anything. If you are stuck sitting on a chair all day, your muscles and joints get stiffer and more sore and it's even harder to get up.

I found that if I change my position by making myself busy around the house and socialising with friends, I feel physically and mentally much better. It is really easy to get used to sitting and forget getting up but once you change it, you see the benefits.

Now, I know I have to get up more and walk more, even with my walker, to control those feelings."

Sit Less with MS

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Events & Fitbit w

ID:						MONTH
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

Sit Less with MS

Events & Fitbit Log

ID:

MONTH

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

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Sit Less with MS

Events & Fitbit Log

ID: MONTH

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

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Sit Less with MS

Events & Fitbit Log

ID: MONTH

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

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Sit Less with MS

Events & Fitbit Log

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

ID:						MONTH
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

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Sit Less with MS

Events & Fitbit w[illegible]

ID:

MONTH

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

1. Please indicate times the Fitbit was Not worn.

2. Please indicate reason for removal (e.g., swimming, shower).

3. Please record any falls.

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Sit Less with MS

Appendix L: Fitbit One Manual

fitbit one

Wireless Activity + Sleep Tracker

BC

Product Manual

Table of Contents

Getting Started

Welcome to the Fitbit One™ Wireless Activity + Sleep Tracker.

What you'll find in the box

Your Fitbit One box includes:

1. Fitbit One Wireless Activity + Sleep Tracker
2. Clip
3. Wireless sync dongle
4. Sleep wristband
5. Charging cable

What's in this document

We get you started quickly by creating a Fitbit® account and making sure the tracker can synchronize the data it collects with your Fitbit dashboard. The dashboard is where you can analyze your data, see historical trends, set goals, log food and water, keep up with friends, and much more. As soon as you're done setting up your tracker, you're ready to start moving.

Next, we explain how to find and use the features that interest you and adjust your preferences. To find more information, tips, and troubleshooting, please browse our comprehensive articles at http://help.fitbit.com.

Setting up your Fitbit One

To make the most of your One, use the free Fitbit app available for iOS®, Android™, and Windows® 10 mobile devices. If you don't have a compatible mobile device, you can use a computer and fitbit.com instead.

Setting up your tracker on your mobile device

The Fitbit app is compatible with more than 200 mobile devices that support iOS, Android, and Windows 10 operating systems.

To get started:

1. Make sure the Fitbit app is compatible with your mobile device by checking http://www.fitbit.com/devices.
2. Find the Fitbit app in one of these locations, depending on your device:
   - The Apple® App Store® for iOS devices such as an iPhone® or iPad®.
   - The Google Play™ Store for Android devices such as the Samsung® Galaxy® S5 and Motorola Droid Turbo.
   - The Microsoft® Windows Store for Windows 10 mobile such as the Lumia™ phone or Surface™ tablet.
3. Install the app. Note that you'll need an account with the applicable store before you can download even a free app such as Fitbit.
4. When the app is installed, open it and tap Join Fitbit to get started. You'll be guided through the process of creating a Fitbit account and connecting (pairing) your One to your mobile device. Pairing makes sure the tracker and mobile device can communicate with one another (sync their data).

   Note that the personal information you're asked during setup is used to calculate your basal metabolic rate (BMR), which helps determine your estimated calorie expenditure. This information is private unless you go into your Privacy settings and opt to share age, height, or weight with Fitbit friends.

After setup you're ready to get moving.

Setting up your tracker on your PC (Windows 10 only)

If you don't have a mobile device, you can set up and sync your tracker on your Windows 10 PC using the same Fitbit app available for Windows mobile devices.

To get the app, click the Start button and open the Windows Store (called Store). Search for "Fitbit app." Note that if you've never downloaded an app from the store to your computer, you'll be prompted to create an account.

Open the app and follow the instructions to create a Fitbit account and set up your One. You can set up and sync wirelessly if your computer has Bluetooth®, otherwise you'll need to use the wireless sync dongle that came in the box with your Fitbit One.

Setting up your tracker on your PC (Windows 8.1 and below)

If you don't have a compatible mobile device, you can set up your tracker with a computer and see your Fitbit stats on fitbit.com. To use this setup method you'll first install a free software application called Fitbit Connect that lets One sync its data with your fitbit.com dashboard.

To install Fitbit Connect and set up your tracker:

1. Go to http://www.fitbit.com/setup.
2. Scroll down and click the option to download.
3. When prompted, save the file that appears.
4. Double-click the file (FitbitConnect_Win.exe). The Fitbit Connect installer opens.
5. Click Continue to move through the installer.
6. When prompted, choose Set up a New Fitbit Device.
7. Follow the onscreen instructions to create a Fitbit account and connect your One. If your computer has Bluetooth, setup can take place wirelessly. If not you'll be prompted to plug in the wireless sync dongle that came in the box with your Fitbit One.

   Note that the personal information you're asked during setup is used to calculate your basal metabolic rate (BMR), which helps determine your estimated calorie expenditure. This information is private unless you go into your Privacy settings and opt to share age, height, or weight with Fitbit friends.

Setting up your tracker on your Mac

If you don't have a compatible mobile device, you can set up your tracker with a computer and see your Fitbit stats on fitbit.com. To use this setup method you'll first install a free software application called Fitbit Connect that lets One sync its data with your fitbit.com dashboard.

To install Fitbit Connect and set up your tracker:

1. Go to http://www.fitbit.com/setup.
2. Scroll down and click the option to download.
3. When prompted, save the file that appears.
4. Double-click the file (Install Fitbit Connect.pkg). The Fitbit Connect installer opens.
5. Click Continue to move through the installer.
6. When prompted, choose Set up a New Fitbit Device.
7. Follow the onscreen instructions to create a Fitbit account and connect your One.

   Note that the personal information you're asked during setup is used to calculate your basal metabolic rate (BMR), which helps determine your estimated calorie expenditure. This information is private unless you go into your Privacy settings and opt to share age, height, or weight with Fitbit friends.

Syncing your tracker data to your Fitbitaccount

Once you've set up and started using One, you'll need to make sure it regularly transfers (syncs) its data to Fitbit so you can track your progress, see your exercise history, earn badges, analyze your sleep logs, and more on your Fitbit dashboard. A daily sync is recommended but not required.

The Fitbit apps use Bluetooth Low Energy (BLE) technology to sync with your Fitbit tracker. Each time you open the app it will sync if the tracker is nearby, and the app will also sync periodically throughout the day if you have the all-day sync setting enabled. If you're running the Fitbit app on a Windows 10 PC that doesn't have Bluetooth, you'll need to make sure the tracker is connected to the computer.

Fitbit Connect on a Mac® also uses Bluetooth for syncing (if available), otherwise you'll need to make sure your wireless sync dongle is plugged into the computer. Fitbit Connect on a PC requires that you plug in your wireless sync dongle. You can force Fitbit Connect to sync at any time or it will happen automatically every 15 minutes if:

- Your tracker is within 20 feet of your computer and has new data to upload (meaning that if you haven't moved, an automatic sync won't occur).
- The computer is powered on, awake, and connected to the Internet.

Getting to know your Fitbit One

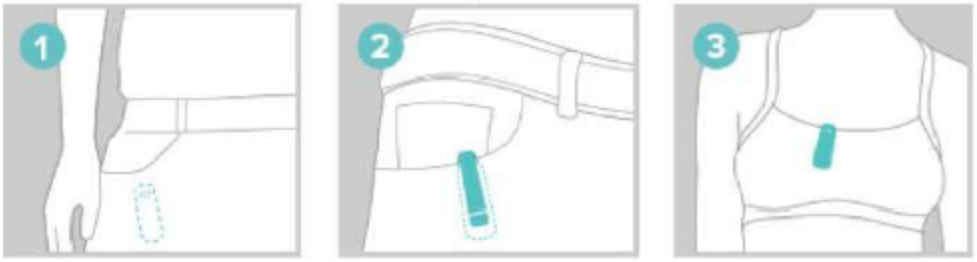
This section tells you how best to wear and recharge your tracker.

