HOME-BASED PROGRESSIVE EXERCISE TRAINING IN MULTIPLE SCLEROSIS:

A PILOT STUDY

by

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(Under the Direction of Lesley White)

ABSTRACT

Clinic-based exercise is shown to enhance physical function and reduce premature disability in persons with multiple sclerosis (MS), however it isn't always feasible. The purpose of this study was to determine the feasibility of home-based exercise and whether it would improve physical performance measures in MS. Seven ambulatory individuals with MS exercised 3 days/wk for 8 wks (15 upper & lower body exercises; 3x10-15). Overall physical function (pre: 45.02±14.31; post: 51.31±16.05; p=0.008), balance & coordination (pre: 44.04±13.64; post: 50.20±16.45; p=0.008) and endurance (pre: 45.19±14.89; post: 51.32±16.94; p=0.008) as part of the CS-PFP10, improved. Two of seven strength measures improved (Seated Row pre: 116.25±38.30; post: 123.57±46.61; p=0.014; Leg Curl pre: 95.63±36.78; post: 103.57±39.87; p=0.008) whereas mobility was unchanged. In conclusion, this pilot study indicates that home-based programs may be feasible, however small improvements were seen when compared to clinic-based programs, suggesting home-based programs may be appropriate when clinic-based exercise aren't available.

INDEX WORDS: Multiple Sclerosis, Home-based exercise training, Continuous Scale Physical Functional Performance Test

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CHAPTER 1

INTRODUCTION

Multiple Sclerosis (MS) is a degenerative disease of the central nervous system (CNS) and is the leading cause of non-traumatic neurological impairment in young adults (Moses, Picone, & Smith, 2008). MS affects approximately 400,000 people in the United States and 2,500,000 worldwide, and is typically diagnosed in Caucasian adults between the age of 20 and 40 years (Moses et al., 2008) with greater prevalence in women than in men (2:1, respectively) (Noseworthy, Lucchinetti, Rodriguez, & Weinshenker, 2000). Characterized by inflammation and demyelination of the axons, MS results in axonal injury, axonal transection, neurodegeneration, and the formation of lesions/plaques in the brain and spinal cord (McDonald & Noseworthy, 2003; Moses, Picone & Smith, 2008). These processes can lead to a wide range of symptoms (fatigue, muscle weakness, spasticity, impaired balance and falling, pain, cognitive dysfunction, etc.) that can ultimately reduce mobility, as well as the ability to perform activities of daily living, quality of life and health. While treatment of MS and its associated symptoms often include the use of various pharmacological agents, exercise has been shown to improve some of the clinical signs and symptoms of the disease (Currie, 2001; Dalgas, Stenager, & Ingemann-Hansen, 2008; Dodd, Taylor, Denisenko, & Prasad, 2006; Gehlsen, Grigsby, & Winant, 1984; Gutierrez et al., 2005; Mostert & Kesselring, 2002; Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996a; Rodgers & Mulcare, 1999; Romberg, Virtanen, & Ruutiainen, 2005; Sutherland & Andersen, 2001; Taylor, Dodd, Prasad, & Denisenko, 2006; L. J. White et al., 2004; (L. J. White & Castellano, 2008)) and decrease heart disease risk (Currie, 2001;

Dalgas, Stenager, & Ingemann-Hansen, 2008; Dodd, Taylor, Denisenko, & Prasad, 2006; Gehlsen, Grigsby, & Winant, 1984; Gutierrez et al., 2005; Mostert & Kesselring, 2002; Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996a; Petajan & White, 1999; Rodgers & Mulcare, 1999; Romberg, Virtanen, & Ruutiainen, 2005; Sutherland & Andersen, 2001; Taylor, Dodd, Prasad, & Denisenko, 2006; L. J. White et al., 2004; L. J. White et al., 2006).

Statement of the problem:

Symptoms linked with MS can contribute to decreases in daily activity as well as reductions in physical fitness and mobility. When a sedentary lifestyle is combined with muscle atrophy and elevated adiposity; both of which, are often associated with MS, it can contribute to accelerated disability and poor physical and mental health. Individuals with MS are often weaker than their non-MS, matched counterparts (de Haan *et al.* 2000; Kent-Braun *et al.* 1994; Lambert *et al.* 2001; Latash *et al.* 1996; Ng *et al.* 2004; Petajan *et al.* 1996), and have fewer type I fibers, reductions in muscle enzymes and all muscle fiber types are smaller, suggesting that muscle atrophy in MS may be altered in a pattern of disuse (Kent-Braun et al., 1997). Loss of muscle strength is also coupled with increased risk of depression, premature osteoporosis, fall risk (Cattaneo et al. 2002) and injury, and development of hypokinetic diseases (heart disease, diabetes and obesity) (Warren & Warren, 1981). As a result of these health risks, interventions designed to attenuate deleterious changes and increase health and fitness may be beneficial for improving long term quality of life and reducing health care consumption in people with MS.

Findings from research conducted in people with MS indicates that clinic-based exercise programs are effective for enhancing fitness and physical function and reducing premature disability (Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996b; Petajan & White, 1999); (Mostert & Kesselring, 2002); (Oken et al., 2004); (Dalgas et al., 2008; Romberg et al., 2005;

Sutherland & Andersen, 2001; L. J. White et al., 2004). While data presented from these clinic studies provides valuable information indicating that some physical limitations may be reversible, clinic-based programs are not always available or affordable for people with MS. To date, there is minimal published data on home-based exercise programs as a means of rehabilitation for those with the disease. To meet the needs of those without the ability or desire to participate in clinic-based programs, other non clinic-based therapies with promise to enhance health, function and quality of life are needed. The primary goal of this pilot study was to determine whether a novel home-based progressive resistance training exercise program would alter functional mobility and strength in people with MS. And thus, expand upon the potential therapeutic strategies and the existing literature that are geared toward attenuating the deleterious symptoms associated with MS.

Study Aims:

The aims of this study were to:

1. Determine the feasibility of an 8-week home-based exercise program for ambulatory individuals with MS.
2. Evaluate physical performance measures in people with MS through 3 general approaches
   A. Physical function as determined by the Continuous Scale Physical Functional Performance (CS-PFP10) test,
   B. Functional mobility as determined by walk time in the 25ft and 100ft walk tests, time on the stair climb test, time on the get-up-and-go test, and distance covered in the 6 minute walk test,

C. Strength and endurance as determined by 1-repetition maximum (1-RM) and by the number of repetitions completed at 60% of 1-RM (while maintaining good form).

Hypotheses:

It was hypothesized that:

1. An 8-week home-based exercise program is feasible for ambulatory individuals with MS, as measured by compliance to training, and subjective feelings of satisfaction with the program.
2. Physical performance would improve following 8 weeks of home-based exercise training in people with MS:
   A. Performance on the CS-PFP10 would improve following 8 weeks of home-based exercise training in people with MS.
   B. Functional mobility as measured by the 25ft, 100ft and 6 minute walk tests as well as time on the stair climbing, and the get-up-and-go tests would improve following 8 weeks of home-based progressive resistance training in ambulatory people with MS.
   C. Muscular strength and endurance, as measured by 1-RM and by the number of repetitions completed at 60% of 1-RM (while maintaining good form), respectively would improve following 8 weeks of home-based exercise training in ambulatory individuals with MS.

Significance of the Study

Multiple sclerosis is the leading cause of non-traumatic neurological impairment in young adults (Moses et al., 2008). It is a chronic, debilitating disease that can significantly affect health and quality of life (QOL), as accumulation of disability can occur over several decades. Furthermore, as disease status progresses, individuals with MS are often unable to continue working, and may lose health benefits, which can leave them with medical bills that can cost as much as $47,000 per year (Kobelt, Berg, Atherly, & Hadjimichael, 2006).

In an attempt to minimize physical function deterioration and premature disability in people with MS, therapeutic strategies such as exercise have been used. Exercise is a low-cost, non-invasive intervention that has shown potential to enhance function in patients with MS (Romberg, 2005). While participation in clinic-based exercise programs have been shown to confer many health benefits, it is not always feasible for all individuals with MS to participate in such programs, therefore the importance of alternative activity programs that are cost effective, easy to implement, and accessible across a wide range of people is of significant value and need.

This study was designed to determine the feasibility of implementing a home-based progressive exercise program and its ability to affect physical performance on activities of daily living, functional mobility, and muscular strength. Identification of therapeutic interventions that can attenuate disability and improve health and quality of life can be beneficial in offsetting the social and economic cost of the disease in addition to improving the lives of individuals with MS.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

Multiple sclerosis (MS) is an autoimmune disease that results in demyelination, axonal injury and neurodegenerative processes in the brain, spinal cord and optic nerve (Moses et al., 2008). In addition to demyelination and axonal injury, MS is associated with breakdown of the blood-brain barrier, which when associated with inflammation leads to the formation of plaques or lesions in the brain and spinal cord (McDonald & Noseworthy, 2003). Mediated by autoimmune T-cells (CD4+ Th17 cells), other components that are significant in initiating and completing the damage of myelin and axons include macrophages, microglia, antibodies as well as other immune factors (McDonald & Noseworthy, 2003). As axonal demyelination occurs, there is a reduced capacity for action potentials to relay information between the brain and spinal cord as well as signal transduction from the periphery back to the brain (McDonald & Noseworthy, 2003). In some instances complete axonal loss can occur, thus preventing action potential propagation and the transfer of signals, which can result in severe disability. Inflammation and demyelination of the central nervous system (CNS), and axonal injury can lead to a variety of clinical symptoms (Teeling & Perry, 2009). For example, individuals with MS experience physical and cognitive symptoms that can result in reduced mobility, health and quality of life. While MS has no known cure, exercise programs show promise for enhancing health, improving physical function and preserving independence in people with the disease. In the following review, a brief summary of some of the symptoms associated with MS and the clinical subtypes, followed by a brief analysis of clinical exercise programs that have been used in MS and other clinical populations will be provided. Finally, home-based exercise programs for individuals with MS will be discussed along with their significance in rehabilitation.

Disease and Symptoms

Multiple sclerosis is variable across individuals, but in most instances the amount and severity of symptoms progress as the disease progresses and as inflammation and new lesions develop (McDonald & Noseworthy, 2003). Disease related symptoms and secondary conditions can be debilitating, and can restrict involvement in normal daily activities. Some of the most commonly reported symptoms in MS include: fatigue, muscle weakness, spasticity, impaired balance that can lead to falling, pain, and cognitive dysfunction (Noseworthy et al., 2000). The following section will provide a brief description of each of these symptoms as they relate to the population of individuals with MS.

Fatigue

One of the most common symptoms of MS that is shown to affect more than 80% of diagnosed individuals and can impact daily activity and quality of life is fatigue (Moses et al., 2008); (Hadjimichael, Vollmer, Oleen-Burkey, & North American Research Committee on Multiple Sclerosis, 2008). Several definitions of fatigue have been identified in MS, and when combined it can be described as a lack of physical or mental energy that can occur spontaneously or as a result of a variety of factors, which leads to tiredness, feelings of exhaustion and inability to initiate or sustain voluntary effort (Mills & Young, 2008). Fatigue in persons with MS can either be primary or secondary (Kos, Kerckhofs, Nagels, D'hooghe, & Ilsbroukx, 2008). Primary fatigue may be related to the disease process of MS (Johnson, 2008; Kos et al., 2008), such as functional changes in the brain that occur as a result of demyelination and axonal injury (Kos et al., 2008). Secondary fatigue may result from factors related to MS such as mobility or respiratory problems that increase energy cost or environmental factors such as heat, or could be independent of MS which include factors such as sleep disorders (Krupp & Christodoulou, 2001). Fatigue can be addressed with pharmacological agents, however exercise has also been shown to reduce the impact of fatigue (Stroud & Minahan, 2009)(Fragoso, Santana, & Pinto, 2008).

Muscle weakness

Another prevalent symptom that can compromise daily activities in persons with MS is muscle weakness. Primary mechanisms in MS that are associated with muscle weakness include "reductions in motor firing rates, impaired motor unit recruitment, and increases in central motor conduction time" (Garner & Widrick, 2003). In a study by Kent-Braun and colleagues, individuals with MS, when compared to controls, have fewer type I fibers, reduced muscle enzymes and smaller muscle fiber types, suggesting that muscle atrophy in MS may be a result of disuse (Kent-Braun et al. 1997). Sharma and colleagues have also shown that following exercise there was a delay in tetanic force, which suggests that there may be abnormal excitation-contraction coupling in individuals with MS (Sharma, Kent-Braun, Mynhier, Weiner, & Miller, 1995). Therefore, reductions in physical activity that are observed in MS are secondary mechanisms that can lead to deconditioning and further contribute to decreased muscle strength and endurance (Garner & Widrick, 2003).

Spasticity

In 1997 a survey from the National MS Society identified that 74% of individuals with MS reported symptoms of spasticity (Beard, Hunn, & Wight, 2003). Spasticity is defined as "a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes, with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex" (Lance, 1981). In MS, spasticity can range from a feeling of tightness in the muscles to painful and uncontrollable spasms of the extremities (Currie, 2001). Most often spasticity can be controlled with the use of pharmacological antispastic agents as well as participation in exercise rehabilitation programs (Currie, 2001).

Impaired balance and fall risk

Balance impairment, which can lead to increased fall risk, can occur frequently in people with MS (D. Cattaneo et al., 2002; Cattaneo & Jonsdottir, 2009; Finlayson, Peterson, & Cho, 2006). Adequate balance is dependent on accurate perception and integration of information from the somatosensory, visual and vestibular systems (D. Cattaneo et al., 2002; Cattaneo & Jonsdottir, 2009). In MS, the formation of lesions in any area that contributes to balance control can cause vertigo, altered balance and lack of coordination (Anacker & Di Fabio, 1992). Muscle weakness, limited motor control and fatigue can also impair balance and increase fall risk in MS (Anacker & Di Fabio, 1992; D. Cattaneo, Jonsdottir, Zocchi, & Regola, 2007; Cattaneo & Jonsdottir, 2009; Martin et al., 2006). Individuals with impaired somatosensory perception may also experience inhibited balance as touch, temperature and vibration may not be felt (Osterberg & Boivie, 2009).

Pain

Approximately 50% of individuals with MS experience chronic pain (Moulin, Foley & Ebers, 1988). The World Health Organization categorizes pain into three categories based on pathophysiological criteria, and they include: neuropathic pain, somatic pain, and psychogenic pain (Solaro, Brichetto, Amato, 2004). In MS, neuropathic pain is typically persistent pain and is initiated by a primary lesion or dysfunction in the CNS (Solaro, Lunardi & Mancardi, 2003).

Somatic pain is a physiological response that results in inappropriate activation of nociceptors (Solaro, Brichetto, Amato, 2004) and painful sensations, such as, piercing, throbbing or aching (Solaro, Lunardi & Mancardi, 2003). Psychopathic pain is associated with psychological factors due to prolonged emotional or mental problems, and can include headache, or muscle, back or stomach pains (Solaro, Lunardi & Mancardi, 2003).

Cognitive dysfunction

Changes in cognition are reported to coincide with decreased white and grey matter brain volumes (Bobholz & Rao, 2003). Rao and colleagues found that individuals with MS who had altered cognitive function were less likely to be working, engaged in fewer social activities, and experienced greater difficulty performing routine household tasks (Rao et al., 1991). In persons with MS, altered cognitive function, including executive function, information processing speed, memory, visuo-spatial abilities and attention, has been shown to affect 45-84% of diagnosed individuals (L. J. White & Castellano, 2008). Within the last six years, studies have introduced the notion that regular participation in exercise has potential to preserve brain matter volume across several populations (Colcombe et al., 2003; Colcombe et al., 2006), including MS (L. J. White & Castellano, 2008). While these studies indicate that exercise participation may lead to better cognitive function, including emotional health and depression, they are mostly limited to older individuals and animal models, and have not been adequately investigated in other populations, such as MS (L. J. White & Castellano, 2008).

Clinical Subtypes of Multiple Sclerosis

People with MS exhibit a constellation of symptoms that progress at various rates. To date, four clinical subtypes of MS are recognized: relapsing/remitting, secondary progressive, primary progressive and progressive relapsing (McDonald & Noseworthy, 2003). The disease pattern typically includes relapsing/remitting or a progressive pattern, or can involve a combination of the two, such that the disease pattern could progress from relapsing/remitting to secondary progressive (McDonald & Noseworthy, 2003).

Relapsing/Remitting MS (RRMS)

RRMS is the most common form of the disease and is present in 85% of patients when first diagnosed (McDonald & Noseworthy, 2003; Moses, Picone & Smith, 2008). RRMS is considered the most stable form of the disease with individuals experiencing clearly defined attacks or relapses separated by periods of remission, during which, symptoms may subside or diminish slightly (Moses, Picone & Smith, 2008). Typically disease progression in RRMS does not occur during periods of remission (McDonald & Noseworthy, 2003), however some evidence indicates that brain lesions can occur without any outward clinical symptoms (Bjartmar, Kinkel, Kidd, Rudick, & Trapp, 2001; Martin et al., 2006).

Secondary Progressive MS (SPMS)

SPMS is often considered the second phase of MS, in which individuals who were initially diagnosed with RRMS progress to SPMS (McDonald & Noseworthy, 2003). SPMS occurs in approximately 50% of individuals with MS (McDonald & Noseworthy, 2003). The secondary progressive form is characterized by a steady progression of the disease with more clinically significant relapses and fewer remissions, often reducing neurologic function and mobility (McDonald & Noseworthy, 2003; Moses, Picone & Smith, 2008). In the SPMS subtype, disability tends to progress between relapses (McDonald & Noseworthy, 2003).

Primary Progressive MS (PPMS)

PPMS is a progressive form of the disease (McDonald & Noseworthy, 2003) and affects approximately 10-15% of individuals diagnosed with MS (Moses, Picone & Smith, 2008).

Unlike RRMS and SPMS, PPMS does not have clearly defined periods of relapses or remissions. Instead, it is characterized by continuous disease progression and accumulating disability (McDonald and Noseworthy, 2003; Moses, Picone & Smith, 2008).

Progressive/Relapsing MS (PRMS)

PRMS is similar to PPMS in that it is progressive from disease onset (McDonald & Noseworthy, 2003). It is the rarest and most severe form of MS (Moses, Picone & Smith, 2008) and is characterized by a steady neurologic decline in addition to clinical relapses or attacks (McDonald & Noseworthy, 2003).

Disability Classification in MS

There are several scales that have been developed to quantify disability in people with MS. These scales are commonly used by clinicians to classify the degree of neurologic dysfunction and to plan treatment measures, and they can include: Scripps Neurologic Rating Scale (SNRS), International Classification of Functioning, Disability and Health (ICF), Multiple Sclerosis severity scale (MSSS), Multiple Sclerosis Impact Profile, (MSIP), Multiple Sclerosis Functional Composite (MSFC), Disease Steps in multiple sclerosis, The Guy's Neurological Disability Scale (GNDS), and Expanded Disability Status Scale (EDSS). The most commonly used measure to quantify disability in MS is the EDSS score.