Placement

The One is most accurate when worn on or very close to your torso. A clip designed to keep the tracker secured to your clothing is included in your package.

A sleep wristband for your One is also included in your package.

To avoid losing your tracker, we recommend that you wear it in your pocket, clipped to your pocket, or clipped to your bra.



The One is not designed to be worn in direct contact with the skin. Always use the silicone holder when clipping it to a bra or waistband, with the display facing outward. Do not wear the One inside your bra.

Some users may experience skin irritation even when wearing the One as instructed on the bra or waistband. If this occurs we recommend clipping it on your pocket, belt, or other external piece of clothing.

The One is sweat-proof and rainproof. It is not waterproof and should not be taken swimming.

Changing the display for left-handed use

By default your tracker is oriented for right-handed individuals. If you're left handed, you can reorient the display to make it easier to read. To do so, log into your fitbit.com dashboard and click the gear icon in the upper right. Click Settings > Devices and then find and adjust the Left-handed button.

Battery life and charging

The One is powered by a rechargeable built-in battery. Your fully charged One has a battery life of up to two weeks.

Determining your current battery level

You can check your battery level in a couple places:

- While charging your One, press the button on your tracker to view the battery indicator on screen.
- On your fitbit.com dashboard.

Charging your tracker

To charge your One, align the gold contacts on your tracker with the gold contacts on the inside of the charging cable, then plug the cable into your computer's USB port. Charging typically takes about an hour.

Note: Every night at midnight, your tracker will reset itself. This means your goal progress and daily data will begin at zero again. This does not delete the data stored on your tracker. That data will be uploaded to your dashboard the next time you sync your tracker. The time this reset occurs is based on the time zone set on your fitbit.com profile.

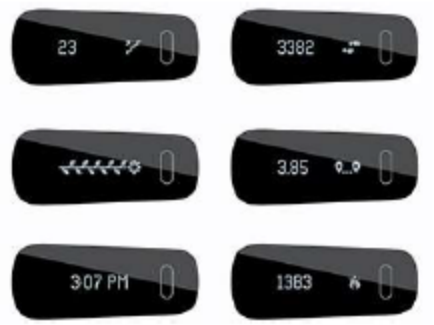
Tracking with Fitbit One

Your One tracks a variety of stats automatically whenever you're wearing it. Your tracker's latest data is uploaded to your Fitbit dashboard whenever you sync.

Viewing all-day stats

Press the button on your One to see the time of day and cycle through these all-day stats:

- Steps taken
- Floors climbed
- Recent activity levels (represented by an expanding flower)
- Distance traveled
- Calories burned



Note that your One resets at midnight according to the time zone you've selected for your account. The reset ensures that One can track your daily totals correctly, and does not delete the previous day's data. All your data will appear on your dashboard when you sync your tracker.

Using the display

When you first set up your One and press the button to scroll through your stats, you see the stat category (e.g. STEPS) followed by the stat and its icon. After you've cycled through each screen 5 times and can recognize the stat icon, the stat category no longer appears so that you can scroll more quickly.

Any time your tracker is reset, it will enter "beginner mode" and show the stat category again for the first 5 cycles. This will happen if you shut down and then restart your tracker, upgrade your tracker, or charge your tracker after the battery drained completely.

Tracking sleep

You can use your One to track how long and how well you sleep. The One will track your movement throughout the night to provide you with information about the quality of your sleep.

1. Place your tracker into the slot in your wristband and wrap it around your non-dominant wrist.

2. Once you are in bed and ready to fall asleep, press and hold the tracker's button for 2+ seconds. You will see a blinking stopwatch and clock. The other icons will also blink, indicating that your tracker is in sleep mode.
3. When you wake up, press and hold the button for 2+ seconds to stop the sleep recording. The icons will stop blinking to indicate you've exited sleep mode. Once you exit sleep mode, your tracker will resume, displaying your daily totals.

Once the data syncs, graphs on your dashboard will reveal how long you slept and the number of times you woke up. You can also use your dashboard to set a goal for hours slept.

Note: If you forgot to press the button on your tracker, but were wearing it while you slept, you can enter your sleep times manually in your online sleep log.

Tracking exercise

Though your One automatically tracks several stats throughout the day, you can also track stats for a specific exercise or workout as well. Similar to the trip mode on a car's odometer, activity mode brings closer scrutiny to a specific time period.

For example, if you put your One in activity mode and go for a run, you can view stats measured for that run, such as calories burned or steps taken. When you end activity mode at the end of the run and sync your data, your can log in to your fitbit.com dashboard and see a summary of the activity's stats such as pace, duration, and more.

To start a recording, hold your tracker's button down for 2-3 seconds until a flashing stopwatch and running numbers appear as they do in sleep mode.

During the activity the display icons will blink. When you press the tracker's button to cycle between screens, the stats represent the activity that has occurred since the recording started.

To exit activity mode, hold your tracker's button down for 2-3 seconds untilthe icons and numbers on the display stop flashing.

Using the fitbit.com Dashboard

Fitbit provides a free online tool — the fitbit.com dashboard — to help you track, manage, and evaluate your fitness progress. Use the dashboard to see your daily totals, analyze details about specific activities, view historical graphs, and log food.

Browser requirements

Browser	Mac Version	Windows Version
Apple Safari	5.0.5 and higher	Not Supported
Google Chrome	12 and higher	12 and higher
Microsoft Internet Explorer	Not Supported	8 and higher
Mozilla Firefox	3.6.18 and higher	3.6.18 andhigher

Adding and removing tiles

Information on the dashboard appears in tiles. Add or remove tiles to customize the dashboard. If you remove a tile, you can add it back at any time.

To add a tile:

1. Click the grid icon on the upper left side of the dashboard.
2. Check the tile(s) you want to add, then click Done.

To delete a tile:

1. Hover over a tile until you see the gear icon at the lower left.
2. Click the gear icon, then click Remove Tile.
3. When prompted, confirm that you want to remove the tile.

Managing your One from fitbit.com

To manage various settings for your account, click the gear icon in the top right corner of your fitbit.com dashboard and select Settings. From here you can edit your personal information, your notification preferences, your privacy settings, and much more.

The Devices page allows you to monitor or edit:

- The date and time of your last sync.
- Your tracker's battery level.
- The firmware version running on your tracker.
- Your time zone.
- Your sleep tracking sensitivity option.
- Your handedness preference: left-handed or right-handed.
- Your tracker's greeting.

Using silent alarms

You can set up to eight gently vibrating silent alarms on your One. Silent alarms can be configured to recur every day, or on particular days of the week.

Note: Setting multiple alarms may drain the battery life of your One. Each alarm increases battery use by a small percentage.

Setting silent alarms

You can add, edit, and delete silent alarms from the Fitbit app or in the fitbit.com dashboard.

To set silent alarms using your fitbit.com dashboard:

1. Log in to your fitbit.com dashboard.
2. Click the **gear icon** in the top right corner of the screen.
3. Click Settings and find Silent Alarms.
4. Click the Add Alarm button.
5. Enter the **time** you want the alarm to alert you.
6. Choose how often you want the alarm to occur:
    a. **Once** – Your alarm will alert you at the specified time and not repeat.
    b. **Repeats** – Choose which days you want this alarm to repeat every week.
7. Click Save.
8. Sync your Fitbit One to update your tracker with the new alarms:
    a. Click the Fitbit Connect icon located near the date and time on your computer.
    b. With your Fitbit One nearby, click Sync Now.
1. Tap Done.
2. Tap the Sync alarms with your tracker button.

Your Android device will now sync the alarm to your One.

Dismissing silent alarms

When your silent alarm goes off, your One will vibrate. This notification will repeat **several times** until dismissed. You can dismiss the alarm by pressing the button.