Expanded Disability Status Scale (EDSS)

EDSS is scored on a scale from 0-10 and used to determine disability for all types of MS. Scores are calculated through a combination of grades within 8 functional systems (pyrimidal, cerebellar, brain stem, sensory, bowel & bladder, visual, cerebral, and other) (Kurtzke, 1983), and are used to quantify disability. An EDSS score between 1.0 and 4.5 indicates that the individuals with MS is able to ambulate without assitance from an aid, whereas scores between 5.0 and 9.5 refer to individuals that have impaired mobility (Kurtzke, 1983).

Exercise and Multiple Sclerosis

For many years, individuals that were diagnosed with MS were instructed by their physician to rest and limit exposure to stressful stimuli, including exercise, because increases in body temperature could exacerbate the disease (Sutherland & Andersen, 2001); (A. T. White, Wilson, Davis, & Petajan, 2000); (Petajan & White, 1999), including sensory symptoms and fatigue that could worsen balance and stability (Dalgas et al., 2008). More recently, it has been found that the heightened symptoms are temporary and tend to normalize in 85% of active MS participants a half hour after completion of exercise (Smith, Adeney-Steel, Fulcher, & Longley, 2006). In addition it has been found that cooling prior to exercise participation can attenuate the severity of symptoms while exercising (A. T. White et al., 2000); (Smith et al., 2006).

In the last ten years, several studies have identified the importance of exercise, highlighting that regular participation in cardiovascular (Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996a); (Sutherland & Andersen, 2001); (Mostert & Kesselring, 2002); (Rodgers & Mulcare, 1999); (L. J. White et al., 2004) and resistance training (L. J. White et al., 2004); (Taylor et al., 2006) can improve health, function and quality of life in persons with MS. Most of the exercise related research studies in people with MS have been clinic-based studies. Tables 1 & 2 identify some of the clinic-based exercise studies that have been conducted on individuals with MS, and the primary findings of their study.

Table 1. Clinic-Based Progressive Resistance Training Studies in People with MS

Reference	**Population**	**Program**	**Changes Observed**
(L. J. White et al., 2004)	Individuals with MS ▪ EDSS 1.0-5.0	▪ 8 weeks ▪ Lower body PRT 2x/week	▪ Significant improvements in knee extension, plantarflexion & stepping performance ▪ Significant reductions in self-reported fatigue and disability ▪ No change in 25 ft walk time (pre: 6.1±2.1s; post: 6.2±2.5s)
(Gutierrez et al., 2005)	Individuals with RRMS ▪ EDSS 2.5-5.5	▪ 8 weeks ▪ Lower body PRT 2x/week	▪ Significant increases in stride time in the swing phase, step length, stride length, and foot angle ▪ Improved isometric leg strength ▪ Decreased fatigue and self-reported disability
(L. J. White et al., 2006)	Individuals with MS ▪ Mildly disabled (EDSS 4.0 ± 1.4)	▪ 8 weeks ▪ Lower body PRT 2x/week	▪ Significant improvements in knee extensor and ankle flexor strength ▪ Significant reductions in self-reported fatigue ▪ Decrease in serum triglyceride concentration
(L. J. White, Castellano, & Mc Coy, 2006),	Individuals with RRMS ▪ EDSS 2.5-5.5	▪ 8 weeks ▪ Lower body PRT 2x/week	▪ Significant reductions in cytokines (IL-4, IL-10, CRP, and IFN-γ) ▪ No change in IL-2 and IL-6
(Dodd et al., 2006)	Individuals with MS ▪ EDSS not noted	▪ 10 weeks ▪ Upper and lower body PRT 2x/week	▪ Reported reductions in fatigue ▪ Qualitative reports indicated that the program had physical, psychological and social benefits
(Taylor et al., 2006)	Individuals with MS ▪ EDSS not noted	▪ 10 weeks ▪ Upper and lower body PRT 2x/week	▪ Significant improvements in arm strength, leg endurance, fast walk speed & distance in 2-min walk test

MS=Multiple Sclerosis, RRMS=Relapsing/Remitting Multiple Sclerosis, EDSS=Expanded Disability Status Scale score, PRT=Progressive resistance training

Table 2. Clinical Aerobic Training Studies in People with MS

Reference	Population	Program	Changes Observed
(Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996b)	Individuals with MS ▪ EDSS not noted	▪ 15 weeks ▪ Combined arm & leg ergometry at 60% of VO_{2max} ▪ 3x/week, for 40 minutes	▪ Significant increases in VO_{2max} ▪ Increases in upper & lower extremity strength ▪ Significant decreases in depression and anger as measured by POMS, fatigue, skinfolds, triglycerides, and very-low-density-lipoproteins
(Mostert & Kesselring, 2002)	Individuals with MS ▪ EDSS 2.5-6.5	▪ 4 weeks ▪ Cycle at 60% of VO_{2max} ▪ 5x/week for 30 minutes	▪ Significant increase in aerobic threshold, health perception and activity level ▪ Low incidence of symptom exacerbation during exercise (6%)
(van den Berg et al., 2006)	Individuals with MS ▪ EDSS not noted	▪ 4 weeks ▪ Treadmill at 55-85% of age predicted HRM	▪ Significant decrease in 10 meter walk time

MS=Multiple Sclerosis, EDSS=Expanded Disability Status Scale score, VO_{2max}=maximal oxygen uptake, POMS=Profile of Mood States, HRM=Heart Rate Maximum

These studies provide evidence that both progressive resistance and aerobic exercise training programs implemented in people with MS can have favorable fitness, function and health outcomes. Resistance training in particular stimulates favorable changes in muscle strength, muscle size, muscle endurance, (L. J. White et al., 2004; L. J. White et al., 2006) and physical function in people with MS. These studies indicate that strength training is associated with reduced disability and improved fatigue (L. J. White et al., 2004; L. J. White et al., 2006). While the findings from clinic-based exercise programs highlight the potential benefits of exercise for individuals with MS, access to such programs may not be possible for many with the disease thus, alternative exercise programs are needed to better serve the entire MS population.

Home-Based Exercise Programs

Based on the review of literature, limited research on home-based exercise programs for people with MS is available. In 2004 Debolt and McCubbin observed that home-based progressive exercise training improved leg extensor strength but had minimal impact on balance and mobility (DeBolt & McCubbin, 2004). In a 10-week home exercise inspiratory training program in community-dwelling individuals with MS, and low to moderate disability (EDSS 2.0-6.5), training improved pulmonary muscle strength and endurance (Fry, Pfalzer, Chokshi, Wagner, & Jackson, 2007). More recently, McCullagh and colleagues (2008) observed that individuals with MS who exercised aerobically 1 day at home and 2 days in clinic showed improvements in aerobic capacity, quality of life and fatigue levels (McCullagh, Fitzgerald, Murphy, & Mater, 2008) (Table 3).

Table 3. Current Home-Based Exercise Programs for Individuals with MS

Reference	Population	Program	Changes Observed
(DeBolt & McCubbin, 2004)	Individuals w/ all types of MS ▪ EDSS 1.0-6.5	▪ 8 weeks ▪ Lower body PRT 3x/week	▪ Large improvements in leg extensor power (23.8%) ▪ No change in balance & mobility ▪ 95% adherence
(Finkelstein, Lapshin, Castro, Cha, & Provance, 2008)	Individuals with MS	▪ 12 weeks ▪ Telerehab. ▪ Strength, flexibility & balance ex.	▪ Moderate to large improvements in 25-ft walk time (18%), 6 minute walk distance (18%), and Berg Balance score (8%) ▪ No adherence reported
(Fry, Pfalzer, Chokshi, Wagner, & Jackson, 2007)	Individuals with MS ▪ EDSS 2.0-6.5	▪ 10 weeks ▪ Inspiratory training	▪ Small improvements in pulmonary muscle strength and endurance ▪ No adherence reported
(McCullagh, Fitzgerald, Murphy, & Mater, 2008)	Individuals with RRMS or SPMS	▪ 12 weeks ▪ 2x/week @ clinic & 1x/week @ home ▪ Aerobic exercise	▪ Moderate to large improvements in exercise capacity (14%), QOL (20%) and fatigue (13%) ▪ Subjects completed 20 of 24 clinic sessions, but no subject completed more than half of the home sessions ▪ No adherence reported

MS=Multiple Sclerosis, RRMS=Relapsing/Remitting Multiple Sclerosis, SPMS= Secondary Progressive Multiple Sclerosis, EDSS=Expanded Disability Status Scale score, PRT=Progressive Resistance Training, QOL=Quality of Life

Home-based programs have been implemented in several other populations, such as older adults (Nelson et al., 2004); (Cyarto, Brown, Marshall, & Trost, 2008)(Miriam, Jennifer, Melissa, Andrea, & et,)(Jette et al., 1996), individuals with Parkinson's disease (Nocera, Horvat, & Ray, 2009); (Ashburn et al., 2007), individuals with chronic obstructive pulmonary disease (COPD) (O'Shea, Taylor, & Paratz, 2007), individuals participating in cardiac rehabilitation (Jolly et al., 2009), individuals who had total hip replacement (Galea et al., 2008), and individuals with ankylosing spondylitis (Durmus, Alayli, Cil, & Canturk, 2008), and while some benefits have been observed, the findings have not shown consistent changes in strength and mobility (Table 4).

Table 4. Current Home-Based Resistance Exercise Programs for Older Individuals & Clinical Populations

Reference	**Population**	**Program**	**Changes Observed**
Older Individuals			
(Jette et al., 1996)	66-87 yrs of age	▪ 12-15 weeks ▪ strength program w/ resistance bands	▪ Reported significant differences only in male populations ▪ Increased knee extensor strength in younger older men ▪ Adherence 87%
(Nelson et al., 2004)	≥ 70 yrs of age	▪ 6 months ▪ progressive strength, balance, & physical activity w/ dumbbells & ankle wt	▪ Reported improvements on the Physical Performance Test and in dynamic balance ▪ No change in strength, gait speed, or cardiovascular endurance ▪ Adherence 82%
(Cyarto et al., 2008)	65-96 yrs of age	▪ 20 weeks ▪ resistance training w/ resistance bands & body wt ▪ 2x/week	▪ Reported improvements in strength and upper body flexibility as part of the Senior Fitness Test ▪ Adherence 66%

(Liu-Ambrose et al., 2008)	Individuals post fall (≥ 70 yrs of age)	▪ 6 months ▪ resistance & balance exercises	▪ Reported statistically significant improvements in executive functioning ▪ No change in balance & mobility
Parkinson's Disease			
(Ashburn et al., 2007)	Individuals with Parkinson's disease	▪ 6 weeks ▪ personalized, strength & strategy program	▪ Reported trend toward lower fall rates ▪ No adherence reported
(Nocera et al., 2009)	Individuals with Parkinson's disease	▪ 10 weeks ▪ personalized, strength & strategy program w/ body wt	▪ No statistical differences in postural control following 10 weeks of home exercise between individuals with Parkinson's disease and age matched controls ▪ No adherence reported
COPD			
(O'Shea et al., 2007)	Individuals with Chronic Obstructive Pulmonary Disease	▪ 12 weeks ▪ progressive strength exercise w/ resistance bands	▪ Reported improvements in knee extensor strength ▪ No change in hip abductor, shoulder horizontal flexor, and shoulder flexor strength or 6 minute walk distance ▪ Adherence 85%
Ankylosing Spondylitis			
(Durmus et al., 2008)	Individuals with ankylosing spondylitis	▪ 12 weeks ▪ 20 exercises for muscle strength, flexibility, and posture ▪ 7x/week	▪ Reported improvements in Quality of Life (QOL), fatigue, depression and functional capacity ▪ No adherence reported
Cardiac Rehabilitation			
(Jolly et al., 2009)	Individuals enrolled in a cardiac rehabilitation program	▪ 12 months ▪ Compared center-based versus home-based exercise	▪ No difference between center-based exercise and home-based exercise on the following assessments: smoking cessation, blood pressure, total cholesterol, psychological status, and exercise capacity ▪ No adherence reported
Total Hip Replacement			
(Galea et al., 2008)	Individuals with total hip replacement	▪ 8 weeks ▪ Comparison of clinic	▪ Reported equal improvements in Clinic- & Home-based exercise in QOL, stair climbing, timed

		versus home exercise	up & go, and 6-min walk ▪ No adherence reported

Until a cure for MS is discovered, developing and evaluating exercise programs with promise for enhancing or attenuating loss of function, improving health, and promoting independence while decreasing the social and economic impact of the disease on the patient and their families is needed, and warrants further research. Therefore, the purpose of this project was to implement a home-based progressive resistance training program, determine it's effectiveness for ambulatory individuals with MS, and expand upon the available research regarding home-based programs for individuals with MS.

CHAPTER 3

MATERIALS AND METHODS

Study Participants

Twelve individuals with MS (11 females and 1 male) volunteered from the local and surrounding communities of Athens, GA to participate in the study. All participants signed an informed consent that was approved by the University of Georgia Institutional Review Board, prior to study participation.

Subject Inclusion Criteria

Prior to enrollment, individuals with RRMS or SPMS obtained physician clearance to participate in exercise. Type of MS and disability status were identified by the individual's neurologist to confirm that they had either relapsing/remitting or secondary progressive disease and an EDSS score of less than 6.5 out of 10 which reflects ambulatory status. Individuals using a stable dose of disease modifying agents, anti-depressents, anti-anxiety medications, or anti-spasticity medications were included in the study. Individuals that had participated 6 months earlier in a clinic-based resistance training program for individuals with MS at the University of Georgia were also eligible to participate in the study, however previous participation in exercise was not required (Table 5).

Study Design

Participants completed a 14-week experimental period consisting of three weeks of baseline testing followed by an 8-week home-based progressive resistance training program and three weeks of post testing (Figure 1). The same tests that were completed at baseline were also completed during post testing. All study participants had previous familiarization to the functional mobility (25ft and 100ft walk tests, get-up-and-go test, stair climb test, and 6 minute walk) and strength measures (L. J. White et al., 2004). Subjects did not receive familiarization to the physical functional measure (CS-PFP10 test)(Cress, Petrella, Moore, & Schenkman, 2005). At study completion participants completed a follow-up questionnaire consisting of 5 questions

Table 5. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
1. Obtained physician clearance to participate 2. RRMS or SPMS w/ no relapses in previous 3 months as determined by neurologist 3. 18-65 years of age 4. EDSS score less than 6.5/10 5. Stable dose of disease modifying agents, anti-depressents, anti-anxiety, and/or anti-spasmodic drugs	1. Failure to obtain physician clearance 2. Metabolic or orthopedic conditions indicated by physician that would preclude safe participation 3. Cognitive or autonomic dysfunction indicated by physician that would preclude safe participation

EDSS=Expanded Disability Status Scale score, 0-10 scale with 0 indicating no disability and 10 indicating death due to MS.

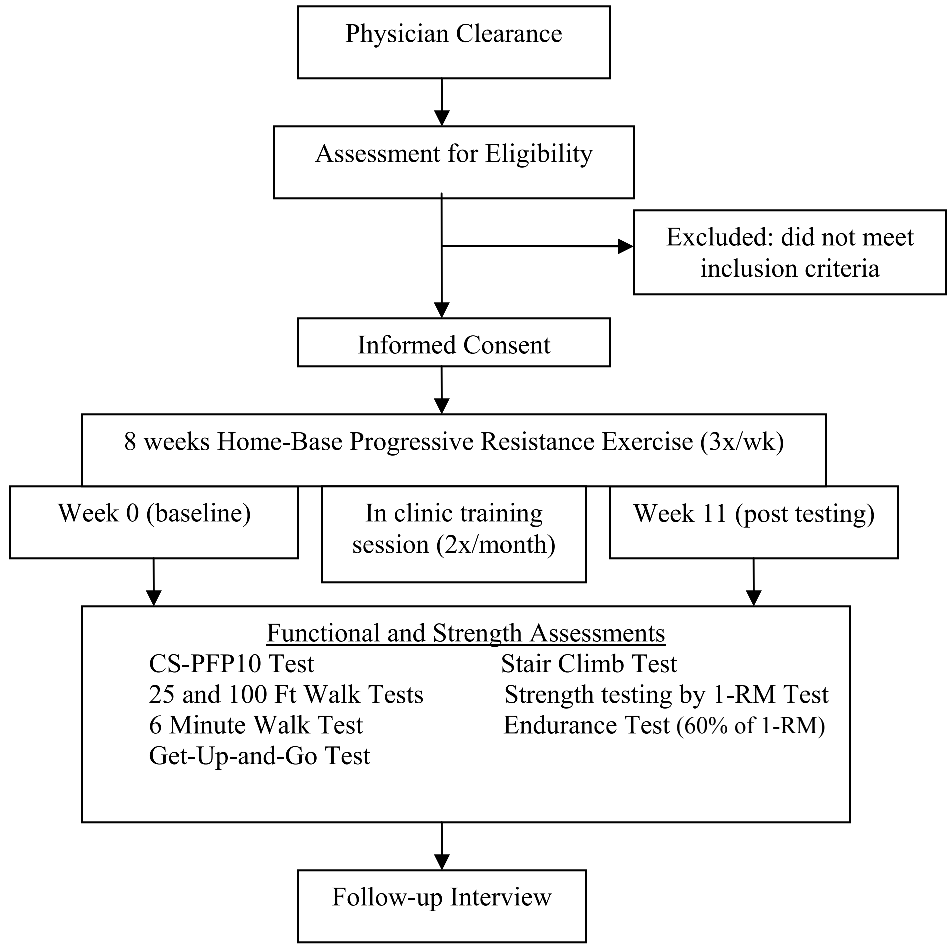

Figure 1. Study Design

Testing and Measurement

Baseline evaluation included the completion of a medical health history questionnaire, assessment of body composition using dual x-ray absorptiometry (DXA) (Lunar Prodigy Radiation Corp., Madison, WI) as well as physical functional, functional mobility and muscular strength assessments (Figure 2).