If you miss your alarm, your One will alert you again after a few minutes.

Updating your Fitbit One

Free feature enhancements and product improvements are occasionally made available through firmware updates. We recommend keeping your One up to date.

You'll be notified in the Fitbit app when an update is available. After you start the update, you'll see a progress bar on your tracker and in the Fitbit app until the process is complete, followed by a confirmation message.

Troubleshooting your Fitbit One

If your tracker is not working properly, review our troubleshooting information below. For other problems or more details, visit http://help.fitbit.com.

If your One is experiencing one of the following problems, it may be fixed by restarting your tracker:

- Not syncing
- Not tracking your steps
- Not responding to battery charge
- Not responding to button presses

Note: Restarting your tracker as described below reboots the device. Note that restarting your tracker does not delete any data.

To restart your tracker:

1. Plug your charging cable into your computer.
2. Plug your One tracker into the charging cable, making sure that the gold contacts on your tracker align with the gold contacts in the inside of the charger.
3. Hold down your tracker's button for 10-12 seconds.
4. Remove your tracker from the charging cable and press its button until the screen turns on.

Your tracker should now work normally.

For additional troubleshooting or to contact Customer Support, see http://help.fitbit.com.

Return Policy and Warranty

Warranty information and the fitbit.com Store Return Policy can be found online at http://www.fitbit.com/returns.

Regulatory and Safety Notices

Model Name: FB103

USA: Federal Communications Commission (FCC) statement

This device complies with FCC part 15 FCC Rules.

Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

FCC Warning

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Note : This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This device meets the FCC and IC requirements for RF exposure in public or uncontrolled environments.

Canada: Industry Canada (IC) statement

IC Notice to Users English/French in accordance with RSS GEN Issue 3:

This device complies with Industry Canada license exempt RSS standard(s). Operation is subject to the following two conditions:

1. this device may not cause interference, and
2. this device must accept any interference, including interference that may cause undesired operation of the device.

Cet appareil est conforme avec Industrie Canada RSS standard exempts de licence (s). Son utilisation est soumise à Les deux conditions suivantes:

1. cet appareil ne peut pas provoquer d'interférences et
2. cet appareil doit accepter Toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositive

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

FCC ID XRAFB103

IC ID 8542A-FB103

European Union (EU)

Declaration of Conformity with Regard to the EU Directive 1999/5/EC

Fitbit Inc. is authorized to apply the CE Mark on One, Model FB103, thereby declaring conformity to the essential requirements and other relevant provisions of Directive 1999/5/EC.

CE

Compliant with the standard R&TTE 99/CE/05

Conforme à la norme R&TTE 99/CE/05

China

Wireless sync dongle

部件名称	有毒和危险品					
Dongle Model FB150	铅 (Pb)	水银 (Hg)	镉 (Cd)	六价铬 (Cr(VI))	多溴化苯 (PBB)	多溴化二苯醚 (PBDE)
表带和表扣	O	O	O	O	O	O
电子	X	O	O	O	O	O

本表格依据 SJ/T 11364 的规定编制

O: 表示该项目中涉及的所有物料, 其包含的有害物质的含量低于 GB/T 26572. 标准的限制要求.

X: 表示该项目中涉及的所有物料中至少有一种, 其包含的有害物质的含量高于 GB/T 26572. 标准的限制要求.

One

部件名称	有毒和危险品					
One Model FB103	铅 (Pb)	水银 (Hg)	镉 (Cd)	六价铬 (Cr(VI))	多溴化苯 (PBB)	多溴化二苯醚 (PBDE)
表带和表扣	O	O	O	O	O	O
电子	X	O	O	O	O	O

本表格依据 SJ/T 11364 的规定编制

O: 表示该项目中涉及的所有物料, 其包含的有害物质的含量低于 GB/T 26572. 标准的限制要求.

X: 表示该项目中涉及的所有物料中至少有一种, 其包含的有害物质的含量高于 GB/T 26572. 标准的限制要求.

Israel

אישור התאמה 51-37309

אין לבצע כל שינוי טכני בחלק המודולארי של המוצר.

Serbia

H005 15

South Korea

" 해당 무선설비는 전파혼신 가능성이 있으므로 인명안전과 관련된 서비스는 할 수 없습니다. "

-. 사용 주파수 (Usedfrequency): 2402 MHz-2480 MHz

-. 채널수 (The number of channels): 40

-. 공중선전계강도 (Antenna power): 0.6 dBi

-. 안테나타입 (Antenna type): Vertical

-. 출력 (Output power): 1.45 mW/MHz E.I.R.P.

-. 안테나 종류 (Type of Antenna): PCB

KCC approval information

2) Certificate number: MSIP-CRM-XRA-FB103

3) Applicant : Fitbit, Inc.

4) Manufacture: Fitbit, Inc.

5) Manufacture / Country of origin: P.R.C.

Taiwan

CCAJ15LP1150T4

Other

211-121203

Complies with IDA Standards DA00006A

N30032

TA-2013/746 APPROVED

Safety statement

This equipment has been tested to comply with safety certification in accordance with the specifications of EN Standard: EN60950-1:2006 + A12: 2011.

Important safety instructions

- Read these instructions.
- Keep these instructions.
- Heed all warnings
- Follow all instructions
- Do not attempt to open the tracker. Substances contained in this product and/or its battery may damage the environment and/or human health if handled and disposed of improperly.
- Do not tamper with your One.
- Do not use abrasive cleaners to clean your One.
- Do not place your One in a Dishwasher, Washing Machine or Dryer.
- Do not expose your One to extremely high or low temperatures.
- Do not use your One in a sauna or steam room.
- Do not leave your One in direct sunlight for an extended period oftime.
- Do not leave your One near open flames.
- Do not dispose of your One in a fire. The battery could explode.
- Do not attempt to disassemble your One, it does not contain serviceable components.
- Never allow children to play with the One; the small components may be a choking hazard!

Built-in battery precautions

- Do not attempt to replace your One's battery. It is built-in and not changeable.

- Charge the battery in accordance with the instructions supplied with this guide.
- Use only the charger that shipped with your product to charge the battery.
- Charge your One using a certified computer, powered hub or power supply.
- Do not attempt to force open the built-inbattery
- Your product uses a California Energy Commission charger.

Disposal and recycling information

The symbol on the product or its packaging signifies that this product has to be disposed separately from ordinary household wastes at its end of life. Please kindly be aware that this is your responsibility to dispose electronic equipment at recycling centers so as to help conserve natural resources. Each country in the European Union should have its collection centers for electrical and electronic equipment recycling.
For information about your recycling drop off point, please contact your local related electrical and electronic equipment waste management authority or the retailer where you bought the product.

- Do not dispose of the One with household waste.
- Batteries are not to be disposed of in municipal waste stream and require separate collection.
- Disposal of the packaging and your One should be done in accordance with local regulations.

Please recycle!

Appendix M: How to Use Fitbit One

What is inside the Fitbit One package?

1. Fitbit One Wireless Activity Tracker
2. Clip
3. Wireless sync dongle
4. Sleep wristband
5. Charging cable

What is Fitbit?
Fitbit is a wireless activity tracker that monitors daily activity levels, including number of interruptions in your sitting, number of steps, distance walked, and number of active minutes per day.

How to turn on your Fitbit?
You will turn on your Fitbit by holding down the button **for 10-12 seconds.**

How to charge your Fitbit?
You will charge your Fitbit by plugging the charging cable into a USB port on a computer (Laptop or Desktop). Make sure to align the gold contacts on your Fitbit with the gold contacts on the inside of the charging cable, then plug it into the computer's USB port. Charging typically takes about an hour or two. A fully charged Fitbit will last about 5 days before another charge is needed.

How to set up your Fitbit on your mobile phone so you can see your activity information?
We will help you to download the Fitbit application on your phone. The Fitbit application is compatible with mobile devices that support iOS and Android. **We will do this with you when we meet you at Corbett Hall.** We are able to remotely log into your web-based Fitbit account to see your activity data and chat with you about your progress.