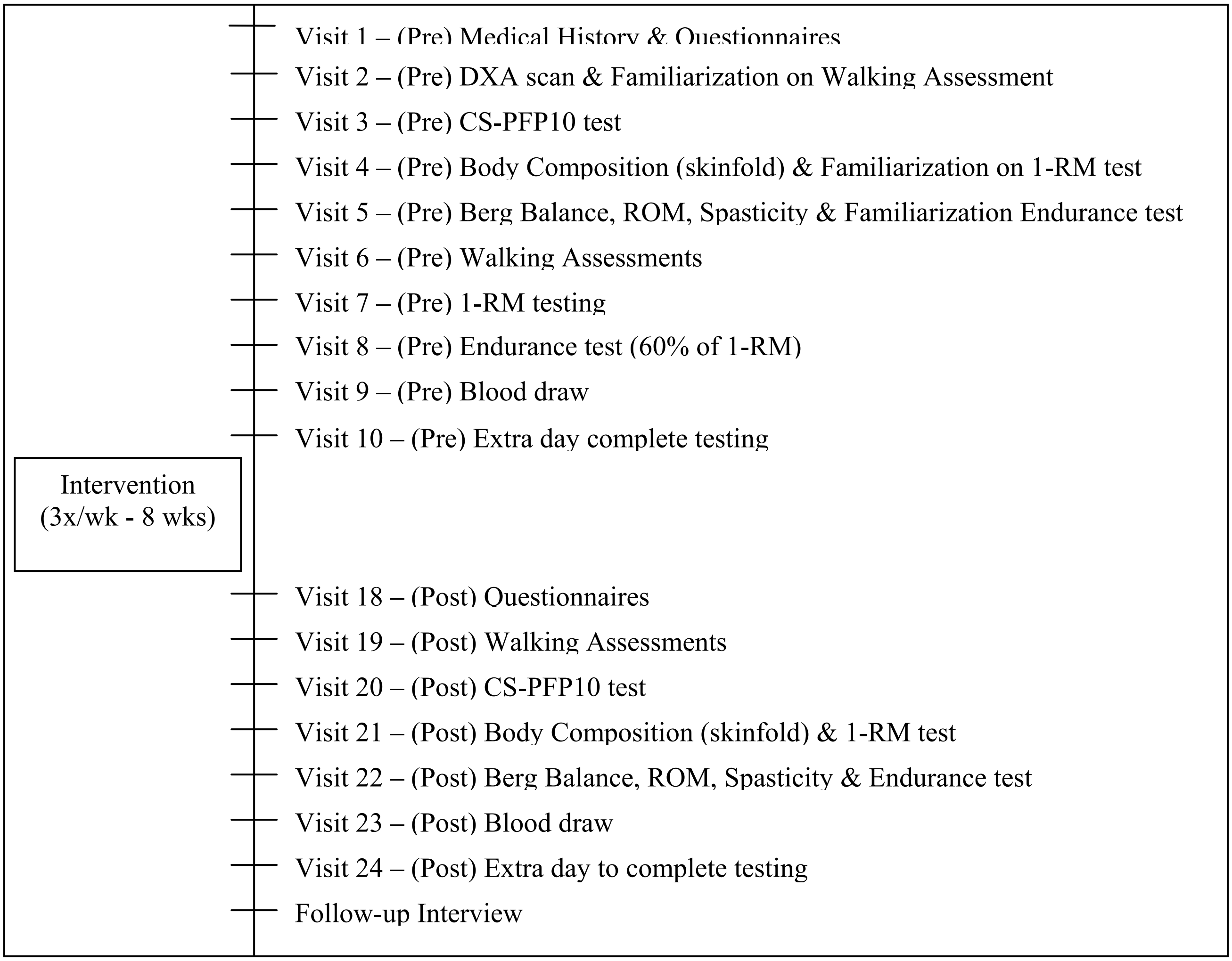

Figure 2. Study Design. Order that assessments were tested in. At least one day of rest was between testing sessions. Walking assessments included the timed 25ft and 100ft walk tests, the timed get-up-and-go, the timed stair climb, and the 6 minute walk test for distance.

Continuous Scale Physical Functional Performance Test (CS-PFP10)

Physical function was assessed using the CS-PFP10 test, which is a comprehensive measure of daily activity and function. It was originally developed for older individuals to help quantify ability to perform daily tasks. This physical functional test was first developed and validated in older adults (Cress et al., 1996) and found to be sensitive to exercise induced change in function (Cress et al., 1999). The original CS-PFP is comprised of 16 functional tasks that reflect physical characteristics in five domains: 1) upper body strength, 2) upper body flexibility, 3) lower body strength, 4) balance and coordination, and 5) endurance, and are administered from easiest to the most difficult task. The CS-PFP tasks are quantified by the time it takes (secs) the individual to complete the task, how much weight (kgs) can be carried, the distance walked or reached, or a combination of time (secs) and weight (kgs). Each task is scored on a scale of 0 to 100, with lower scores indicating less physical function. Domain scores are the average of tasks that require that physical characteristic (upper body strength, etc) and the CS-PFP total is the average of all tasks. The shortened version, CS-PFP10, consists of 10 tasks which was validated in older adults (Cress et al., 2005) and used for this study.

Prior to CS-PFP10 testing, each subject was given standardized instructions to complete each task as safely and quickly as possible. According to standardized instruction, subjects were also told that they may stop to rest if they needed to, or use assistive devices if they were needed. All participants wore a transfer belt and were closely monitored to ensure their safety during the entire test. The test included ten components, 1) carrying a self determined weight in a pan, 2) putting on and removing a jacket, 3) picking up four scarves from the ground, 4) maximal over-head reach, 5) sweeping a half cup of kitty litter off a 3-foot by 4-foot area of floor, 6a) removing 6 articles of clothing from the washer and placing them in the dryer, 6b) moving 6 articles of clothing from the dryer to a basket and placing the basket on the dryer, 7) transitioning from a standing position to a sitting position on the floor and back to a standing position, 8) climbing and descending 4 stairs, 9) carrying the maximal weight of groceries a distance of 42.3 yards including 4 steps, and 10) walking the maximal distance possible in six minutes (Cress et al., 2005). Following the reach task and the floor down/up task, study participants were offered a drink of water as per standard procedures. At the end of the CS-PFP10 test, participants were asked to evaluate their rating of perceived exertion (RPE) using the Borg 20 point RPE scale

(Noble, Borg, Jacobs, Ceci, & Kaiser, 1983). One investigator, trained in the administration of the CS-PFP10, conducted all physical function performance tests.

Clinical Assessments of Mobility

Functional mobility was assessed using a series of timed tests. The assessments used in this study were selected because many of them are standard clinical measures used for individuals with MS (DeBolt & McCubbin, 2004; Finkelstein, Lapshin, Castro, Cha, & Provance, 2008; Kaufman, Moyer, & Norton, 2000; Podsiadlo & Richardson, 1991; Savci et al., 2005) and because they are listed under the clinical study measures used on the National Multiple Sclerosis Society research resource website and have been repeatedly used in the Neuromuscular Physiology laboratory at the University of Georgia. All participants performed timed 25 foot (25ft) and 100 foot (100ft) walk tests, a 6 minute walk test as well as a timed get-up-and-go test and stair climbing test. A digital timing system (Brower IRD-T175, Salt Lake City, Utah) was used for all tests to enhance reliablity. All pre- and post-mobility assessments were performed at the same time of day and each subject received specific instructions and standard encouragement from the investigator. Participants were instructed to wear regular walking footwear and active wear for completion of all tasks. Two trials of each task were performed, with the exception of the 6 minute walk test where only one test was performed, and the best performance was used in the analyses. Subjects had previous familiarization with all the walking assessments.

Walking Assessments

The 25ft and 100ft walk tests were used to assess mobility and leg function performance. The 25ft test has high inter-rater (ICC=0.97-0.99) and intra-rater reliability (ICC=0.93-1.00) (Solari, Radice, Manneschi, Motti, & Montanari, 2005). Two trials of each test were performed and the faster trial was used for data analysis. The six minute walk test also has both high inter-rater (ICC=0.91) and intra-rater (ICC=0.94) reliability (Goldman, Marrie, & Cohen, 2008).

Stair climbing

The stair climbing test is a timed test that is used to measure mobility. For this test participants were instructed to climb up 6 stairs (each stair is 0.15 meters high) as quickly and safely as possible. Participants were timed at the first stepping motion from the base of the stairs until the leading leg broke the plane of the digital timing system which was placed in the middle of the top stair. Two trials were performed and the fastest time was used for analysis.

Get-up-and-Go

The get-up-and-go test is a timed test that is used to measure balance and physical mobility skills and has high reliability (ICC=0.98) (Nilsagard, Lundholm, Gunnarsson, & Dcnison, 2007). Completion of the get up and go includes: rising up from a chair, walking 3 meters, turning around, walking back to the chair and sitting down, while doing this as quickly as possible (Nilsagard et al., 2007). A standard chair with arm rests was used and instructions for test completion were standardized (Podsiadlo & Richardson, 1991). Each participant performed 2 trials, and the fastest time was used for analysis.

Muscle Performance Assessments

Muscular strength

Muscular strength testing of both the upper body and lower body was assessed on all participants using one-repetition maximum (1-RM) testing on Cybex Eagle (Los Angeles, CA) weight machines and included leg extension, leg curl, leg press (L. J. White et al., 2004), chest press, seated row, shoulder press and lat pull down. Study participants had received 3-4 prior familiarization sessions for all 1-RM tests. During 1-RM testing, participants started with a light weight and extended their arms or legs in a controlled manner through the full range of motion, followed by a controlled return to the starting position for a total of one repetition. Weight was added until the participant could no longer complete one repetition. Participants received 3-5 minutes of rest in-between each lift and exercise (de Salles et al., 2009). The last weight successfully lifted through the full range of motion was considered the 1-RM (Barnard, Adams, Swank, Mann, & Denny, 1999). This method has been used in both healthy and diseased populations (Benton, Swan, & Peterson, 2009)(Verdijk, van Loon, Meijer, & Savelberg, 2009)(Hass, Collins, & Juncos, 2007; Levinger et al., 2009).

Muscular Endurance

Muscular endurance was assessed with the chest and leg press lifts using Cybex Eagle (Los Angeles, CA) weight lifting equipment, and was completed using 60% of each participant's 1-RM (Vincent et al., 2002). Study participants were asked to perform as many repetitions, through full range of motion, for each exercise (leg press and chest press) until they reached a fatigue endpoint, which was defined as the inability to continue completing repetitions without rest or complete the next repetition through full range of motion. The 60% of 1-RM load was selected for muscular endurance testing because it has been used in older adults and clinical populations (Vincent et al., 2002).

Resistance Training Intervention

Following baseline testing, participants returned to the Neuromuscular Physiology Laboratory at the University of Georgia on 3 separate days to meet with the study investigator (same investigator that conducted pre- and post-testing) and receive specific instructions for executing each exercise with the appropriate technique, and to allow for supervised practice sessions for each of the fifteen exercises, 8 for lower body, 4 for upper body, and 3 for the abdominals and back, as displayed in a detailed training program guide (Appendix A). The 3 training days that were conducted in the Neuromuscular Physiology Laboratory were included as part of the 8 week intervention. The exercise program, including the warm-up exercises, was designed specifically to focus of the major muscle groups of the body particularly those that tend to be weaker in people with MS. Each exercise session began with 5-10 minutes of warm-up activities that included light stretching and movement as follows: 1 set of 15 repetitions single arm over head reaches, 1 set of 15 repetitions alternating toe taps, 3 sets of 5 second hold with sitting hamstring stretch, 1 set of 20 steps marching in place (standing), and 5 sets of 10 second hold with one leg balance, standing next to a counter. Resistance exercises for the lower body included: toe curls and lifts, toe raises, calf raises, chair squats, leg extensions, leg curls, leg abduction, and leg adduction. Exercises for the upper body consisted of: tricep extension, bicep curl, chest press, and shoulder retraction, and the abdominal and back exercises included: forward crunches, side-to-side crunches, and pelvic lifts. Each training session was designed to last approximately 60 minutes. Following the 3 supervised training sessions in the Neuromuscular Physiology Laboratory, subjects were given detailed instructions as well as a detailed handout with pictures and descriptions of the exercise program (Appendix A), and were instructed to complete 3 training sessions per week for a total of 8 weeks at home. While at home, study participants completed 2-3 sets of 10-15 repetitions for each exercise, as instructed by the study investigator during the supervised training sessions. Participants were also asked to take at least one day of rest after each exercise session, and complete a training journal. One week after the subjects were sent home to complete the exercises, they received a phone call from the study investigator to answer any questions that they had about the exercise program. This phone call was also used to schedule a visit to the Neuromuscular Physiology Laboratory.

Two weeks after going home, the study participants were asked to visit the exercise Neuromuscular Physiology Laboratory to complete a training session while under the supervision of the study investigator. The sessions at the University were used to evaluate exercise technique and adjust the number of sets, repetitions and intensity using the Borg 10 scale (Borg, 1990; Neely, Ljunggren, Sylven, & Borg, 1992). This pattern of contact from the trainer continued during the course of the 8 week program. Following post-testing, study participants were allowed to keep the exercise guide and resistance bands that they acquired throughout the study.

Resistance Training Progression

When completing each of the exercises, participants were instructed to perform each exercise through full range of motion. Once participants were able to complete 3 sets of 15 repetitions with the correct technique and through full range of motion, the resistance level (i.e. Theraband color: yellow<red<green<blue<black) or intensity was increased.

Resistance Training with Bands

Each resistance band was a latex free thera-bands from Isokinetics, Inc. (De Queen, AR) that was approximately 66 inches in length. The following exercises incorporated resistance bands: leg extensions, leg curls, leg adduction, leg abduction, tricep extension, bicep curl, chest press, and shoulder retraction. The set up position for each exercise was designed so that the band had no slack however it was not taut either. During the initial 3 visits to the Neuromuscular Physiology Laboratory a resistance was established that elicited an RPE of 7 out of 10 using the Borg 10 scale (Borg, 1990; Neely et al., 1992). This RPE level was maintained throughout the program.

Resistance Training without Bands

The exercises that did not incorporate resistance bands were: toe curls and lifts, toe raises, calf raises, chair squats, forward crunches, side-to-side crunches, and pelvic lifts. Toe curls and lifts were progressed in 3 phases: 1) they began by completing the range of motion and when they were able, 2) they performed the curls while pulling back a towel, and 3) for the final progression a 2-lb weight was added to the far end of the towel. The toe raises had only two levels where the first level was performed in a seated position and the second level was completed while standing. The calf raises were conducted similar to the toe raises however, when the participant was able to complete the exercise standing and their RPE dropped below 7 out of 10 using the Borg 10 scale, the participants were asked to perform the exercise in a standing position, one leg a time. The chair squats were initiated with the use of the arms to aid movement into and out of the chair. The chair squat was progressed so that there was no aid from the arms when standing and sitting, and the final progression was a 2 second rise out of the chair and a 2 second lowering into the chair. The forward crunches, side-to-side crunches, and the pelvic lifts were progressed by increasing the number of repetition completed in each set. were using latex free thera-bands from Isokinetics, Inc. (De Queen, AR).

Post-Test Evaluation

After the home exercise intervention, participants were assessed on all testing measures that were performed at baseline. All measurements (except DXA) and testing sessions were performed at the same time of day and in the order that they were completed during baseline testing.

Follow-Up Interview & Incentives to Participants

Following the post-test evaluation, all participants that completed 4 or more weeks of the home-based program were contacted by phone to determine whether they would be willing to participate in a follow-up interview. All participants that agreed to be interviewed returned to the Neuromuscular Physiology Laboratory at the University of Georgia to sign a new informed consent that was approved by the University of Georgia Institutional Review Board, as the follow-up interview and the incentive to the participants were not included in the original approved informed consent. Once the participants signed a new informed consent, documents to receive the incentive were completed and the follow-up interview was scheduled. The follow-up interview required approximately 15-20 minutes to complete and was conducted by the study investigator over the phone (Appendix B). Participants were asked a total of 6 questions, each question targeting various aspects of the home-based program. The follow-up interview was collected from each of the participants 4-9 months after completing the 8 week home-based progressive exercise program. In addition to completing a follow-up interview, particpants received $10/month plus $5 for completion of the phone interview, therefore those that completed 8 weeks of the program and the phone interview received $25.

Statistical Analysis

Data collected during the post-testing phase were used for comparision with information gathered at the beginning of the study to determine improvements in physical function, functional mobility and muscular strength during the experimental period. All comparisons of functional and strength measures between pre- and post-testing are expressed as a mean $\pm$ standard deviation (SD). Statistical Package for Social Sciences (SPSS) software (version 17.0, Chicago, Il, 2007) was used to perform descriptive and inferential statistical analyses, and included Pearsons correlations between post-testing measures and Friedman's non-parametric analysis. Friedman's non-parametric analysis was chosen because of the small sample size, and because it is based on no assumptions about the distribution of the data. An alpha level (α) of

0.05 was set for the use of statistical comparisons, and the test statistic used for the Friedmans' test is a Chi-sqaure. To determine power, a repeated measures t-statistic was used. A Bonferroni correction was used to correct for multiple comparisons (20 comparisons), therefore an alpha level (α) of 0.01 was used instead of 0.05. Interview datum were compared to explore similarities and differences in the participants' perceptions and experiences and results are expressed through grouping of responses and first-person quotations of the participants' experiences.

CHAPTER 4

RESULTS

Participants

Of the 12 individuals that were enrolled, 7 completed the study. All participants that were interested in participating met the inclusion criteria. Participant characteristics can be found in Table 6 and are identified by number consistenly throughout the results. Reasons that individuals withdrew from the study included: 2 had an illness (1 had completed 2 weeks of the intervention and 1 did not return for post-testing), 1 was injuried at work (completed 1 week of the intervention), 1 was injured while at home (unrelated to the study and had completed 7 weeks of the intervention), and 1 had family obligations (completed 6 weeks of the intervention) that prevented program completion.

Compliance to Home-Based Exercise Program

The exercise intervention consisted of 24 training days (8 weeks, 3 days/week), which included the 3 sessions that were completed in the Neuromuscular Physiology Laboratory after baseline testing. Compliance was determined by adding the number of completed exercise sessions that each participant recorded in their training journal. The mean number of exercise sessions completed by the group was 18, representing 75% of the total sessions, and the range was between 13 and 22 sessions.

Table 6. Baseline characteristics of participants that completed exercise intervention.

Subject	Sex	Age (yrs)	Type of MS	EDSS score	Height (cm)	Weight (kg)
1	F	53	RRMS	5.5	162.6	76.3
2	M	52	RRMS	5.0	170.4	71.8
3	F	61	RRMS	5.0	167.6	90.4
4	F	33	RRMS	4.0	154.9	63.2
5	F	51	RRMS	1.0	166.4	62.6
6	F	49	RRMS	0.0	171.2	67.7
7	F	33	RRMS	0.0	172.4	111.6
Mean (n=7)		47.4 ± 10.5		2.9 ± 2.5	166.5 ± 6.1	77.7 ± 17.7
Range (n=7)		33-61		0.0-5.5	154.9-172.4	62.6-111.6
8*	F	50	SPMS	6.0	165.1	102.6
9*	F	26	RRMS	1.0	165.1	49.9
10*	F	53	RRMS	3.0	180.3	120.8
11*	F	51	RRMS	3.5	171.5	74.6
12*	F	30	RRMS	0.0	152.4	87.3
Mean (n=12)		45.2 ± 11.4		2.8 ± 2.3	166.7 ± 7.6	81.6 ± 21.4
Range (n=12)		26-61		0.0-6.0	152.4-172.4	49.9-120.8

Data are expressed as Mean ± SD.
* Withdrew from the study.

Continuous Scale Physical Function Performance Test

Performance on the CS-PFP10 total increased significantly following 8 weeks of home-based progressive exercise (14.0%, p=0.01), (Table 7) (Figure 8). Domain scores for balance and coordination (14.0%, p=0.01) (Figure 6) and endurance (13.6%, p=0.01) (Figure 7) also increased significantly, whereas domain scores for upper body strength (12.6%, p=0.06) (Figure 3), upper body flexibility (10.0%, p=0.06) (Figure 4), and lower body strength (17.5%, p=0.06) (Figure 5) were unchanged. The change in the average amount of weight carried by the group for the pot carry (pre: 16.6kg ± 6.8kg, post 18.4kg ± 6.3kg, p=0.06); and the grocery task (pre 15.1kg ± 8.4kg, post 16.5kg ± 6.8kg, p=0.06) was not significantly different. The mean distance covered in the six minute walk, one of the individual tasks of the CS-PFP was not significantly different (pre: 456.1 ± 165.2; post: 489.4 ± 173.5, p=0.06). The average sum of all timed tasks for the group from baseline to post-testing (pre: 213.4sec ± 62.4sec, post: 190.01sec ± 61.6sec) was decreased significantly (p=0.01). The overall RPE reported by participants after CS-PFP10 testing was unchanged (pre: 12.57 ± 0.53; post: 12.29 ± 1.80, p=1.00).

Table 7. Continuous Scale Physical Function Performance Test at baseline and 8 weeks after the home-exercise intervention.

CS-PFP10	Baseline	8 Weeks	% Change	p-value
Upper Body Strength Score	49.8 ± 18.0	56.1 ± 16.6	12.6%	0.059
Upper Body Flexibility Score	63.7 ± 8.4	70.1 ± 12.4	10.0%	0.059
Lower Body Strength Score	38.0 ± 15.9	44.6 ± 16.9	17.5%	0.059
Balance and Coordination Score	44.0 ± 13.6	50.2 ±16.5	14.0%*	0.008
Endurance Score	45.2 ± 14.9	51.3 ± 16.9	13.6%*	0.008
CS-PFP10 Total	45.0 ± 14.3	51.3 ± 16.1	14.0%*	0.008

(n=7) Data are expressed as Mean ± SD. Upper body strength score, lower body score, upper body flexibility, balance and coordination, endurance, and CS-PFP total are all scored on a range of 0 to 100, with 100 being the most possible points that can be obtained. * (p<0.01), differences for baseline versus 8 week comparison.

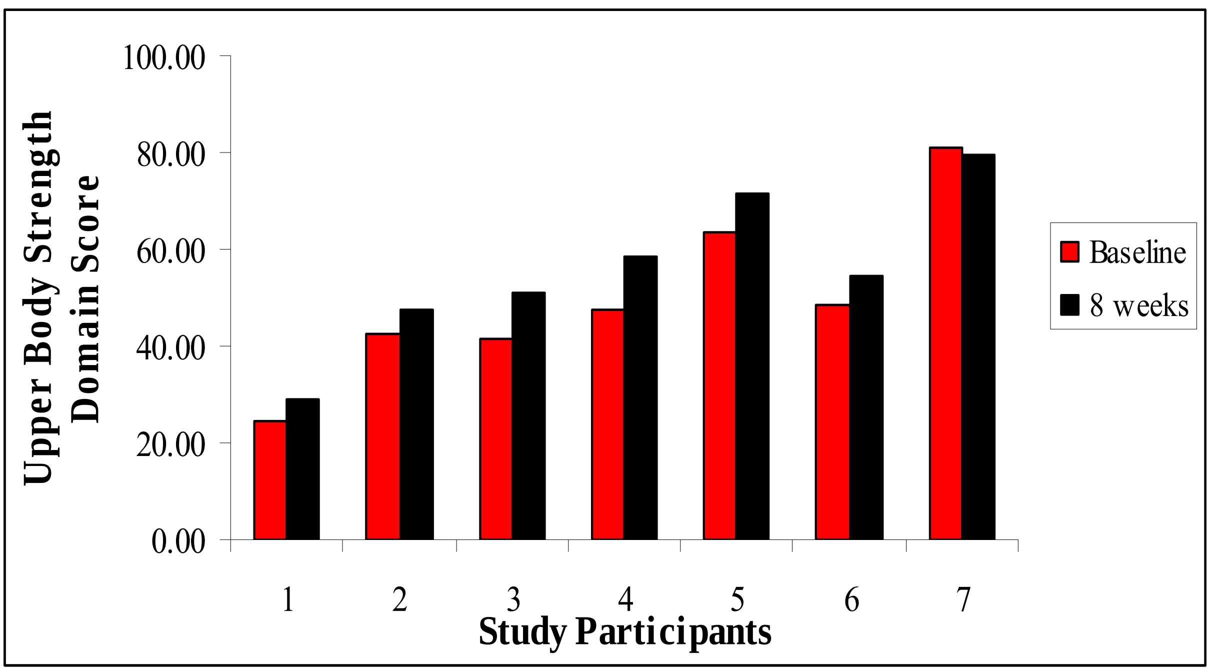

Figure 3. (n=7) Upper Body Strength (UBS) domain scores for each participant before and after the 8-week exercise intervention. Composed of the pot carry, both laundry tasks, and the groceries task.

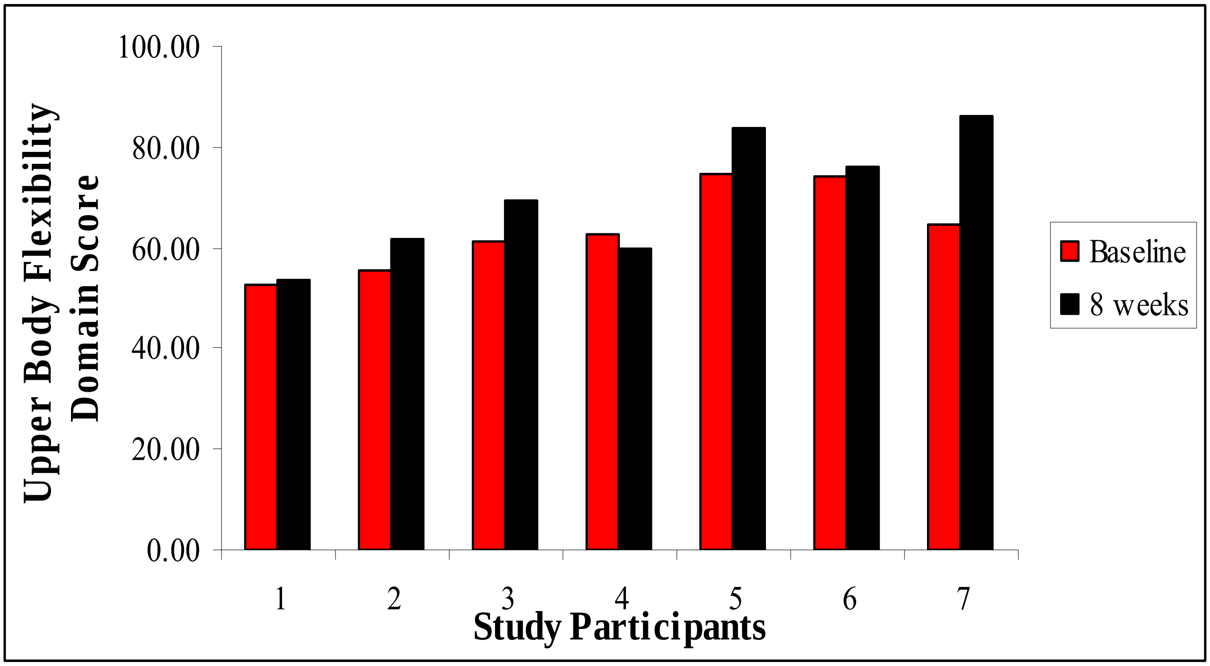

Figure 4. (n=7) Upper Body Flexibility (UBF) domain scores for each participant before and after the 8-week exercise intervention. Composed of following tasks: jacket put on and removal and the overhead reach.

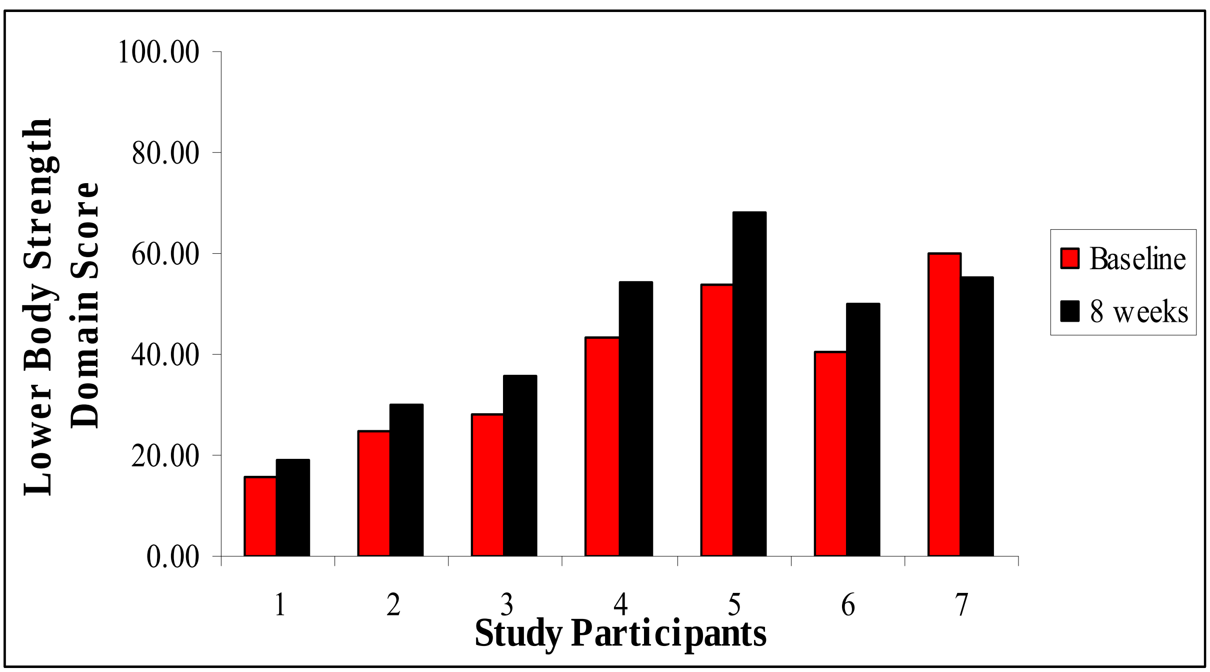

Figure 5. (n=7) Lower Body Strength (LBS) domain scores for each participant before and after the 8-week exercise intervention. Composed of the scarves task, floor sweep, both laundry tasks, the groceries task, the floor down/up, and the stair climb.

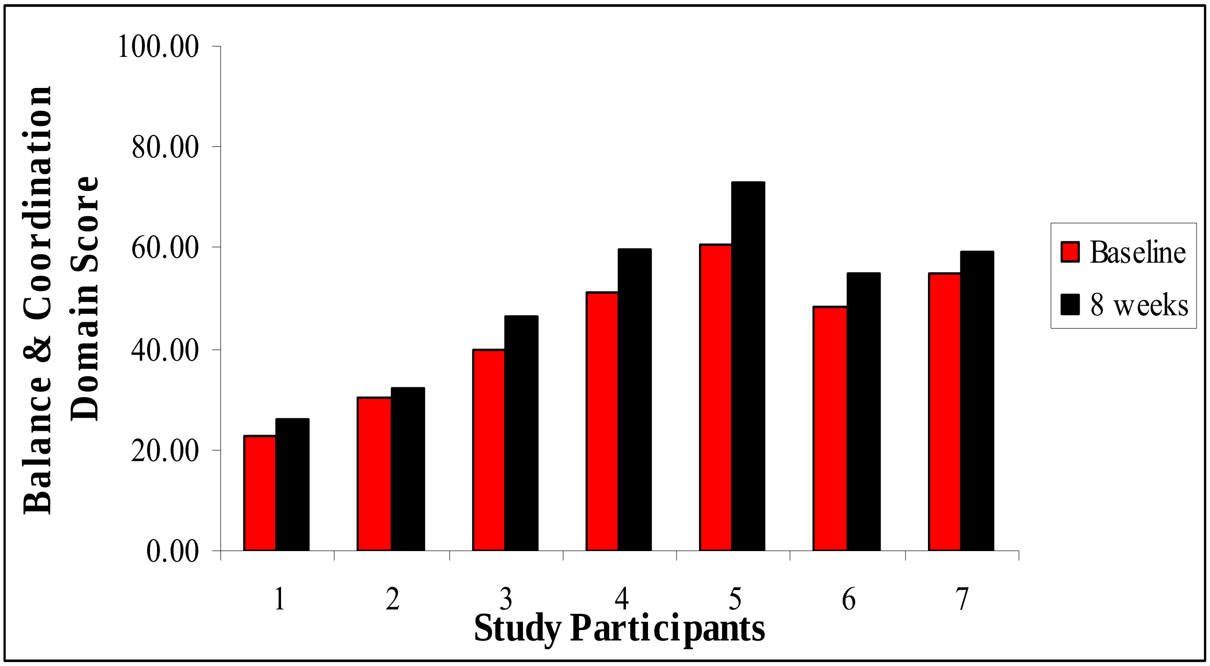

Figure 6. (n=7) Balance & Coordination (B&C) domain scores for each participant before and after the 8-week exercise intervention. Composed of the following tasks: pot carry, jacket on and removal, the scarves task, floor sweep, both laundry tasks, the groceries task, the floor down/up and the stair climb.

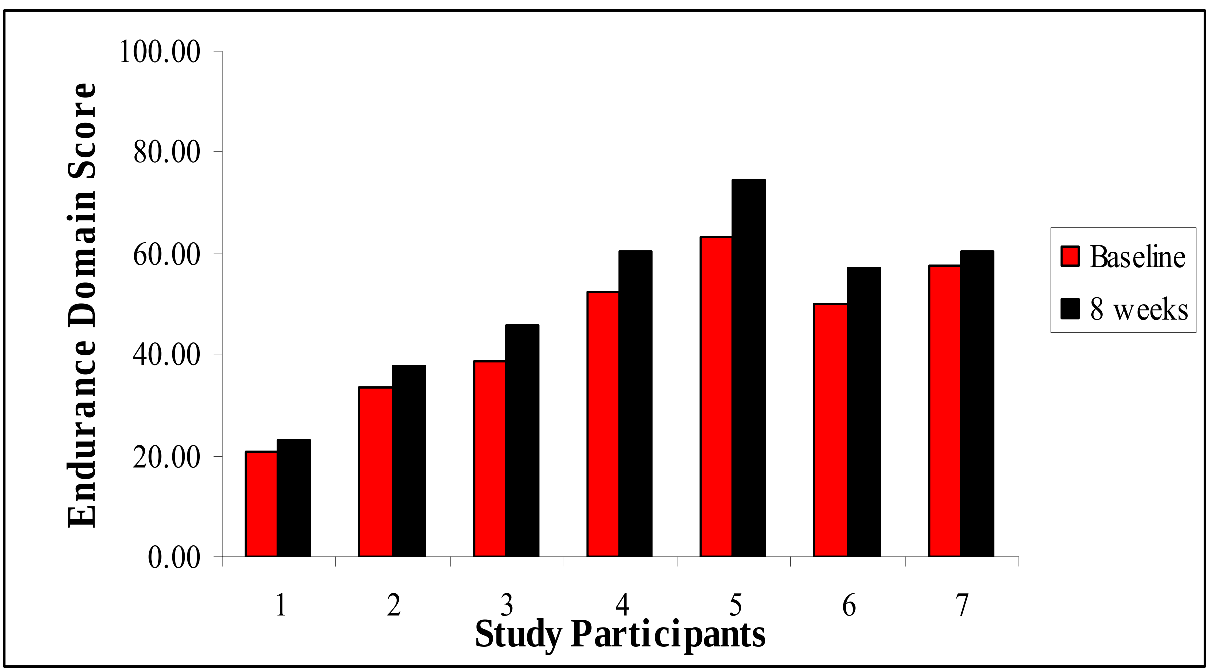

Figure 7. (n=7) Endurance (E) domain scores for each participant before and after the 8-week exercise intervention. Composed of the 6 minute walk task.

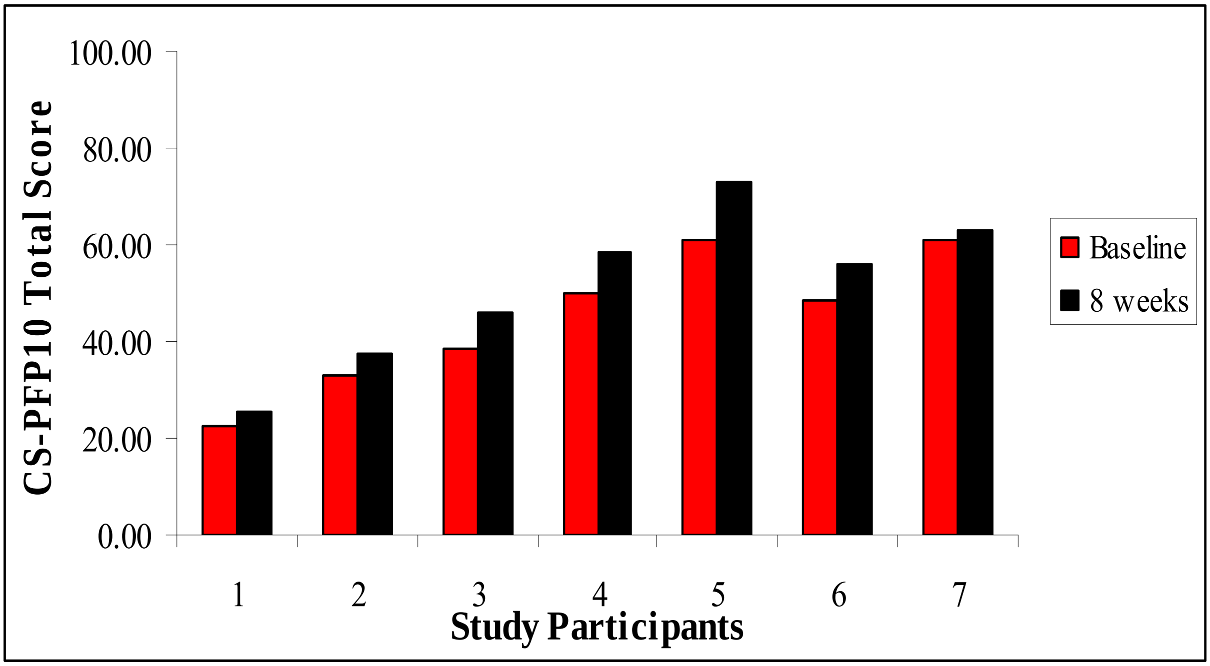

Figure 8. (n=7) CS-PFP10 Total Scores for each participant before and after the 8-week exercise intervention. Composed of all 10 tasks: pot carry, jacket on and removal, scarf retrieval, overhead reach, floor sweep, both laundry tasks, floor down/up, stair climb, grocery task, and the 6 minute walk.