How to synchronize your Fitbit information on your mobile phone?
To update your Fitbit activity information, we ask you regularly synchronize (sync) your Fitbit. To do this, turn on your mobile's Bluetooth, then open the Fitbit application, click "**sync**" on your Fitbit application. Your Fitbit must be within 20 feet of your mobile to be synchronized and let it to upload new information.

How to wear your Fitbit?
The Fitbit tracker should be attached on your hip (on your waist-band, clipped to your pocket or attached to a belt). The Fitbit is not waterproof and should be taken off showering, swimming or other water-based events. During the day, we would like you to wear the Fitbit at all times (except water activities).

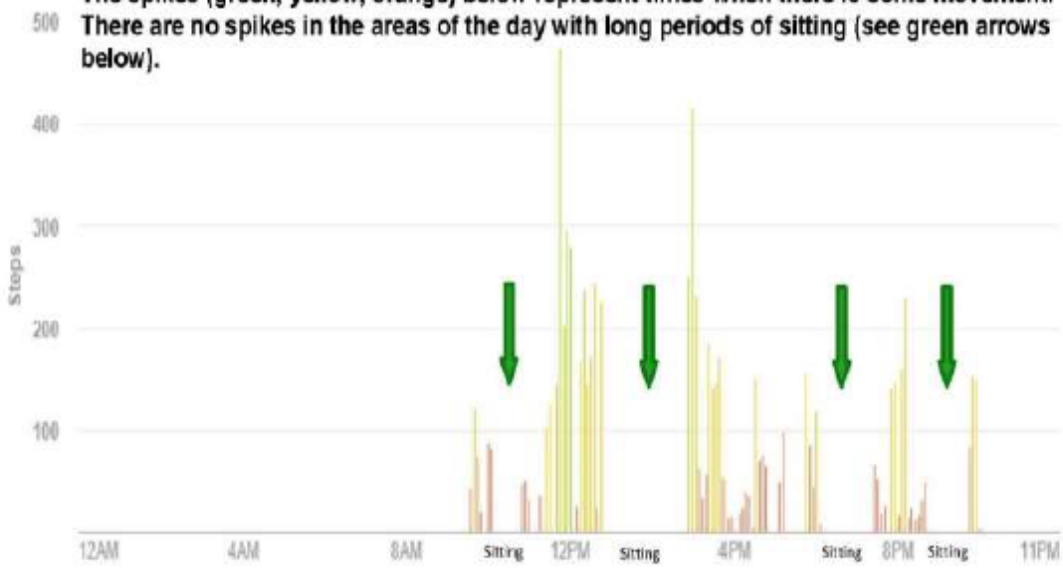
What information can you get by just looking at your Fitbit?

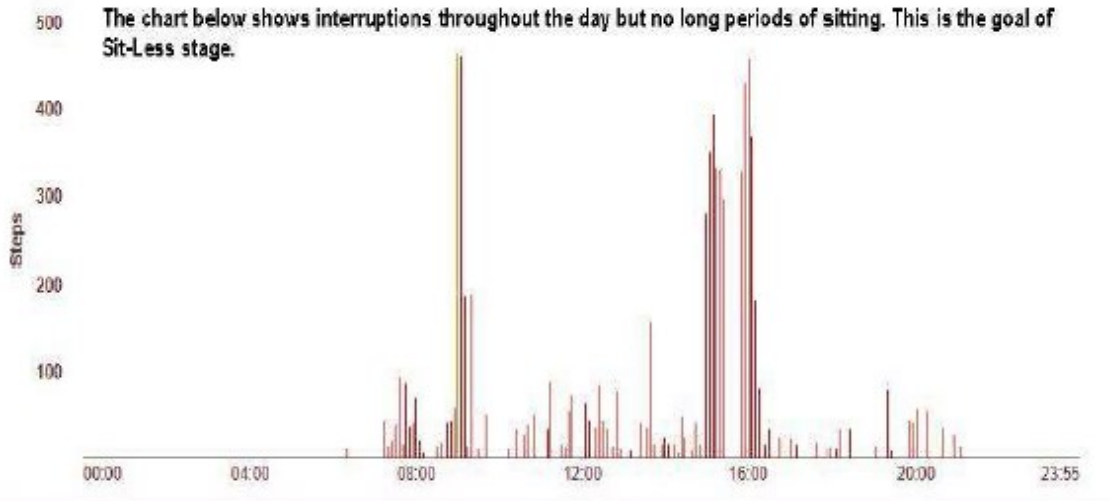
1. Steps taken
2. Floors climbed
3. Recent activity levels(represented by an expanding flower)
4. Distance traveled
5. Calories burned

What are we looking at SIT-LESS stage?

At this stage, monitoring is designed to increase your understanding of how much you are interrupting sitting. This information is found only when you log in to the Fitbit website (www.fitbit.com); using the username MSSitLessStudy.....@gmail.com, and the password rehab2017. You won't find it on the dashboard on your mobile. Once you log in, go to "log", and then go to "activities" for that day (see the graphs below). **We will do this with you at the first Skype chat (coaching session).**

The spikes (green, yellow, orange) below represent times when there is some movement. There are no spikes in the areas of the day with long periods of sitting (see green arrows below).





What are we looking at MOVE-MORE stage?
At this stage, the message is Move More – thus, the focus is on number of steps per day, as displayed on the Fitbit dashboard on your phone (see below). During the coaching sessions, we'll touch base about this.

Appendix N: ActivPAL3™ Log

Phase II & III - ActivPAL Instruction and Compliance Log

Dear Participant,

Please read below instruction to learn more about the ActivPAL3™ monitor:

ActivPAL3™ monitor

- The ActivPAL is a lightweight device that measures your sitting, standing and walking time, and step counts.
- The ActivPAL should be placed on the mid-line of your right thigh with 3M Tegaderm™ Film. Please ensure the orange side is on top and the man pictured is facing upward.
- The ActivPAL should be worn on **your right thigh for seven continuous days**. Please ensure that you **wear the device all the time.**
- If for any reason, you have to remove the ActivPAL from your thigh, please write it down in the log book attached to this instruction, and put the device back on as soon as you can.
- Please ensure that you write down your **wake-up time** and **bed-time** in the log book.

Please do not hesitate to call me on **587-936-1180** if you have any questions.
Saeideh Aminian, Post-Doctoral Research fellow

Participant ID:

PARTICIPANT LOG

Please complete the log below for the next eight days starting from today. We would appreciate if you wear the monitor **all the time.**

	Starting Day 1 Date_____	**Day 2** Date_____	**Day 3** Date_____	**Day 4** Date_____	**Day 5** Date_____	**Day 6** Date_____	**Day 7** Date_____	**Day 8** Date_____
a. For each day, what time did you **wake up?**								
b. For each day, what time did you **go to bed?**								
c. For each day, what times were the monitor **Not** worn (e.g., 1:00pm-2:45pm)?	ActivPAL:	ActivPAL:	ActivPAL:	ActivPAL:	ActivPAL:	ActivPAL:	ActivPAL:	ActivPAL:
d. For each day, what was you were doing when you were **NOT** wearing the monitor? (e.g., swimming, showering)								

Appendix O: Patient-Determined Disease Steps

PDDS: Patient-Determined Disease Steps

Participant ID: _____

Date: _____

This questionnaire is related to how well you walk. Please read the choices listed below and choose the one that best describes your own current situation. You might not find a description that reflects your condition exactly, but please mark the one category that describes your situation the closest.

□ **0 Normal:** I may have some mild symptoms, mostly sensory due to MS but they do not limit my activity. If I do have an attack, I return to normal when the attack has passed.

□ **1 Mild Disability:** I have some noticeable symptoms from my MS but they are minor and have only a small effect on my lifestyle.