Clinical Assessments of Mobility

Following the 8 week program, mean performance on the 25ft walk (pre: 4.76 ± 1.43 seconds; post: 5.58 ± 2.88 seconds; p=0.71), 100ft walk (pre: 19.66 ± 6.30 seconds; post: 22.37 ± 13.14 seconds; p=0.71), get-up-and-go test (pre: 6.98 ± 2.61 seconds; post: 7.65 ± 3.95 seconds; p=0.41), stair climb test (pre: 2.91 ± 1.57 seconds; post: 2.93 ± 1.79 seconds, p=0.71), and 6 minute walk (pre: 492.64 ± 148.74 meters; post: 481.51 ± 183.76 meters; p=0.71) were not significantly changed from baseline. One subject was more than 2 SD slower on the 25ft walk, 100ft walk, and get-up-and-go tests (32-38%) and covered less distance on the 6 minute walk (87%) compared to the other six study participants (Figures 9-13).

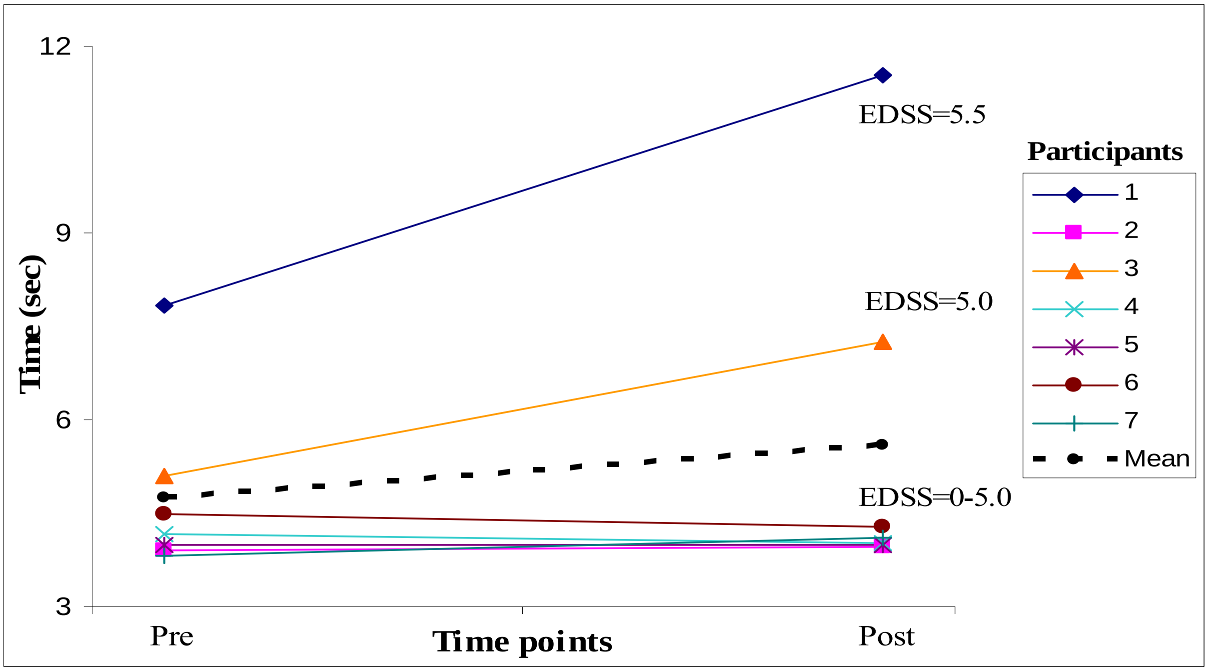

Figure 9. (n=7) 25ft walk before and after 8 weeks of the exercise intervention. EDSS = Expanded Disability Status Scale score. A lower EDSS score indicates less disability. Each line represents one study participant's performance.

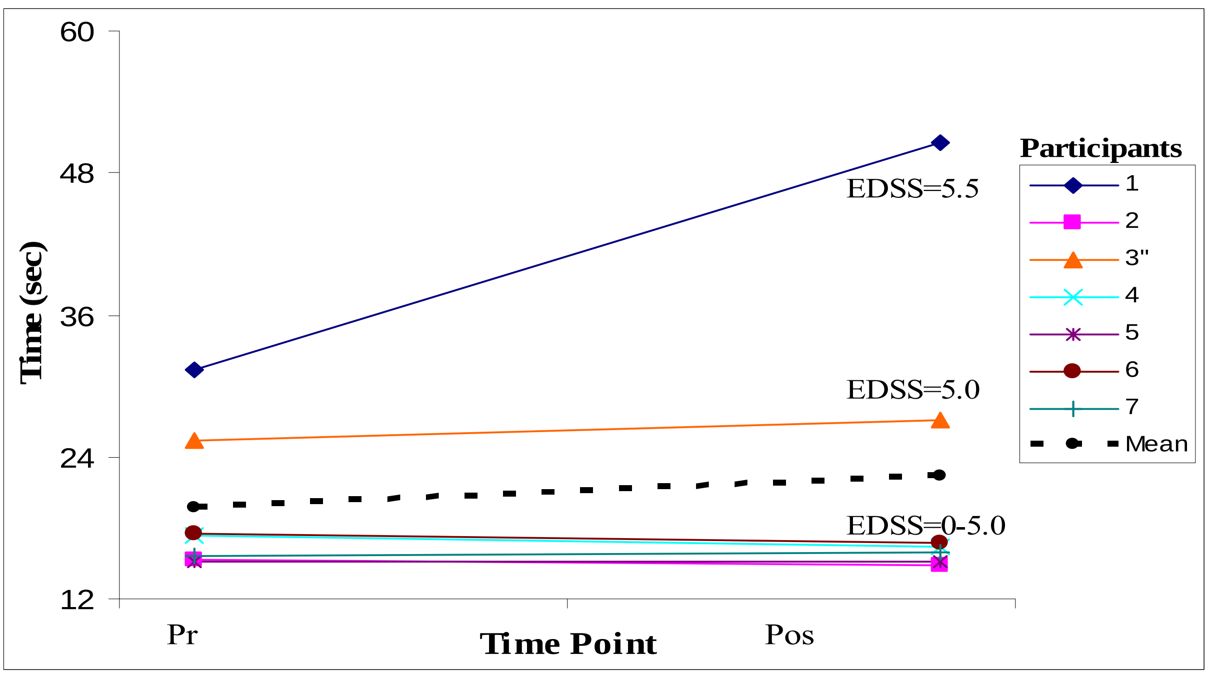

Figure 10. (n=7) Individual performances on the 100ft walk before and after 8 weeks of the exercise intervention. EDSS = Expanded Disability Status Scale score. A lower EDSS score indicates less disability. Each line represents one study participant's performance.

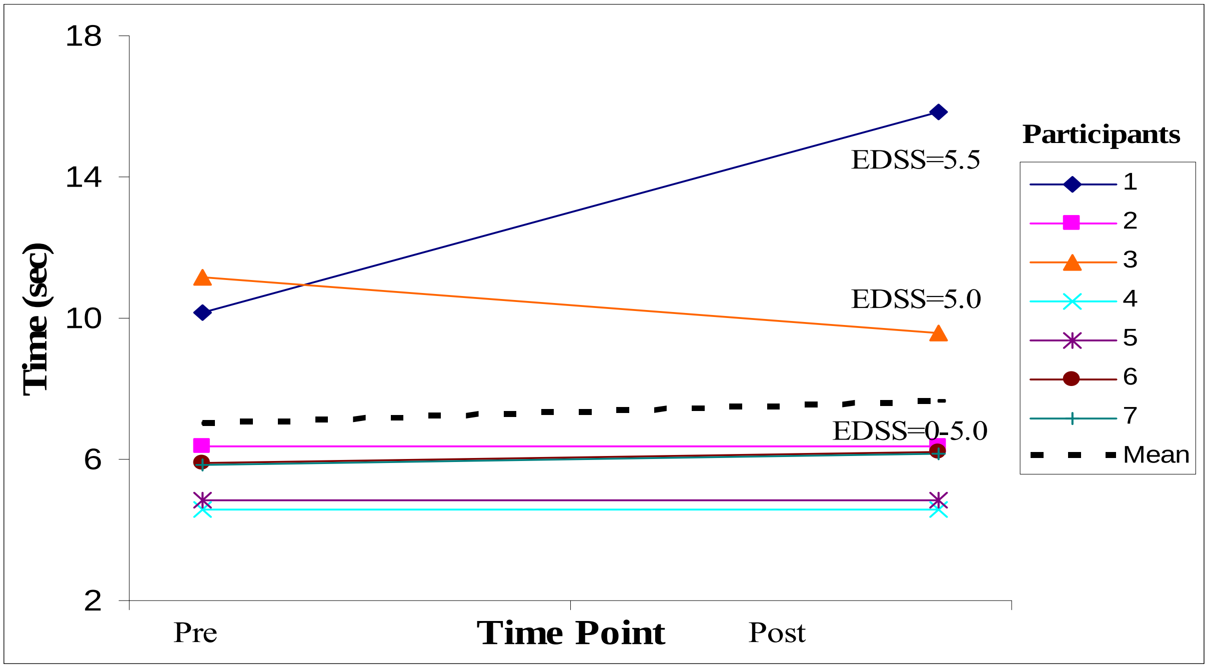

Figure 11. (n=7) Individual timed Get-Up-and-Go Performance before and after 8 weeks of progressive exercise training. EDSS = Expanded Disability Status Scale score. A lower EDSS score indicates less disability. Each line represents one study participant's performance.

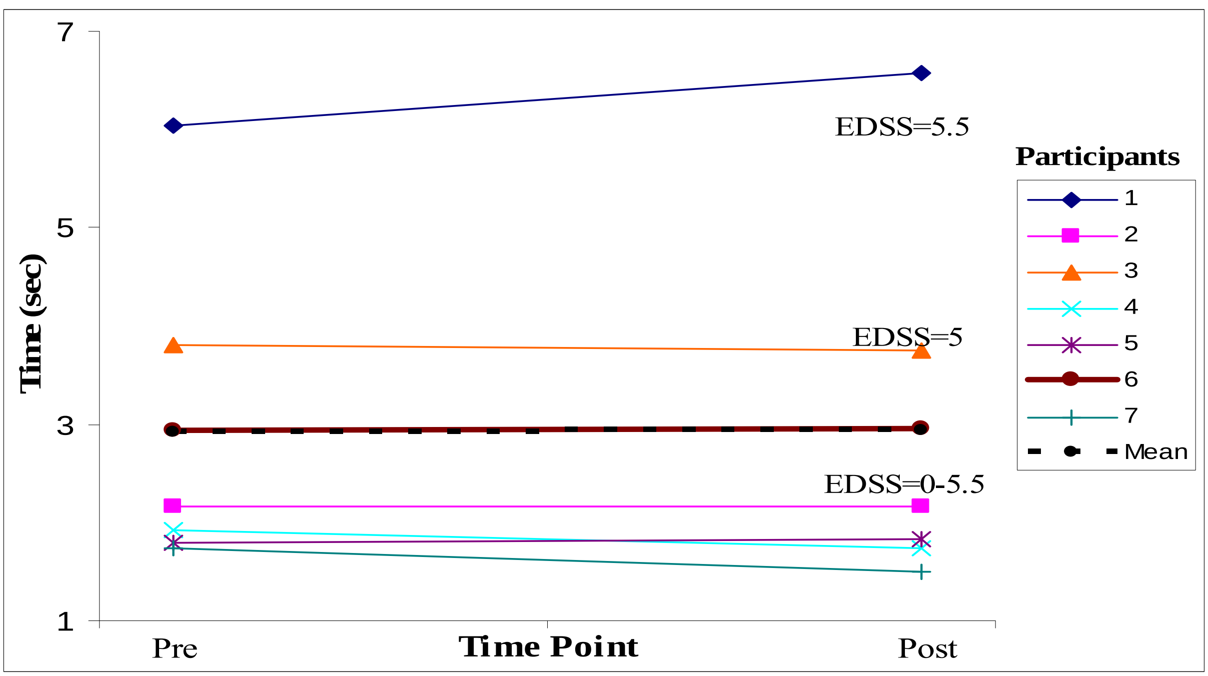

Figure 12. (n=7) Changes in individual performance on the stair climb test before and after the 8 week exercise intervention. EDSS = Expanded Disability Status Scale score. A lower EDSS score indicates less disability. Each line represents one study participant's performance.

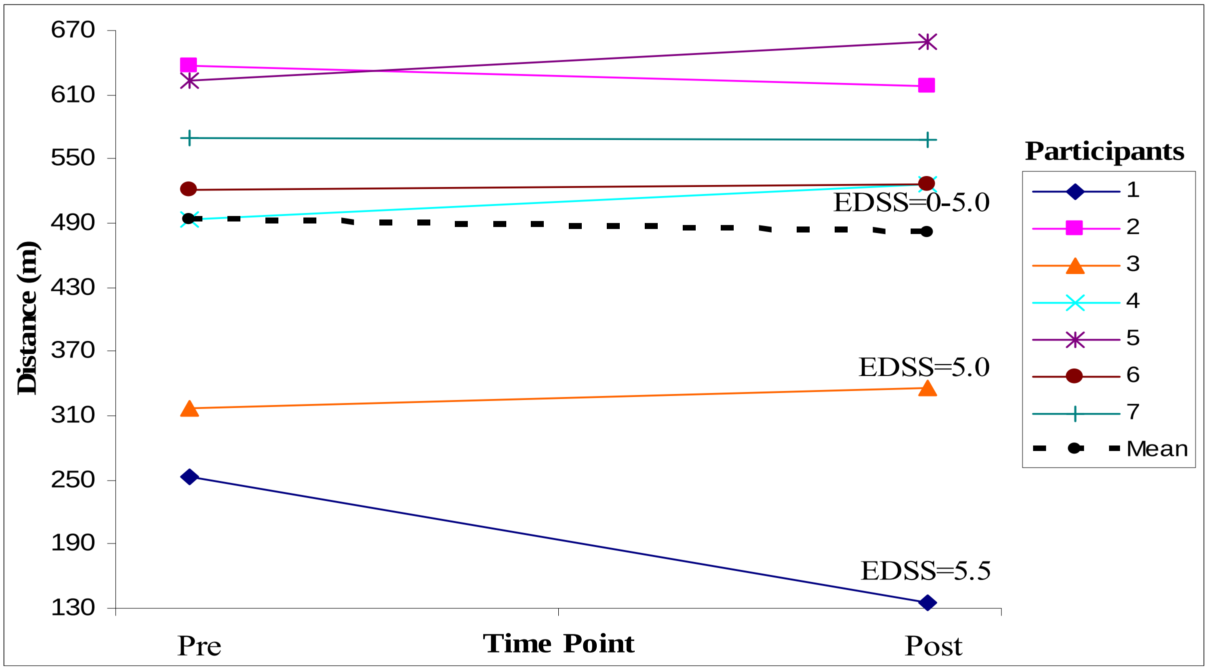

Figure 13. (n=7) Individual performances on the 6 minute walk test before and after 8 weeks of progressive exercise. EDSS = Expanded Disability Status Scale score. A lower EDSS score indicates less disability. Each line represents one study participant's performance.

Muscle Performance Assessments

Muscular Strength

Performance on 1-RM strength tests of chest press (Figure 14), shoulder press (Figure 15), lat pulldown (Figure 16), leg press (Figure 18), and leg extention (Figure 20) were unchanged (Table 8), except on the leg curl (Figure 19) (8.3%, p=0.008) and seated row (Figure 17) (6.3%, p=0.014) tests which improved significantly. Achievement of 1-RM took approximately 3-4 lifts for each person and for each exercise during both pre-testing and post-testing sessions.

Table 8. Isotonic strength before and after 8 weeks of home-based resistance training.

Isotonic Strength	Baseline	8 weeks	% Change	p-value
Chest Press (lbs)	116.9 ± 58.6	124.3 ± 63.6	6.3%	0.102
Shoulder Press (lbs)	72.5 ± 30.5	74.3 ± 31.6	2.5%	0.180
Lat Pull down (lbs)	108.8 ± 41.7	108.6 ± 45.8	-0.2%	0.102
Seated Row (lbs)	116.3 ± 38.8	123.6 ± 46.6	6.3%	0.014*
Leg Press (lbs)	306.9 ± 136.8	374.7 ± 244.4	22.1%	0.102
Leg Curl (lbs)	95.6 ± 36.8	103.6 ± 39.9	8.3%	0.008*
Leg Extension (lbs)	161.9 ± 60.6	166.4 ± 73.2	2.8%	0.059

(n=7) Data are expressed as Mean ± SD. * ($p<0.01$), differences for baseline versus 8 week comparison.

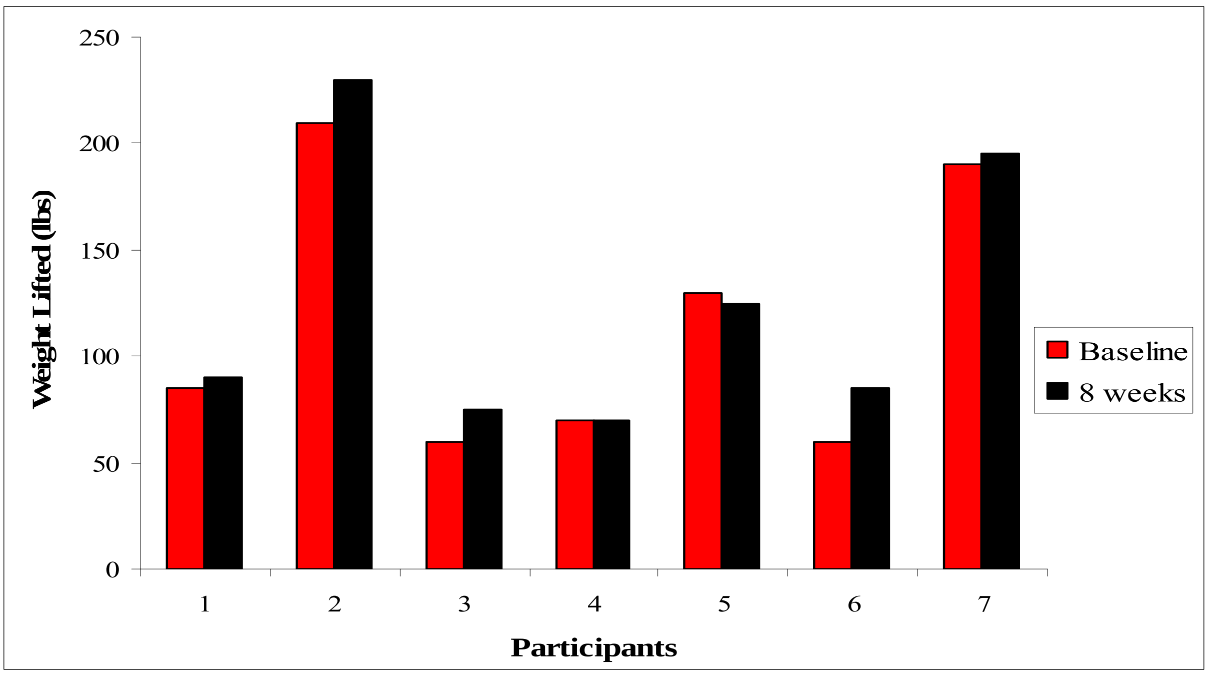

Figure 14. (n=7) Individual 1-RM chest press values at baseline and 8 weeks.

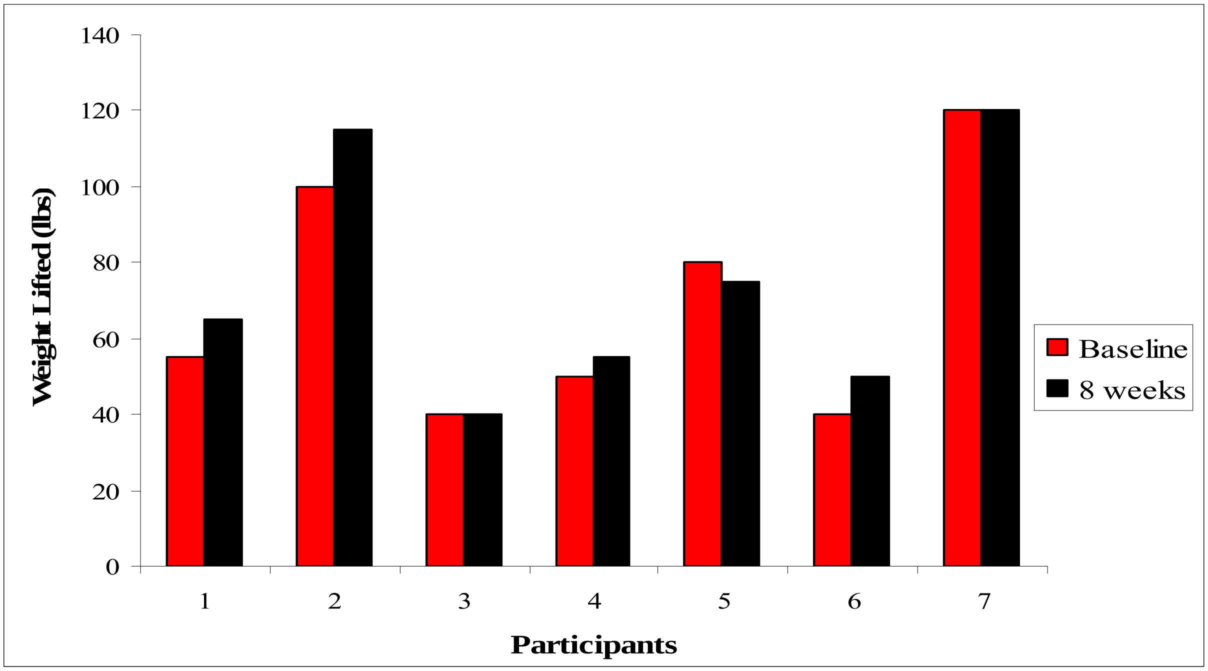

Figure 15. (n=7) Individual 1-RM shoulder press values at baseline and 8 weeks.

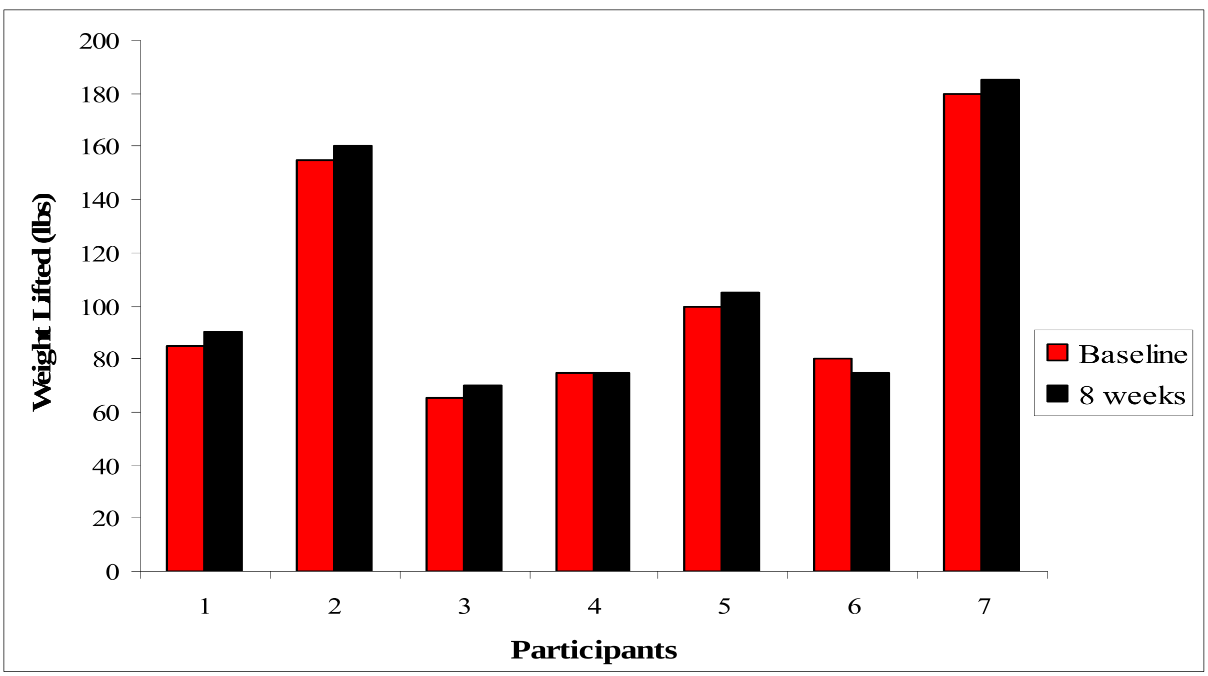

Figure 16. (n=7) Individual 1-RM lat pulldown values at baseline and 8 weeks.

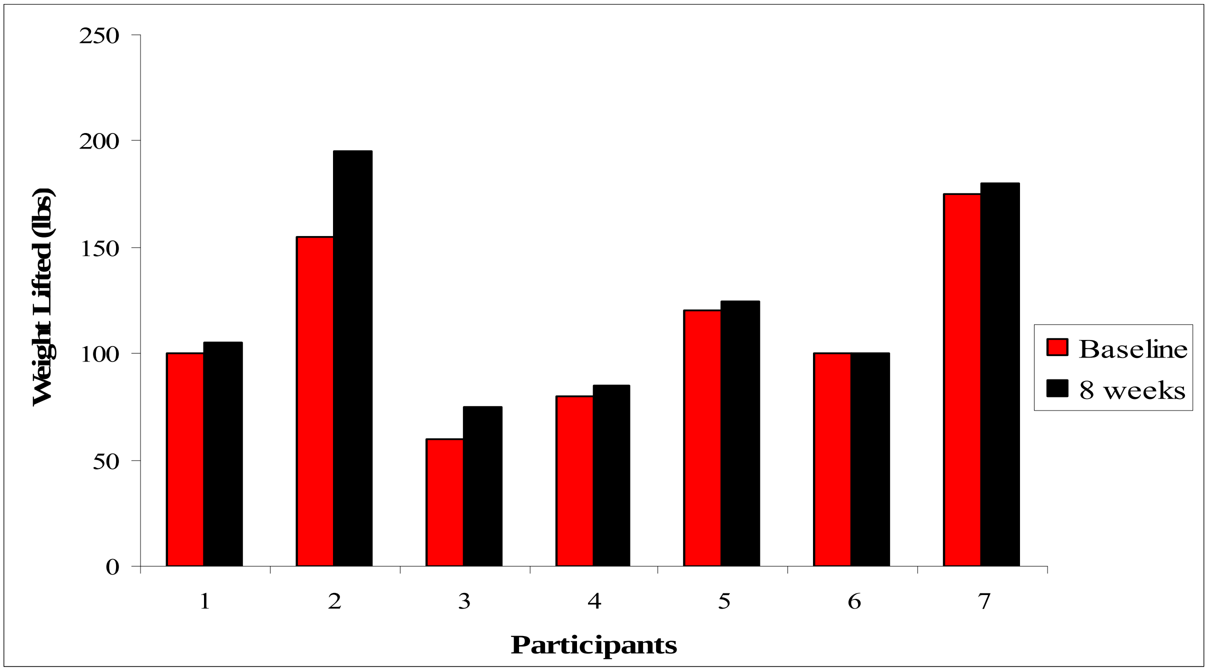

Figure 17. (n=7) Individual 1-RM seated row values at baseline and 8 weeks.

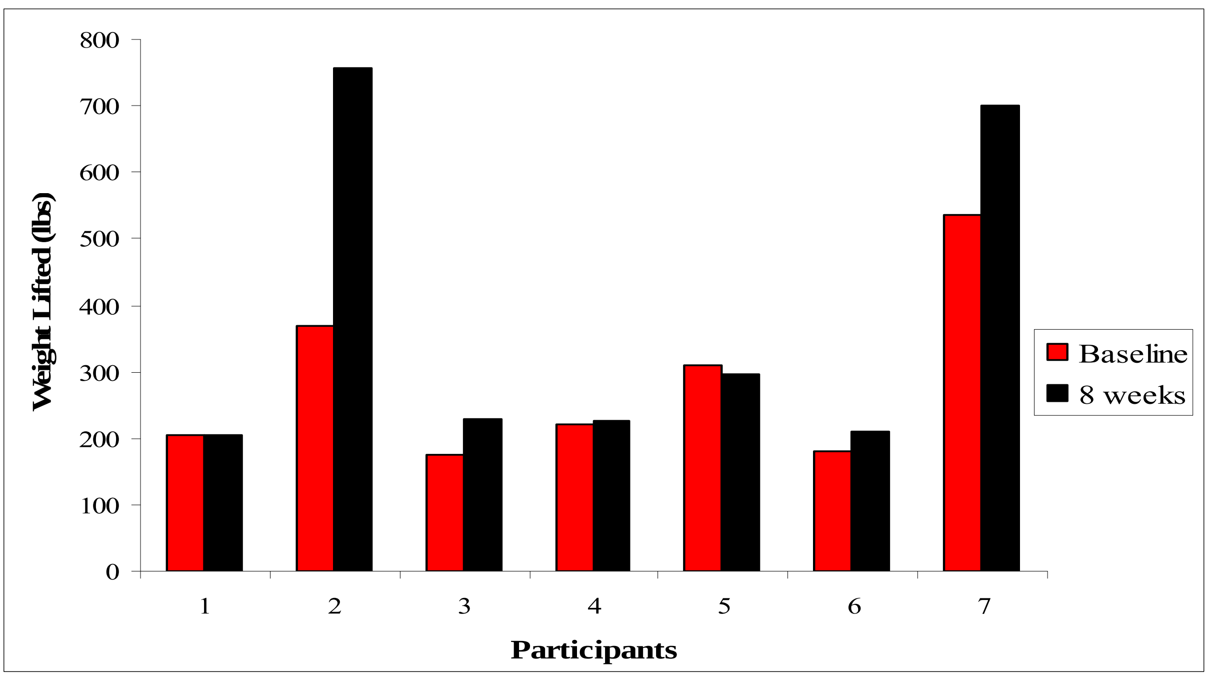

Figure 18. (n=7) Individual 1-RM leg press values at baseline and 8 weeks.

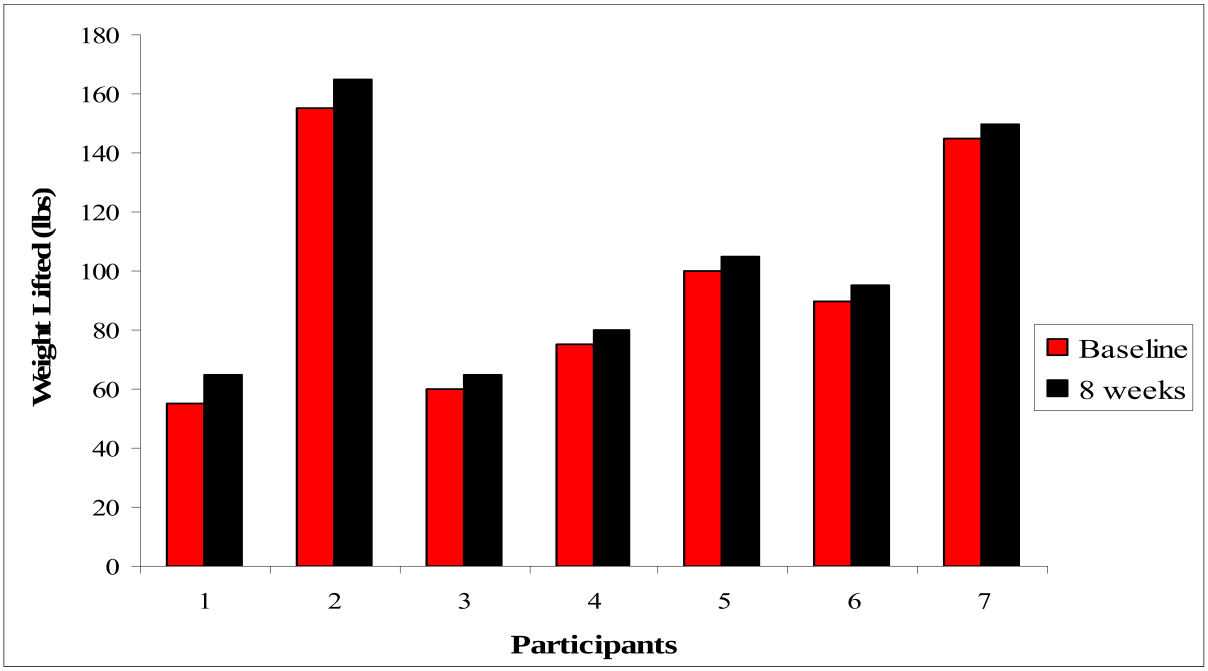

Figure 19. (n=7) Individual 1-RM leg curl values at baseline and 8 weeks.

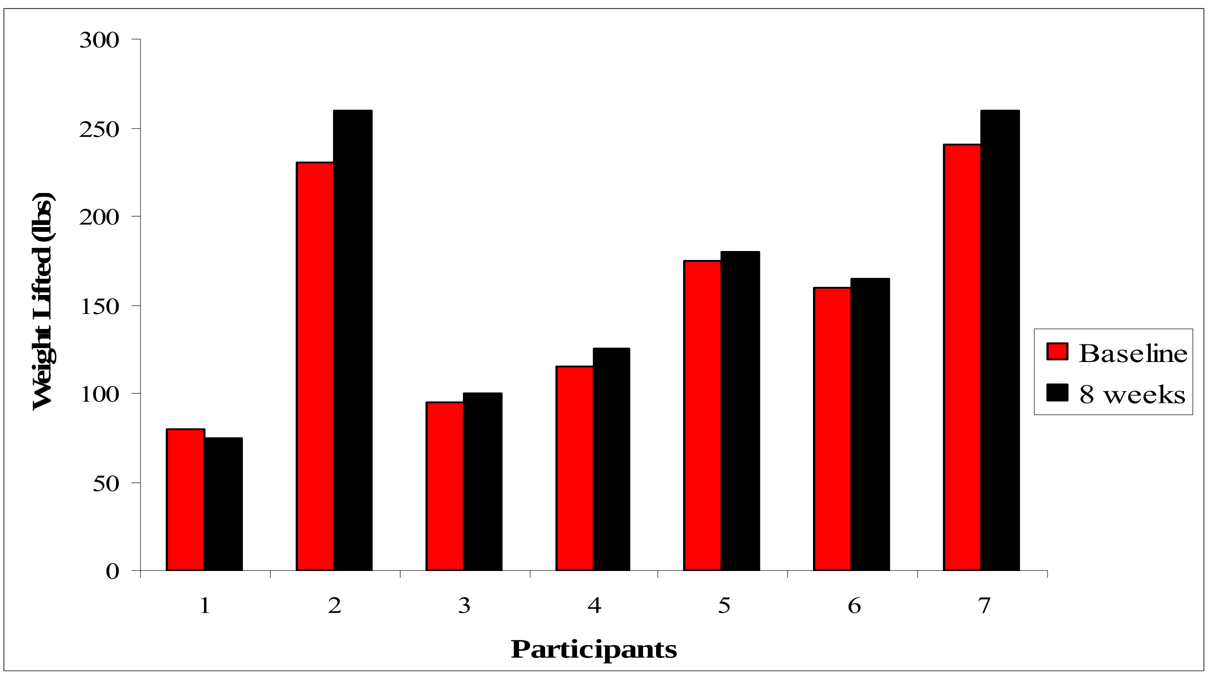

Figure 20. (n=7) Individual 1-RM leg extension values at baseline and 8 weeks.

Musclar Endurance

Muscle endurance performance was unchanged for the chest (Figure 21) (1.1%) and leg press (Figure 22) (6.8%) following the exercise intervention (Table 9).

Table 9. Mean number of repetitions completed on muscular fatigue tests.

Muscular Endurance	Baseline	8 weeks	% Change	p-value
Leg Press (# of reps)	45.7 ± 14.43	48.9 ± 15.4	6.8%	0.705
Chest Press (# of reps)	23.9 ± 8.03	24.1 ± 9.3	1.1%	0.257

(n=7) Data are expressed as Mean ± SD. Endurance tests were conducted at 60% of 1-RM

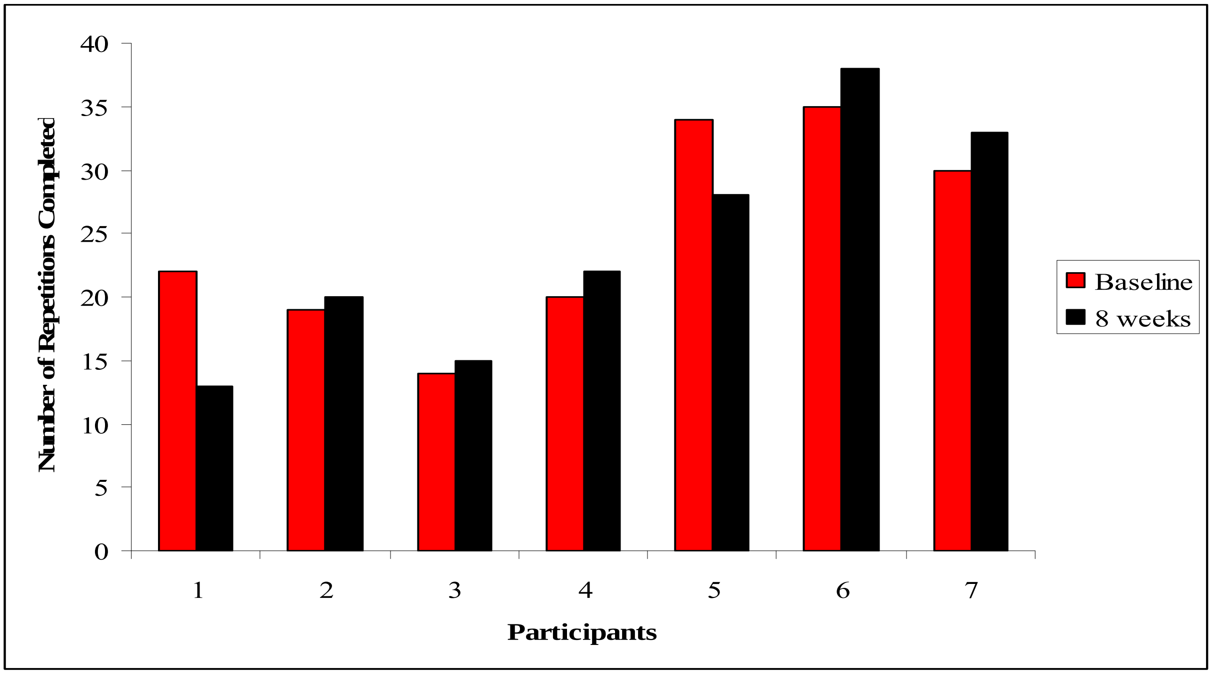

Figure 21. (n=7) Individual performance on chest press endurance test at baseline and 8 weeks. The number of repetitions completed indicated the total repetitions completed through full range of motion. The weight lifted was 60% of each individual's 1-RM on chest press.