□ **2 Moderate Disability:** I don't have any limitations in my walking ability. However, I do have significant problems due to MS that limit daily activities in other ways.

□ **3 Gait Disability:** MS does interfere with my activities, especially my walking. I can work a full day, but athletic or physically demanding activities are more difficult than they used to be. I usually don't need a cane or other assistance to walk, but I might need some assistance during an attack.

□ **4 Early Cane:** I use a cane or a single crutch or some other form of support (such as touching a wall or leaning on someone's arm) for walking all the time or part of the time, especially when walking outside. I think I can walk 25 feet in 20 seconds without a cane or crutch. I always need some assistance (cane or crutch) if I want to walk as far as 3 blocks.

□ **5 Late Cane:** To be able to walk 25 feet, I have to have a cane, crutch or someone to hold onto. I can get around the house or other buildings by holding onto furniture or touching the walls for support. I may use a scooter or wheelchair if I want to go greater distances.

□ **6 Bilateral Support:** To be able to walk as far as 25 feet I must have 2 canes or crutches or a walker. I may use a scooter or wheelchair for longer distances.

PDDS Score: _____

1

Appendix P: Kurtzke Expanded Disability Status Scale (EDSS)

Kurtzke Expanded Disability Status Scale (EDSS)

Participant ID: _____

Date: _____

- ☐ 0.0 Normal neurological exam (all grade 0 in all Functional System (FS) scores)
- ☐ 1.0 No disability, minimal signs in one FS (i.e. grade 1)
- ☐ 1.5 No disability, minimal signs in more than one FS (> one FS grade 1)
- ☐ 2.0 Minimal disability in one FS (one FS grade 2, others 0 or 1)
- ☐ 2.5 Minimal disability in two FS (two FS grade 2, others 0 or 1)
- ☐ 3.0 Moderate disability in one FS (one FS grade 3, others 0 or 1) or mild disability in three or four FS (3 or 4 FS grade 2, others 0 or 1) though fully ambulatory
- ☐ 3.5 Fully ambulatory but with moderate disability in one FS (one grade 3) and one or two FS grade 2; or two FS grade 3 (others 0 or 1) or five grade two (other 0 or 1).
- ☐ 4.0 Fully ambulatory without aid, self sufficient, up and about some 12 hours a day despite relatively severe disability consisting of one FS grade 4 (others 0 or 1) or combination of lesser grades exceeding limits of previous steps; able to walk without aid or rest for some **500 meters or 6 city blocks**.
- ☐ 4.5 Fully ambulatory without aid, up and about much of the day, able to work a full day, may otherwise have some limitation of full activity or require minimal assistance; characterized by relatively severe disability usually consisting of one FS grade fours (others 0 or 1) or combinations

of lesser grades exceeding limits of previous steps; able to walk without aid or rest some **300 meters or nearly 4 city blocks**.

- 5.0 Ambulatory without aid or rest for about **200 meters or 2.5 city blocks**; disability severe enough to impair full daily activities (e.g. to work a full day without special provisions); FS equivalents are one grade five alone (others 0 or 1); or combinations of lesser grades usually exceeding specifications for step 4.0.

- 5.5 Ambulatory without aid for about **100 meters or 1.25 city blocks**; disability severe enough to preclude full daily activities; usual FS requirements are one grade 5 alone (others 0 or 1); or a combination of lesser grades usually exceeding those for step 4.0.

- 6.0 **Intermittent or unilateral constant assistance** (cane, crutch, brace) required to walk about **100 meters or 1.25 city blocks** with or without resting; FS equivalents are combinations with more than two FS grade 3+.

- 6.5 Constant bilateral assistance (canes, crutches, braces) required to walk about 20 meters without resting; (Usual FS equivalents are combinations with more than two FS grade 3+).

Note: EDSS steps 1.0 to 4.5 refer to patients who are fully ambulatory and the precise step number is defined by the FS scores. EDSS steps 5.0 to 9.5 are defined by the impairment to ambulation and usual equivalents in FS scores are provided.

Kurtzke Functional Systems Scores (FSS)

A. Pyramidal Functions

0 - Normal
1 - Abnormal signs without disability
2 - Minimal disability
3 - Mild (4+/5) to moderate (3/5) para-paresis or hemi-paresis (detectable weakness but most function is sustained for short periods, a fatigue problem)
- Severe (≤2/5) mono-paresis (almost no function)
4 - Marked (≤2/5 in 2 ore more muscle groups) para-paresis or hemi-paresis (function is difficult)
- Moderate quadriparesis (function decreased but can be sustained for short periods)
- Monoplegia
5 - Paraplegia, hemiplegia, or marked quadriparesis
6 - Quadriplegia
9 - Unknown

B. Cerebellar Functions

0 - Normal
1 - Abnormal signs without disability
2 - Mild ataxia (tremor or clumsy movements easily seen, minor interference with function)
3 - Moderate truncal or limb ataxia (tremor or clumsy movements interfere with function in all spheres)
4 - Severe ataxia in all limbs (most function is very difficult)
5 - Unable to perform coordinated movements due to ataxia
9 - Unknown

C. Brainstem Functions

0 - Normal
1 - Signs only
2 - Moderate / intermittent nystagmus or other mild disability
3 - Severe / constant nystagmus, marked extraocular weakness (difficulty tracking), or moderate disability of other cranial nerves.
4 - Marked dysarthria or other marked disability
5 - Unable to swallow or speak
9 - Unknown

Sit Less with MS

D. Sensory Function

0 - Normal
1 - Vibration sense decrease in 1-2 limbs

2 - Mild decrease in touch or pain or position sense (2-3 incorrect in any limb)
- Vibratory decrease in 1-4 limbs
3 - Moderate decrease in touch, pain or position sense (4-5 incorrect in any limb)
- Essentially lost vibration in 1-2 limbs
4 - Marked decrease in touch or pain (6+ incorrect) in 1 or 2 limbs
- Loss of proprioception (0 correct) in 1 or 2 limbs
- Moderate decrease in touch or pain (4-5 incorrect) in more than 2 limbs
- Severe proprioceptive decrease (6+ incorrect) in more than 2 limbs
5 - Loss of sensation (8+ incorrect in touch, pain, and vibration) in 1 or 2 limbs
- Loss of proprioception for most of the body below the head
6 - Sensation essentially lost below the head
9 - Unknown

E. Bowel and bladder Function

0 - Normal
1 - Mild urinary hesitance, urgency, or retention (less than 50% of the time)
2 - Moderate hesitance, urgency, retention of bowel or bladder (more than 50% of the time)
- Rare urinary incontinence (intermittent catheterization, manual compression to evacuate bladder, or finger evacuation of stool)
3 - Frequent urinary incontinence (more than 50% of the time)
4 - Need for almost constant catheterization and constant use of measures to evacuate stool
5 - Loss of bladder function
6 - Loss of bowel and bladder function
9 - Unknown

F. Visual Function

0 - Normal
1 - Scotoma (an area of partial alteration in the field of vision – either diminished or entirely degenerated visual acuity) with visual acuity (corrected) better than 20/30
2 - Worse eye with scotoma with maximal visual acuity (corrected of 20/30.20/59
3 - Worse eye with large scotoma, or moderate decrease in fields, but with maximal visual acuity (corrected) of 20/60.20/99
4 - Worse eye with marked decrease of fields and maximal visual acuity corrected of 20/100.20/200
- Grade 3 plus maximal acuity of better eye 20/60 or less
5 - Worse eye with maximal visual acuity (corrected) less than 20/200
- Grade 4 plus maximal acuity of better eye of 20/60 or less
6 - Grade 5 plus maximal visual acuity of better eye 20/60 or less
9 - Unknown

□ Record #1 if participant has presence of temporal pallor

G. Cerebral (or mental) Functions

0 - Normal
1 - Mood alteration only (does not affect EDSS score)
2 - Mild decrease in mentation / mental activity
3 - Moderate decrease in mentation
4 - Marked decrease in mentation (chronic brain syndrome)
5 - Dementia or chronic brain syndrome – severe or incompetent
9 - Unknown

Appendix Q: Fatigue Severity Scale

Fatigue Severity Scale:

Participant ID: _____

Date: _____

This questionnaire is about fatigue and how it affects your function. Please circle the number between 1 and 7 that you feel best describes your usual way of life within the last 4 weeks. 1 indicates "strongly disagree" and 7 indicates "strongly agree."