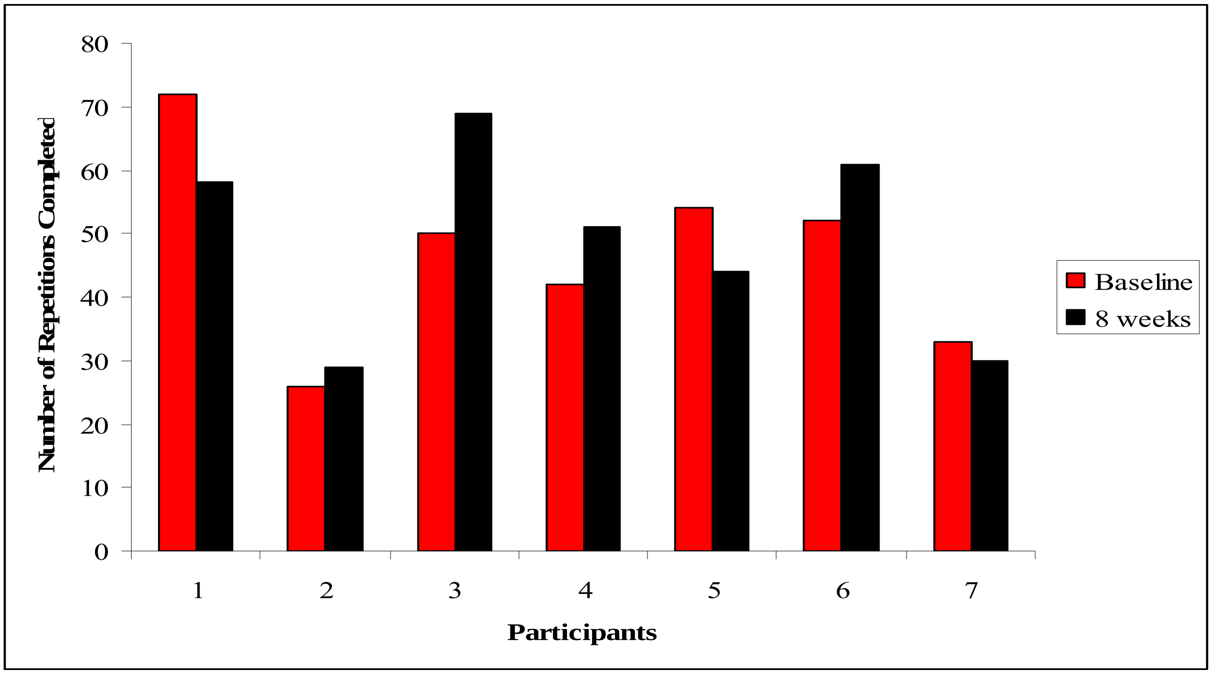

Figure 22. (n=7) Individual performance on leg press endurance test at baseline and 8 weeks. The number of repetitions completed indicated the total repetitions completed through full range of motion. The weight lifted was 60% of each individual's 1-RM on leg press.

Correlation between CS-PFP10 domains & Functional Mobility Assessments

When comparing the post-test CS-PFP10 domain scores (higher scores indicate better function) with functional mobility performance outcomes (walking time, stepping time, get-up-and-go time when longer time indicates worse function), moderate to strong negative correlations were observed, with the exception of the six minute walk, which was positively correlated with each of the CS-PFP domains (Table 10).

Table 10. Correlations between the CS-PFP domain scores and functional mobility post-tests

Correlations	25ft walk time	100ft walk time	6 min walk distance	Stair climb time	Get-up-and-go time
Upper Body Strength	-0.762*	-0.765*	-0.759*	-0.871**	-0.780*
Upper Body Flexibility	-0.575	-0.596	0.606	-0.618	-0.566
Lower Body Strength	-0.745*	-0.730*	0.743*	-0.819*	-0.813*
Balance & Coordination	-0.673*	-0.671*	-0.760*	-0.763*	0.657
Endurance	-0.770*	-0.767*	0.760*	-0.836**	-0.840**
Total CS-PFP	-0.745*	-0.742*	0.738*	-0.826*	-0.811*

* Correlation is significant at 0.05 level. ** Correlation is significant at 0.01 level.

Resistance Training Intervention

Study participants indicated that the time to complete exercise sessions 4-8 took on average between 60 and 90 minutes, and commented that they were reading the exercise descriptions each time in order to ensure proper set-up and execution. The first exercise session back at the University after completing exercise sessions 4-8 at home, (session 9) was used to provide strategies to shorten each training session, where subjects then indicated that in took on average 40 to 60 minutes to complete the exercise sessions. The mean number of exercise progressions, which indicates increases in intensity, that occurred during the 8 week intervention was 2.3 out of 3 possible (range of 1 to 3). The number of exercise progressions during 8 weeks was as follows: 1 person progressed 1 time, 3 people progressed 2 times, and 3 people progressed 3 times. In addition, throughout the 8 week training program three study participants indicated that a resistance band broke. All bands that broke were of the highest two resistance levels (blue or black resistance bands) and only occurred for 2 of the 7 participants.

Follow-up Interview

Eleven participants were contacted by phone to participate in the follow-up interview (1 individual only completed 1 week of the home-based program and therefore was not contacted due to limited exposure to the exercise intervention) and 9 decided to participate and signed a new copy of the informed consent. Of the 9 that completed the follow-up interview, 2 indicated that they were currently exercising, however they were not continuing to use the home-based exercise program. The remaining 7 who were not exercising also indicated that they were not currently using the home-based exercise program. None of the participants indicated that they were continuing to use any element of the program.

Education/Benefits of the Home-Based Program

When asked whether the home program was educational/beneficial or not, all 9 participants indicated that they learned something from participating and that it was beneficial. For instance, one person stated "I learned that exercise will keep me going because it keeps my muscles stronger which keeps my whole body stronger. I learned exercises that I can do and that I can do at home that benefit my body" (Participant 1). Another person stated "Benefits that I gained were functionality. I could carry bowls with both hands which was something I never would have tried before because of my spasticity and tremor" (Participant 2).

Favorite Exercises

Four of the nine participants indicated that the arm exercises were their favorite exercises. One stated "I enjoyed all the arm exercises and felt strong when I did them. They were empowering" (Participant 7). Other favorited exercises that were indicated included the calf raises, the abductor and adductor exercises, the leg extensions, and the warm-up marching and stretching exercises. Another participant commented that "The marching warmup activities were my favorite activities because it was good practice for something I like to do and I do on a daily basis" (Participant 2).

Least Favorite Exercises

Three of the nine participants stated that their least favorite exercises was the leg extension exercise and two of nine indicated that the chair squats were their least favorite exercises. For instance, one person stated "The chair squats and leg extensions were my least favorite exercises because they were more difficult particularly because my MS targets the thigh area" (Participant 6). Another person said "The leg exercises where the band had to be connected to something were my least favorite exercises because they were difficult for me because of both the set up and the execution of the exercise" (Participant 3). Other least favorite exercises that were indicated included the crunches, chest press (2 indicated that this exercise was their least favorite), and seated row.

Home-Based Program Value for Others with MS

All nine participants stated that they felt the current home-based program that they participated in would be valuable to other people with MS. One person stated "Yes, I think that home-based program has value for others because a lot of people with MS are conditioned to believe that they can't exercise but this program proves the opposite. They can exercise and can do it at very little expense" (Participant 5). Another person offered the following "I definitely think the home-based program is valuable for other people with MS, especially for people with mobility issues since this program doesn't require a lot of mobility to be able to participate in the activities" (Participant 11).

Opinions for Improving the Home-Based Program

Four of the nine participants indicated that they would have liked shorter exercise sessions, and three of these four suggested exercising six days per week, alternating between the upper body and lower body (Participants 2, 3, 7, 9). For instance, one stated "Would have preferred to break up the exercise sessions and do arms on one day and legs on the next. The sessions weren't horribly long but would have preferred shorter sessions none-the-less." Five of the nine participants indicated that they wouldn't change anything. For example, one person stated "I don't know that I can think of a way that it could be improved. I think it was a great program and that y'all covered everything well."

Hypothesis Testing

Using Chi-square as the test statistic for the Friedman's test there is sufficient evidence to reject all 3 hypotheses identified in this study. The hypotheses for this study were:

Hypothesis 1: An 8-week home-based exercise program is feasible for ambulatory individuals with MS, as measured by compliance to training, and subjective feelings of satisfaction with the program.

- Based on qualitative analysis we failed to reject the hypothesis and showed that the home-based exercise program was favorable for individuals with MS.

Hypothesis 2: Physical performance would improve following 8-weeks of home-based exercise training in people with MS:

A. Performance on the CS-PFP10 would improve following 8-weeks of home-based exercise training in people with MS.

B. Functional mobility as measured by the 25ft, 100ft and 6 minute walk tests as well as time on the stair climbing, and the get-up-and-go tests would improve following 8-weeks of home-based exercise training in people with MS.

C. Muscular strength and endurance, as measured by 1-repetition maximum (1-RM) and by the number of repetitions completed at 60% of 1-RM (while maintaining good form), respectively would improve following 8-weeks of home-based exercise training in ambulatory individuals with MS.

- Based on quantitative data we rejected the hypothesis based on the chi squared and showed that the home-based exercise program was favorable for improving performance in 2 of the 6 domain scores (Balance & Coordination score and Endurance score) and the CS-PFP10 total score and in 2 of the 7 musclar strength measures (seated row and leg curl), however walking performance was unchanged with training.

CHAPTER 5

DISCUSSION

This study was designed to assess the feasibility of a home-based progressive resistance training program and determine whether it would improve functional mobility, muscular strength, and physical function in ambulatory people with MS. There were several major findings of this pilot study. First, following 8 weeks of home-based progressive resistance training program, improvements were observed in 2 of the 6 domain scores (Balance & Coordination score and Endurance score) and the CS-PFP10 total score. Second, 2 of the 7 musclar strength measures (seated row and leg curl) improved with training while 5 were unchanged. Third, while average scores improved, performance from pre to post remained unchanged ($p>0.01$). Finally, program adherence was 75% and there were no adverse events reported. Participants also commented in the follow-up interview that they felt the program was beneficial and that they would recommend it to other individuals with MS.

Program Adherence

Participants who completed the 8-week study reported completing 75% of the total workout sessions, and the range of completed sessions was between 13 and 22 of 24. In another home exercise intervention that was also 8 weeks in duration, Debolt and McCubbin reported 95% program adherence in participants with MS of similar disability. In a home-based exercise program for older individuals adherence was 82-89% after 10 to 24 weeks of training (3x/week) (Jette et al., 1999; Latham et al., 2003; Nelson et al., 2004). Compliance in clinical populations, such as COPD, was reported as 85% after 12 weeks (3x/week) (O'Shea et al., 2007), while compliance was at 90% for individuals with heart failure who participated in 12 weeks of moderate intensity home exercise. (Oka et al., 2000). A study that evaluated adherance to a 6 month home-based aerobic exercise in healthy middle-aged adults reported approximately 75% adherence (King, Taylor, Haskell, & Debusk, 1988)(King, Taylor, Haskell, & DeBusk, 1989). Compared to reports from home-based studies in various clinical populations and in older adults (DeBolt & McCubbin, 2004; Jette et al., 1999; Latham et al., 2003; Nelson et al., 2004; O'Shea et al., 2007; Oka et al., 2000), compliance in the current study was lower than in other reports of similar study duration. While speculative, our study compliance may have been related to the time of year when this study was conducted, which was primarily during the summer (May-September). For example, in the current study 83% of the participants reported on a medical questionnaire that their MS-related symptomology got worse in the heat. Therefore, heat sensitive individuals with MS may experience heightened symptoms and fatigue which may have influenced compliance. The length of the training sessions (reported 45-90 minutes) and difficulties using resistance bands (setting them up and securing them, along with bands breaking with higher resistance exercise) may have also reduced program adherence. Training intensity was set to elicit a RPE of 7 out of 10 using the Borg 10 scale (Borg, 1990; Neely et al., 1992), which was consistent with 3 other home-based exercise programs (Dolan et al., 2006; Nelson et al., 2004; Oka et al., 2000), however commonly reported for reasons why the current participants did not like certain exercises were because they were difficult and/or challenging because of the intensity. Similar to what was found in the current study, Jette and colleagues (Jette et al., 1999) also reported challenges associated with resistance band use including reduction in resistance band tension when used for several sessions as well as bands breaking.

Participant Withdrawal

The percentage of individuals that withdrew from the current study was 52%, representing five of the twelve that were enrolled in the study. Published data suggests that olders individuals show a much lower drop out rate, between 3-9% (Nelson et al., 2004); (Latham et al., 2003), while clinical populations, such as COPD, have drop out rates that are more consistent with the current study (O'Shea et al., 2007). O'Shea and colleagues (O'Shea et al., 2007) reported that 44% of study participants with COPD withdrew for similar reasons that were found in the current study, such as illness and injury unrelated to the study. The main difference between those that completed the study and those that withdrew from the study was employment status. For example, all but one participant that completed the 8-week study either did not work or worked part-time in the summer, whereas those that withdrew either worked full-time or were taking care of someone other than themselves full-time.

Continuous Scale Physical Function Performance Test

The CS-PFP10 was developed to quantify physical function in older individuals, and is predictive of ability to live independently, however this was the first time the CS-PFP10 had been used to assess physical functional performance in persons with MS. Physical function performance, as measured by the CS-PFP10, improved in the current study through a decrease in the average sum in all the timed taskes and improved performance in the following domains: balance and coordination, endurance, and overall performance on the CS-PFP10. The faster overall time to complete the timed tasks suggests that there may be an improved ability to walk, however this was not captured in the functional mobility tasks (timed 25 and 100ft walk tests, timed get-up-and-go test, timed stair climb test, and 6 minute walk for distance). Domain scores from the current study were on average 15-20 points lower in each domain (each domain score ranges from 0-100) compared to healthy individuals (44±8 years of age) of similar age from a 2006 study (Panton et al., 2006). CS-PFP10 performance compared between those in the current study and women with fibromyalgia, was similar in all domain scores (Kingsley et al., 2005; Panton et al., 2006). In people with fibromyalgia 12 weeks of strength training improved performance on the CS-PFP10 similarly to the performance results from the current study (Kingsley et al., 2005). When compared to older adults (65-94 years), domain scores for upper body strength, balance and coordination, and endurance were similar to those found in the current study (Cress et al., 2005). Older adults, however, performed better in the upper body flexibility and lower body strength domains and in the total CS-PFP10 score when compared to the MS participants in the current study (Cress et al., 2005). While performance on the upper body strength domain, upper body flexibility domain, and lower body strength domain were not statistically different from pre to post training, trends toward improvement were observed. Following 8 weeks of home-based progressive resistance training the improvements that were seen on the CS-PFP10 were re-emphasized by the qualitative data were participants indicated improvements in daily function (Education/benefits of the home-based program - page 44).

While there are no known published reports on the effectiveness of a balance training program on CS-PFP10 scores, the current exercise program included balancing activities, therefore, the improvement observed in the balance and coordination domain may be linked with these balancing activities. Another set of exercises that may have been beneficial and aided the improvements in balance were leg adduction and abduction, which may be important for medial-lateral balance. The current program also incorporated marching in the warm-up activities, and while speculative, the improvements seen in the endurance domain, which is primarily the six minute walk, may have been due to specificity of training improving neurological factors to improve gait mechanics learned during the marching exercise. The lap length during the six minute walk of the CS-PFP10 was also longer than the six minute walk as part of the functional mobility, therefore the transition from one direction to another, which occurs at the end of each lap length, may be more difficult for individuals with MS and may explain why significant results were seen on the six minute walk in the CS-PFP10 but not as part of the functional mobility. A shorter lap length in the 6 minute walk as part of the functional mobility tests also resulted in a greater number of times needed to change directions which may have also lead to a decrease in momentum compared to the 6 minute walk as part of the CS-PFP10, and may explain why a lack of change was seen in the functional mobility 6 minute walk test. The CS-PFP10 is used to show how people do tasks serially, and for people who fatigue, like individuals with MS, the rest in between tasks when directions are being administered may be adventageous and related to the improvements observed in the total CS-PFP10 score. While preliminary, the data from this pilot study indicate similarities in CS-PFP10 performance between individuals with MS and older individuals and persons with fibromyalgia.

Clinical Assessments of Mobility

Functional mobility performance for the timed 25ft and 100ft walk, 6 minute walk distance, timed stair climb, and timed get-up-and-go tests were unchanged following the training program, which is in contrast to our hypothesis that mobility would improve. At baseline, participants completed the 25ft walk in 4.8 ± 1.4 seconds, which is about 9.0 seconds faster than the baseline results from another home-based study for individuals with MS, who had self-reported moderate severity of MS (Finkelstein et al., 2008). Performance on the get-up-and-go at baseline was 7.0 ± 2.6 seconds, and about 4.3 seconds faster than baseline results from MS participants with similar disability (EDSS 4.0±1.8) in an 8-week home-based study (DeBolt & McCubbin, 2004).

This may suggest that the initial function of participants in the current was better than the participants in previous home-based programs which may impact potential changes.

Baseline performance for the six minute walk was 492.6 ± 148.7 meters, which when compared to individuals with moderately severe MS, was 284.3 meters further (Finkelstein et al., 2008). In another study that evaluated differences in six minute walk distance in healthy controls and across 3 different levels of MS, the healthy controls covered 123.0 meters more than those in the current study (Goldman et al., 2008). In the same study individuals with mild MS (EDSS 0-2.5) covered 595.0 ± 50.3 meters, those with moderate MS (EDSS 3.0-4.0) covered 496.0 ± 106.3 meters, and individuals with severe MS (EDSS 4.5-6.5) covered 378.0 ± 83.1 meters (Goldman et al., 2008). Therefore, performance in the current study was similar to the results found in the study by Goldman and colleagues (Goldman et al., 2008).