Read and Circle a Number	Strongly Disagree →						Strongly Agree
1. My motivation is lower when I am fatigued.	1	2	3	4	5	6	7
2. Exercise brings on my fatigue.	1	2	3	4	5	6	7
3. I am easily fatigued.	1	2	3	4	5	6	7
4. Fatigue interferes with my physical functioning	1	2	3	4	5	6	7
5. Fatigue causes frequent problems for me.	1	2	3	4	5	6	7
6. My fatigue prevents sustained physical functioning.	1	2	3	4	5	6	7
7. Fatigue interferes with carrying out certain duties and responsibilities.	1	2	3	4	5	6	7
8. Fatigue is among my most disabling symptoms.	1	2	3	4	5	6	7
9. Fatigue interferes with my work, family, or social life.	1	2	3	4	5	6	7

FSS Scoring:

Add up total of circled numbers: _____

Divide by 9:_____TOTAL SCORE

Appendix R: Modified Fatigue Impact Scale

Participant ID: _____

Date: _____

Fatigue is a feeling of physical tiredness and lack of energy that many people experience from time to time. People who have medical conditions like MS tend to experience stronger feelings of fatigue more often than others. This leads to a greater impact on their life.

The following is a list of statements that describe the effects of fatigue. Please read each statement carefully, and **circle** the number that best indicates how often fatigue has affected you in this way **over the past 4 weeks**. Please answer every question. If you are not sure which answer to select, choose the one that comes closest to describing you. Please ask the interviewer to explain any words or phrases that you do not understand.

Because of fatigue over the past 4 weeks:
0 = Never 1 = Rarely 2 = Sometimes 3= Often 4 = Almost Always

1.	I have been less alert.	0	1	2	3	4
2.	I have had difficulty paying attention for long periods of time.	0	1	2	3	4
3.	I have been unable to think clearly	0	1	2	3	4
4.	I have been clumsy and uncoordinated.	0	1	2	3	4
5.	I have been forgetful.	0	1	2	3	4
6.	I have had to pace myself in my physical activities.	0	1	2	3	4
7.	I have been less motivated to do anything that requires physical effort.	0	1	2	3	4
8.	I have been less motivated to participate in social activities.	0	1	2	3	4
9.	I have been limited by my ability to do things away from home.	0	1	2	3	4
10.	I have trouble maintaining physical effort for long periods.	0	1	2	3	4
11.	I have had difficulty making decisions.	0	1	2	3	4
12.	I have been less motivated to do anything that requires thinking.	0	1	2	3	4
13.	My muscles have felt weak.	0	1	2	3	4
14.	I have been physically uncomfortable.	0	1	2	3	4
15.	I have had trouble finishing tasks that require thinking.	0	1	2	3	4

16. I have had difficulty organizing my thoughts when doing things at home or at work.	0	1	2	3	4
17. I have been less able to complete tasks that require physical effort.	0	1	2	3	4
18. My thinking has been slowed down.	0	1	2	3	4
19. I have had trouble concentrating.	0	1	2	3	4
20. I have limited my physical activities.	0	1	2	3	4
21. I have needed to rest more often and for longer periods.	0	1	2	3	4

Instructions for Scoring the MFIS

Items on the MFIS are aggregated into 3 subscales: physical, cognitive, and psychosocial, as well as the total MFIS score. All items are scaled so that higher scores indicate a greater impact of fatigue on a person's activities.

Physical Subscale:

This scale can range from 0-36. It is computed by adding raw scores on the following items: 4+6+7+10+13+14+17+20+21 _____

Cognitive Subscale:

This scale can range from 0-40. It is computed by adding raw scores on the following items. 1+2+3+5+11+12+15+16+18+19 _____

Psychosocial Subscale:

This scale can range from 0-8. It is computed by adding raw scores on the following items. 8+9 _____

Total MFIS Score:

The total MFIS score can range from 0-84. It is computed by adding scores on the above 3 subscales. _____

Appendix S: SF-36 Quality of Life Questionnaire

Participant ID: _____

Date: _____

This questionnaire will ask you questions about your overall health. For each question, select the answer that most closely describes you.

Choose one option for each questionnaire item.

1. In general, would you say your health is:
   □ 1 – Excellent
   □ 2 – Very good
   □ 3 – Good
   □ 4 – Fair
   □ 5 – Poor

2. **Compared to 1 year ago**, how would you rate your health in general **now**?
   □ 1 – Much better now than one year ago
   □ 2 – Somewhat better now than one year ago
   □ 3 – About the same
   □ 4 – Somewhat worse now than one year ago
   □ 5 – Much worse now than one year ago

The following are activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

	Yes, Limited a lot	Yes, limited a little	No, not limited at all
3. **Vigorous activities** such as running, lifting heavy objects, strenuous sport participation.	□ 1	□ 2	□ 3
4. **Moderate activities** such as moving a table, pushing a vacuum, playing golf	□ 1	□ 2	□ 3
5. Lifting or carrying groceries	□ 1	□ 2	□ 3
6. Climbing **several** flights of stairs	□ 1	□ 2	□ 3
7. Climbing **one** flight of stairs	□ 1	□ 2	□ 3
8. Bending, kneeling, or stooping	□ 1	□ 2	□ 3
9. Walking **more than a mile**	□ 1	□ 2	□ 3
10. Walking **several blocks**	□ 1	□ 2	□ 3
11. Walking **one block**	□ 1	□ 2	□ 3
12. Bathing or dressing yourself	□ 1	□ 2	□ 3

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

	Yes	No
13. Cut down the amount of time you spent on work or other activities	□ 1	□ 2
14. Accomplished less than you would like	□ 1	□ 2
15. Were limited in the kind of work or other activities	□ 1	□ 2
16. Had difficulty performing the work or other activities (for example, it took extra effort.)	□ 1	□ 2

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of any emotional issues** (such as feeling depressed or anxious)?

	Yes	No
17. Cut down on the **amount of time** you spent on work or other activities	□ 1	□ 2
18. **Accomplished less** than you would like	□ 1	□ 2
19. Didn't do work or other activities as **carefully** as usual	□ 1	□ 2

20. During the **past 4 weeks**, to what extent has your physical health or emotions interfered with your normal social activities with friends, family, neighbours, or groups?
    - □ 1 – Not at all
    - □ 2 – Slightly
    - □ 3 – Moderately
    - □ 4 – Quite a bit
    - □ 5 – Extremely

21. How much **bodily** pain have you had during the **past 4 weeks**?
    - □ 1 – None
    - □ 2 – Very mild
    - □ 3 – Mild
    - □ 4 – Moderate
    - □ 5 – Severe
    - □ 6 – Very severe

22. During the **past 4 weeks**, how much did **pain** interfere with your normal work (including both work outside the home and housework)?
    - □ 1 – Not at all
    - □ 2 – Slightly
    - □ 3 – Moderately
    - □ 4 – Quite a bit
    - □ 5 – Extremely

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling.

How much time during the **past 4 weeks**…

	All of the time	Most of the time	A good of the time	Some of the time	A little of the time	None of the time
23. Have you felt full of energy?	□	□	□	□	□	□
24. Have you been nervous?	□	□	□	□	□	□
25. Have you felt so down in the dumps that nothing could cheer you up?	□	□	□	□	□	□
26. Have you felt calm and peaceful?	□	□	□	□	□	□
27. Have you had a lot of energy?	□	□	□	□	□	□
28. Have you felt downhearted and blue?	□	□	□	□	□	□
29. Have you felt worn out?	□	□	□	□	□	□
30. Have you been a happy person?	□	□	□	□	□	□
31. Have you felt tired?	□	□	□	□	□	□

32. During the **past 4 weeks**, how much has your **physical health or emotional issues** interfered with your social activities (like visiting with friends, etc.)?
    - □ 1 – All of the time
    - □ 2 – Most of the time
    - □ 3 – Some of the time
    - □ 4 – A little of the time
    - □ 5 – None of the time

How TRUE or FALSE are **each** of the following statements for you?

33. I seem to get sick a little easier than others
    - □ 1 – Definitely true
    - □ 2 – Mostly true
    - □ 3 – Don't know
    - □ 4 – Mostly false
    - □ 5 – Definitely false

34. I am as health as anybody I know
    - □ 1 – Definitely true

□ 2 – Mostly true

□ 3 – Don't know
□ 4 – Mostly false
□ 5 – Definitely false

35. I expect my health to get worse
□ 1 – Definitely true
□ 2 – Mostly true
□ 3 – Don't know
□ 4 – Mostly false
□ 5 – Definitely false

36. My health is excellent
□ 1 – Definitely true
□ 2 – Mostly true
□ 3 – Don't know
□ 4 – Mostly false
□ 5 – Definitely false

Appendix T: Godin Leisure-Time Exercise Questionnaire

Godin Leisure-Time Exercise Questionnaire

Participant ID: _____

Date: _____

1.) This question asks about your usual leisure-time exercise habits in a normal week. Fill out **how many times** on average you take part in mild, moderate, and strenuous exercise **for at least 15 minutes at a time** during your free time in a one-week period**.** Record this number on the line beside the question.

	Times per Week
A. STRENUOUS EXERCISE (Heart beats rapidly) (e.g., running, jogging, vigorous swimming, vigorous long distance cycling, basketball, soccer, cross country skiing.)	_____
B. MODERATE EXERCISE (Not exhausting) (e.g., fast walking, easy swimming, easy cycling, baseball, tennis, volleyball, alpine skiing, dancing.)	_____

2.) During a typical **7-day period** (a week), in your leisure time, how often do you engage in any regular activity **long enough to work up a sweat** (heart beats rapidly)?

OFTEN □ SOMETIMES □ NEVER/RARELY

Appendix U: Hospital Anxiety and Depression Scale

Hospital Anxiety and Depression Scale (HADS)

Participant ID: _____

Date: _____

Instructions: This questionnaire asks about your feelings over the past week. Please read each heading and circle the reply that comes closest to describing how you have been feeling in the past week. Don't take too long to consider your replies, your immediate reaction to each item will be more accurate than a long thought out response.

1.) I feel tense or 'wound up':	A
Most of the time	3
A lot of the time	2
Time to time, occasionally	1
Not at all	0

2.) I still enjoy the things I used to enjoy:	D
Definitely as much	0
Not quite so much	1
Only a little	2
Not at all	3

3.) I get a sort of frightened feeling like something awful is about to happen:	A
Very definitely and quite badly	3
Yes, but not too badly	2
A little, but it doesn't worry me	1
Not at all	0

4.) I can laugh and see the funny side of things:	D
As much as I always could	0
Not quite so much now	1
Definitely not so much now	2
Not at all	3

5.) I feel as if I am slowed down:	D
Nearly all of the time	3
Very often	2
Sometimes	1
Not at all	0

6.) I get a sort of frightened feeling like 'butterflies in the stomach':	A
Not at all	0
Occasionally	1
Quite often	2
Very often	3

7.) I have lost interest in my appearance:	D
Definitely	3
I don't take as much care as I should	2
I may not take quite as much care	1
I take just as much care as ever	0

8.) I feel restless as if I have to be on the move:	A
Very much indeed	3
Quite a lot	2
Not very much	1
Not at all	0

1

9.) Worrying thoughts go through my mind:	A
A great deal of the time	3
A lot of the time	2
From time to time but not too often	1
Only occasionally	0

10.) I feel cheerful:	D
Not at all	3
Not often	2
Sometimes	1
Most of the time	0

11.) I can sit at ease and feel relaxed:	A
Definitely	0
Usually	1
Not often	2
Not at all	3

12.) I look forward with enjoyment to things:	D
A much as I ever did	0
Rather less than I used to	1
Definitely less than I used to	3
Hardly at all	2

13.) I get sudden feelings of panic:	A
Very often indeed	3
Quite often	2
Not very often	1
Not at all	0

14.) I can enjoy a good book or radio or TV program:	D
Often	0
Sometimes	1
Not often	2
Very seldom	3

Scoring:
Total Score: Depression (D) _____ Anxiety (A) _____

Appendix V: Short Form McGill Pain Questionnaire

Sit Less with MS

Short Form McGill Pain Questionnaire

Participant ID: _____

Date: _____

This questionnaire relates to the pain that you typically experience.

1.) Please place a tick in the box that best represents the degree to which you experience each type of pain listed, on average day to day.

	None (0)	Mild (1)	Moderate (2)	Severe (3)
Throbbing				
Shooting				
Stabbing				
Sharp (intense)				
Cramping				
Gnawing (dull, constant)				
Hot-Burning				
Aching				
Heavy (part of body feels heavy)				
Tender (to touch)				
Splitting (intolerable, overpowering)				
Tiring/Exhausting				
Sickening				
Fearful				
Punishing/Cruel				

2.) Please make a mark on the line below to indicate the intensity of pain you feel on a typical day.

No Pain ⟸⟹ Worst Possible Pain

1

Sit Less with MS

3.) Please select one of the 6 words below that best describes your typical pain by placing a check mark on the line that corresponds to that level of pain.

(0) No Pain _____

(1) Mild Pain _____

(2) Discomforting _____

(3) Distressing _____

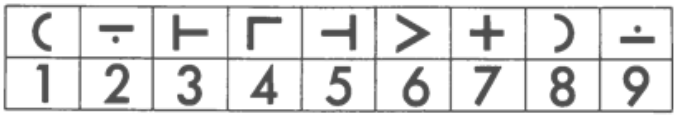
(4) Horrible _____

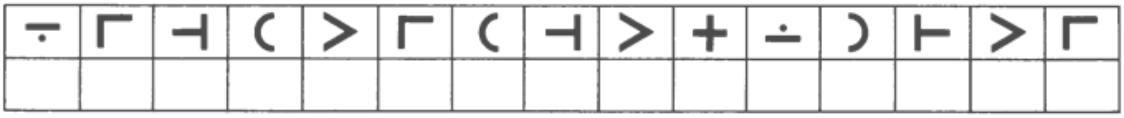
(5) Excruciating _____

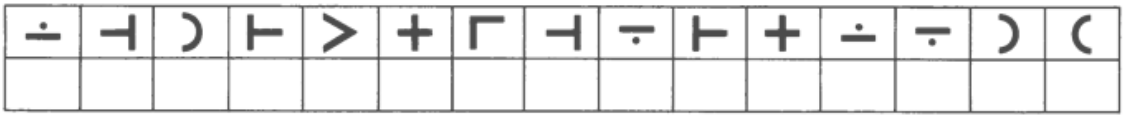
Scoring:

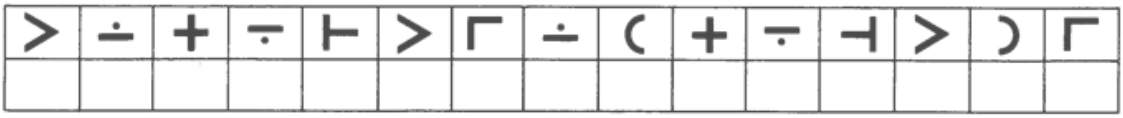
		Score
I-a	S-PRI (Sensory Pain Rating Index)	
I-b	A-PRI (Affective Pain Rating Index)	
I-a+b	T-PRI (Total Pain Rating Index)	
II	PPI-VAS (Present Pain Intensity – Visual Analog Scale)	
III	Evaluative Overall Intensity of Total Pain Experience	

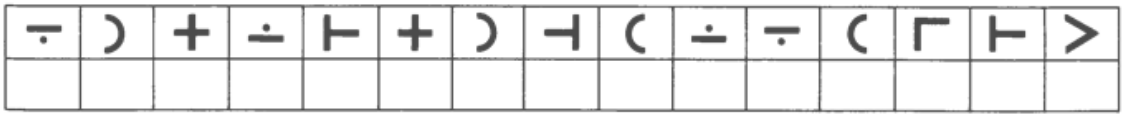
Appendix W: Symbol Digit Modalities Test

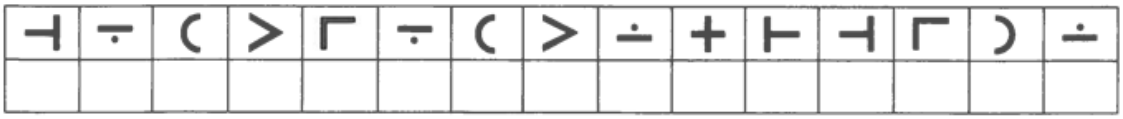












Appendix X: 10 Meter Walk Test Score Sheet

Participant ID: _____

Date: _____

Assistive Devices and/or Bracing Used: _____

Seconds to ambulate 10m (only the interim 10m are timed)

Self-Selected Velocity: Trial 1_____sec.
Self-Selected Velocity: Trial 2_____sec.
Self-Selected Velocity: Trial 3_____sec.
Self-Selected Velocity: Average Time_____sec.

Actual Velocity: Divide 10 by the average seconds above

Average Self-Selected Velocity:_____m/sec

Appendix Y: 6 Minute Walk Test Score Sheet

Participant ID: _____

Date: _____

Assessor 1:

Rate of perceived exertion before test:_____(RPE: 1-10)

Blood pressure before test: _____

Heart rate before test: _____

Assistive devices and/or bracing used: _____

Rate of perceived exertion at 2 minutes: _____

Rate of perceived exertion at 4 minutes: _____

Rate of perceived exertion upon completion of test: _____

Stopped or paused before 6 minutes? No / Yes If

yes: Duration:_____min _____sec

Reasons for stopping: _____
(*1 = desaturation, 2 = orthopedic pain, 3 = muscle fatigue or pain, 4 = breathlessness, 5 = adverse event*) If adverse event, record event: *angina, lightheadedness, intolerable dyspnea, leg cramps, staggering, diaphoresis, pale appearance, mental confusion, headache, etc.*

Participant ID: _____

Date: _____

Assessor 2:

Time of day at start of 6MWT:_____am / pm

Lap counter:

Number of Laps Completed: _____

Residual distance walked in final lap:_____meters

Total distance covered in 6 minutes:_____meters

Supplemental oxygen during the test: No

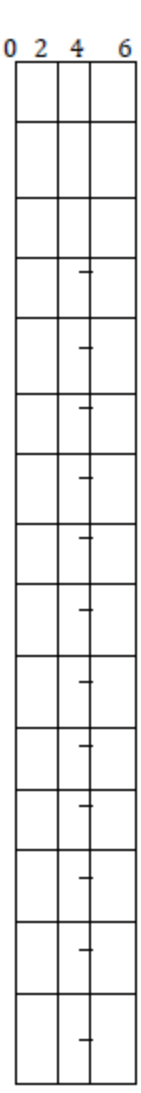
Yes, Flow:_____L/min

RPE: _____ SPO_2: _____ HR: _____ BP: _____

Sit Less with MS

Rate of Perceived Exertion (RPE) Scale:

Rating	Perceived Exertion
6	No effort
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal effort



3

Appendix Z: Short Physical Performance Battery Score Sheet

Short Physical Performance Battery (SPPB) Score Sheet:

Participant ID: _____

Date:

SCORING:

A. Side-by-side-stand
Held for 10 sec ❒ 1 point
Not held for 10 sec ❒ 0 points
Not attempted ❒ 0 points
If 0 points, end Balance Tests

Number of seconds held if less than 10 sec: ___.__ _sec

If participant did not attempt test or failed, circle why:
Tried but unable 1
Participant could not hold position unassisted 2
Not attempted, you felt unsafe 3
Not attempted, participant felt unsafe 4
Participant unable to understand instructions 5
Other (specify) _____ 6
Participant refused 7

B. Semi-Tandem Stand
Held for 10 sec ❒ 1 point
Not held for 10 sec ❒ 0 points
Not attempted ❒ 0 points *(circle reason above)*
If 0 points, end Balance Tests

Number of seconds held if less than 10 sec: ___.__ _sec

C. Tandem Stand
Held for 10 sec ❒ 2 points
Held for 3 to 9.99 sec ❒ 1 point
Held for < than 3 sec ❒ 0 points
Not attempted ❒ 0 points (circle reason above)

Number of seconds held if less than 10 sec: ___.__ _sec

D. Total Balance Tests score_____(sum points)

Comments: _____
_____
_____
_____
_____
_____
_____

1

GAIT SPEED TEST SCORING:

Length of walk test course: Four meters ❒ Three meters ❒

A. Time for First Gait Speed Test (sec)

1. Time for 3 or 4 meters __ __.__ __sec
2. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not walk unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify) _____	6
Participant refused	7

Complete score sheet and go to chair stand test

3. Aids for first walk.....None ❒ Cane ❒ Other ❒

Comments:_____

_____

_____

B. Time for Second Gait Speed Test (sec)

1. Time for 3 or 4 meters __ __.__ __ sec
2. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not walk unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)	6
Participant refused	7

3. Aids for second walk..... None ❒ Cane ❒ Other ❒

What is the time for the faster of the two walks?
Record the shorter of the two times __ __.__ __ sec
[If only 1 walk done, record that time] __ __.__ __ sec

If the participant was unable to do the walk: ❒ **0 points**

For 4-Meter Walk:		**For 3-Meter Walk:**	
If time is more than 8.70 sec:	❒ **1 point**	If time is more than 6.52 sec:	❒ **1 point**
If time is 6.21 to 8.70 sec:	❒ **2 points**	If time is 4.66 to 6.52 sec:	❒ **2 points**
If time is 4.82 to 6.20 sec:	❒ **3 points**	If time is 3.62 to 4.65 sec:	❒ **3 points**
If time is less than 4.82 sec:	❒ **4 points**	If time is less than 3.62 sec:	❒ **4 points**

Sit Less with MS

SCORING

Single Chair Stand Test

		YES	NO	
A.	Safe to stand without help	❒	❒	
B.	Results:			
	Participant stood without using arms	❒		→ Go to Repeated Chair Stand Test
	Participant used arms to stand	❒		→ End test; score as 0 points
	Test not completed	❒		→ End test; score as 0 points

C. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not stand unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify) _____	6
Participant refused	7

Repeated Chair Stand Test

		YES	NO
A.	Safe to stand five times	❒	❒

B. If five stands done successfully, record time in seconds.

Time to complete five stands __ __.__ __ sec

C. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not stand unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)	6
Participant refused	7

Scoring the Repeated Chair Test

Participant unable to complete 5 chair stands or completes stands in >60 sec:	❒ 0 points
If chair stand time is 16.70 sec or more:	❒ 1 points
If chair stand time is 13.70 to 16.69 sec:	❒ 2 points
If chair stand time is 11.20 to 13.69 sec:	❒ 3 points
If chair stand time is 11.19 sec or less:	❒ 4 points

Sit Less with MS

Final Scores for SPPB:

Test Scores	
Total Balance Test score	_____ points
Gait Speed Test score	_____ points
Chair Stand Test score	_____ points
Total Score	_____ points (sum of points above)