Following 8 weeks of participation in the home-based progressive resistance training program, performance on the 25ft walk test was unchanged (pre: 4.8 ± 1.4 seconds; post: 5.58 ± 2.88 seconds). In a similar 12-week home-based telerehabilitation program participants with MS improved performance on the 25ft walk by 4% (pre: 13.8 ± 8.3seconds; mid: 13.3 ± 7.6seconds) after 6 weeks of participation in the intervention and by 18% (pre: 13.8 ± 8.3 seconds; post: 11.3 ± 5.4seconds) after 12 weeks of participation (Finkelstein et al., 2008). Participant performance on the get-up-and-go was unchanged (pre: 7.0 ± 2.6 seconds; post: 7.65 ± 3.95 seconds) after the exercise intervention which is similar to previous findings indicating no change in performance after home exercise in persons with MS or controls (DeBolt & McCubbin, 2004). The lack of change may be a result of initial function which indicates that participants in the current study were on average faster at baseline than the MS participants from other studies and therefore had less potential for improvement.

Following an 8-week progressive resistance training program, performance on the six minute walk was unchanged (pre: 492.6 ± 148.7 meters; post: 481.5 ± 183.8 meters). In a telerehabilitation intervention for people with MS, six minute walk distance improved by 12% after 6 weeks of the intervention and by 15% after 12 weeks (Finkelstein et al., 2008), however the participants covered, on average, 235 meters less than the average distance completed by participants in the current study, therefore indicating better overall function in the current study. While functional mobility performance as a group did not change, the individual time to complete the tasks and distance covered was, on average, faster and further than the performance results of other individuals with MS of similar disability who participated in previous studies. For example, 4 of the 7 people showed improvement on the 6 minute walk and covered great distance than individuals with MS from previous studies.

We found that CS-PFP10 domain scores were significantly correlated with other functional mobility tests (timed walking, walking distance, stepping, get-up-and-go). These correlations indicate similarities between the CS-PFP10 test and functional mobility assessments in our participants with MS. Two possible explanations for why improvements were observed in 3 of the domains of the CS-PFP10 but not in the functional mobility tests (25ft and 100ft walk, get-up-and-go time, stair climb time, and 6 minute walk distance). First, the CS-PFP10 a series of tasks encompass one domain, whereas each functional mobility tasks indicate a single time or distance traveled. Second, familiarization with the mobility tests but not the CS-FPP10 may have resulted in the adoption of strategies that could improve performance on the CS-PFP10. Additional work to determine the validity and reliability of the CS-PFP10 in people with MS is needed to determine whether there is a learning effect, however it may be important to note that sequential familiarization with a forty minute test would not be practicial in this population because of fatigue unless if testing was performed on separate days.

Muscle Performance Assessments

Muscle strength is important for functional capacity and performance of daily tasks (L. J. White & Dressendorfer, 2004). When compared to age-matched controls, participants in the current study were below normal for the leg press and leg extension exercises (Verdijk et al., 2009). Following the home exercise program, participants showed improvements in the seated row and leg curl exercise, which may be important for maintaining posture, balance and aid in walking mechanics. Potential improvements in posture, balance and ambulatory status may be of significance to individuals with MS because commonly reported symptoms can include muscle weakness and impaired balance. While Debolt and McCubbin found an increase in leg extensor power following an 8-week home program of similar intensity and exercise training duration the magnitude of change in muscle performance was similar to that observed in the current study (DeBolt & McCubbin, 2004). Compared to the current study greater improvements in strength have been observed in older individuals and in clinical populations such as those with COPD and HIV following home programs of similar duration (Jette et al., 1996)(Jette et al., 1996; O'Shea et al., 2007)(Dolan et al., 2006). For example, Jette and colleagues (1996) reported a significant 6-12% improvement in lower extremity strength (hip extension, hip abduction, and knee extension). Following 8-weeks of home-based progressive exercise, improvements were observed in 2 of 7 strength tests, however training programs of longer duration or greater intensity may be beneficial for determining whether additional improvements in strength may be possible.

When comparing the current home-based exercise program with clinic-based resistance programs of similar duration, it appears that results may be comparable. The overload for the clinic-based and current home-based program however, were of different duration and intensity (Taylor et al., 2006; L. J. White et al., 2004). For example, White and colleagues (L. J. White et al., 2004) showed a similar increase in muscle strength when their participants completed 1 set of leg muscle group exercise, two days per week compared to three sets of exercise three days per week with resistance bands as was done in the current study (L. J. White et al., 2004).

Progressive resistance training programs have been shown to cause neurological adaptations that can influence muscle force development. Neural adaptations typically occur during the first 8-12 weeks of resistance exercise and include increases in muscle fiber recruitment and motor unit firing patterns (Sale, 1988). Previous research conducted in this laboratory to assess muscle activation (central activation ratio CAR) in people with MS compared to controls showed that following a resistance exercise intervention muscle activation increased in individuals with MS, providing some evidence for possible neural changes. Therefore, some of the results from the current study were, in part, due to neural adaptations.

Study Limitations

Limitations of this study include the small sample size, a high drop out rate, and the lack of a control group. Additionally, participants were not familiarized with the CS-PFP test, limiting our ability to determine whether training or learning influenced the test outcomes.

One limitation of this pilot study was the small sample of twelve participants, with only 7 completing the study. To further understand the impact of the exercise training program on outcomes measures, effects sizes were calculated using the Cohen's D effect size equation, power was also calculated. The effect size and power calculated by the total CS-PFP score was

.41 (power<0.28), while upper body strength and upper body flexibility domains had an effect size of .36 (power<0.23) and .60 (power<0.55), respectively. For lower body strength, balance & coordination, and endurance domains, effect sizes were .41 (power<0.28), .41 (power<0.28) and .38 (power<0.28), respectively. For the 25ft and 100ft walk and get-up-and-go, effect sizes were .30 (power<0.18), .26 (power<0.14) and .16 (power<0.14), respectively. Effects sizes were less than .10 (power<0.06) for all walking tests. For upper body strength, effect sizes ranged from 0 to .17 (power<0.08) and for lower body strength .06 (power<0.05) to .34 (power<0.23). Finally, the effect sizes for the number of repetitions completed on the chest press and leg press endurance tests were .03 (power<0.05) and .21 (power<0.10), respectively. While the *a priori* power calculation identified that at least twenty participants were needed with a control group for the current study, only one group of twelve were recruited to determine if the home-based program was a practical progressive exercise training intervention that would elecit some improvements in physical functional performance (CS-PFP10), functional mobility (timed 25ft and 100ft walk, get-up-and-go time, stair climb time, and six minute walk distance), and strength. In addition, of the twelve participants that were rectruited and enrolled, five dropped out as a result of illness (2 individuals), an injury that occurred at work (1 individual), an injury that occurred at home independent of the study (1 individual), and family obligations that prevented participation (1 individual). The individuals that withdrew from the study did so for reasons unrelated to the study. However, given the dropout rate, this indicates the difficulty in implementing a training program for people with MS even in trying to make it convenient as possible (at home) with instruction and encouragement. A larger sample size is of importance to ensure that statistical power does not get deflated, which increases the risk of a type II error, as well as determine whether the results found are representative of the population and not just the sample. For example, had there been a larger sample size, the changes observed in the strength training measures may have been significant, but because of the small sample size and diversity among the sample (1 male, 6 females, age range 26-61, EDSS range 0-6) the estimated power was most likely reduced resulting in a Type II error. It may also be of importance to correct for factors such as disease severity, age, gender, and prior exercise training as each of these factors can affect the impact the intervention can have along with the results found.

It has been previously reported in exercise interventions, in which the MS control group does not exercise, that physical performance and quality of life indices decrease (DeBolt & McCubbin, 2004; Mostert & Kesselring, 2002; Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996a). In addition, van den Berg and collegues, found that after a 4 week rest period, the improvements that were observed with 12 weeks of treadmill training had returned to baseline scores in persons with MS (van den Berg et al., 2006). In our study, a control group was not included, in part, because previous reports (DeBolt & McCubbin, 2004; Mostert & Kesselring, 2002; Petajan, Gappmaier, White, Spencer, Mino, & Hicks, 1996a) suggest that reductions in physical performance and quality of life may occur when people with MS do not participate. Also, witholding a program with potential benefits is inconsistent with the goals of the current study. It would be possible however to design a cross-over study where participants would serve as their own control, therefore allowing data collection of controls without witholding potential benefits to the participants. While the inclusion of a control group in the current study may not have increased the number of significant findings since our sample size was so small, it would have been of importance for determining whether the changes observed in some measures were due to the intervention or from unrelated variables, such as interaction with the investigator or walking in and out of the building.

The CS-PFP10 is as a measure of physical functional performance. While the validity and relability, nor the test-retest reliability of the CS-PFP10 has been determined in the MS population, it has been determined in older adults which may be of importance for future performance comparisons on the CS-PFP10 between MS and older individuals. In the CS-PFP10 validation study in healthy older adults reliability ranged from 0.92-0.98 and test-retest correlations ranged from 0.85 to 0.97 (Cress et al., 1996)(Cress et al., 2005). The CS-PFP10 has also been been used to measure physical functional performance in women with fibromyalgia, and in a study by Panton a high retest reliability (r=0.90) was indicated (Panton et al., 2006)). While this was the first known investigation to propose the use of the CS-PFP10 to test physical function in people with MS, the validation of a measure that assesses ability to complete common daily tasks in this population may be important in determining the value of future therapies as they are developed and evaluated.

Future Studies

Future studies may benefit from fewer testing measures, as the total number evaluated was twenty. Since the physical functional measure (CS-PFP10) and functional mobolity measures (25ft and 100ft walk, get-up-and-go, stair climb, and 6 minute walk test) were strongly correlated, completing only one of these tests would be sufficient, only if further validation of the CS-PFP10 confirms correlation results in this population. In the current study, we were particularly interested in performance on the CS-PFP10 because it can capture changes in ability to perform daily activities, something that was commonly reported to change following participation in a clinic-based strength program for individuals with MS. While the inclusion of testing with an isokinetic dynamometer in addition to the 1-RM and endurance tests was of importance the unreliability of equipment allowed us to only gather 1-RM and muscle endurance data due to isokinetic dynamometer failure during testing. The use of an isokinetic dynamometer may be of more benefit because the results can provide important information such as time-to-peak-tension, isokinetic and isometric speed, and production of force at varying speeds in addition to dynamometer results being more commonly reported in the literature.

Evaluation of a combined clinic- and home-based exercise program may warrant further investigation, to determine the best exercise protocol, as both have strengths and weaknesses that may be minimized with a combined program. For many individuals with MS, clinic-based programs are not always feasible, due to cost, lack of facilities, and lack of transportation. In addition, home-based programs may not be feasible because study participants may require more feedback on technique, and higher functioning individuals may need a greater exercise stimulus that may be difficult to achieve with the use of lower weights which are often more readily available and transportable in the home. Future home-based studies could include the use of a DVD rather than exercise handouts as the set-up and execution of each exercise may be more easily understood after watching repeated demonstations of the required techniques. This may also influence compliance. Based on participant feedback from the current study, exercise lasting 30 minutes of less may improve compliance. Current participants also indicated that they would have preferred the use of a resistance source that did not require as much set up (no Thera-bands). It may also be of interest to further study whether leg extensor power as a measure of leg strength is associated with mobility, such that lower leg extensor power may predict impairments in mobility, as this relationship has been documented in the elderly population (DeBolt & McCubbin, 2004).

Conclusion

The purpose of this study was to determine the feasibility of an 8-week home-based progressive exercise training program and whether it would lead to improvements in physical performance measures. This study was feasible based on the program adherence, which was 75% and that there were no adverse events reported. Participants also commented in the follow-up interview that they felt the program was beneficial and that they would recommend it to other individuals with MS. Of the 12 that enrolled only 7 completed the 8-week intervention, however a relatively low adherance when compared to healthy populations is expected and should be factored in when designing and implementing a study with individuals who have MS. The physical performance results indicated improvements in 2 domains of CS-PFP10 and total CS-PFP10 as well as improvements in 2 of 7 1-RM measurements. The remaining domain scores as part of the CS-PFP10, the upper (chest press, shoulder press, and lat pulldown) and lower (leg press and leg extension) body strength, muscle endurance and walking performance (25ft and 100ft walk time, 6 minute walk distance, get-up-and-go time and stair climb time) were unchanged with training. This preliminary study showed that home-based progressive exercise training has potential for adding to the various forms of therapeutic strategies used for individuals with MS, however more research is needed to determine the best protocol for various disability levels that can be seen in this population.

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Home Exercise
"Step forward program"

Pre-exercise Warm-up activities

Before you begin your exercises, please spend several minutes conducting the following activities that will help loosen up your muscles and get your body ready to move around.

1) Start in either a sitting or standing position with the head and chest aligned for excellent posture. Take a slow deep breath and exhale with puckered lips. Repeat 5 times. Take another series of 10 deep breaths, this time reaching one arm to the sky with each breath, so that you can feel a light stretch through the chest and shoulders. Alternate arms with each breath taken. Throughout the exercise, maintain comfort in your neck and head.
2) Start in either a sitting or standing position, with feet shoulder width apart. Perform alternating toe taps between the right and left feet.
3) Start in a seated position, with feet shoulder width apart. Keeping one foot flat on the ground with the knee bent at a 90 degree angle, slowly extend the other leg by sliding the heel outward. Gently lean forward a few inches and feel a stretch in ham strings. Hold for a count of 5 seconds and return to the starting position. Repeat the exercise on the opposite side.
4) Start in a standing position, so that head, chest and torso are aligned for excellent posture. March in place for a total of 20 steps to get your legs loosened up. For people with balance concerns, stand sideways next to the countertop and use it for support as you march in place.
5) Start in a standing position, next to the table. Keep one foot planted solidly to the ground while slowly lifting the other leg off the ground so that you are balancing on one leg. Hold for a count of ten seconds and return foot to the ground. Perform on both legs, for a total of 5 repeats. The counter top can be used to help maintain balance if needed.

Program Notes

The exercise program is designed to be performed in the seated or standing position depending on your level of muscle strength and comfort. Consult with you trainer who will guide you through the exercise program. When using a chair, be sure it is a strong and stable chair that sits on a flat surface. The wall or doorway or countertop may also be used for support. Exercises will begin with the use of body weight and progress to adding resistance as you improve. Each exercise should be executed using 1-3 sets of 8-15 repetitions. If you are not feeling well use good judgment. Focusing on core stability and strength while performing these exercises can help reduce the occurrence of injury and can enhance the exercise program by targeting all major muscle groups.

Please keep a daily exercise diary that includes the date, number of sets and reps for each exercise. We have included a diary for you to complete.

Posture notes. Poor (standing and sitting) increases the strain on joints and supporting tissues, thus creating less efficient movements and balance. If resting posture is incorrect (i.e forward head position) it can create more stress on the spine.

Spasticity. If spasticity is aggravated, discontinue exercise and contact your trainer.

Home Exercise
"Step forward program"

Consult with your physician before beginning this program or any other exercise program.

The information presented in this handout is not intended to be a substitute for medical care.

- ✓ **When performing the exercises described in this program, a solid, well built chair that sits flat on the floor as well as a stable table or countertop that is approximately waist height will be useful.**
- ✓ **During each exercise you should conduct all movements in a smooth and controlled manner, while maintaining a regular breathing pattern-no breath holding.**
- ✓ **Please use good posture when in both sitting and standing positions, as this will help strengthen the abdominal and lower back muscles.**
- ✓ **When completing the exercises that specify a time limit, each second should be counted as one-one-thousand, two-one-thousand, etc.**

Trainer Name:________________________ **Trainer's Phone #:_________________________**

Training Dates:___________________________ **Trainer's Signature:________________________**

Leg Exercise Name	Exercise Description

1. Toe Curls and Lifts

Perform this exercise by doing both feet at the same time.

Start in seated position, with feet shoulder width apart and flat on the floor. Begin with both feet by curling toes to shorten your feet as much as possible, pause for a count of one. Next, lift your toes only, lengthening your feet as much as possible, and again pause for a count of one. Focus on moving only your toes.

NOTES:

PUT SHOES BACK ON!

2. Seated Toe Raise

*** Focus on pushing heels into the ground while pulling your toes to your shins.**
*** One second pause during each repetition.**

Start in a seated position with feet shoulder width apart and knees bent at a 90º angle. Lift toes upward while keeping heel in contact with the floor.

NOTES:

3. Calf Raise

*** Perform this exercise standing next to a counter and with both legs.**
*** One second pause during each repetition.**

Start in a standing position next to a counter, with feet shoulder width apart. Push toes into the ground while lifting both heels, pause for a count of one and return to the starting position.

NOTES:

4. Chair Ups/ Mini Squats

*** Set up: Chair should be facing the counter and be approximately 2.0 feet from the counter.**
*** Maintain body control when sitting and standing – don't swing you upper body forward. Keep toes pointed straight forward.**

Start in standing position facing table, feet shoulder width apart. Lower body into a chair, and then return to a standing position with minimal support from the arms. When lowering body and returning to a standing position focus on maintaining an upright posture with your chest, as well as keeping your knees directly over your toes. Use the table for support as needed.

NOTES:

5. Hamstring Curls

***Set up: Hook the band around a sturdy and heavy object and tie a knot with the 2 ends of the band, so that it forms a circle and is around the heavy object. Set the chair you will sit in so that it is ~3.5 feet from the table that the band is around and is also facing the table. Hook the band behind your ankle and adjust the chair so that when you extend your leg there is no slack in the band. Pull leg back to a 90 degree angle.**

Keep one foot planted at 90 degrees. Extend the other leg outward and slide back to 90 degrees. Alternate to the opposite side and repeat the exercise.

I. Curls with resistance band

NOTES:

6. Leg Extension (front thigh)

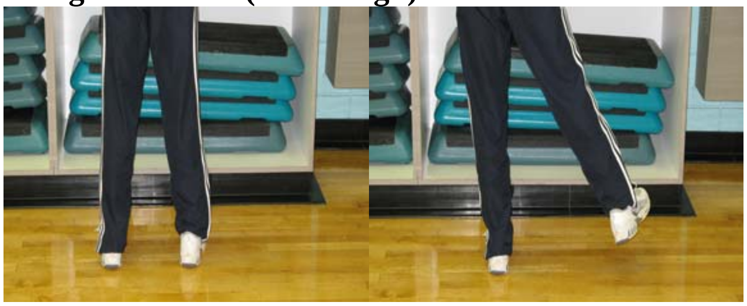
*** Set up: Hook the band around the back leg of you chair and tie a knot with the 2 ends of the band. Bring the band underneath the chair and through the front so that you can hook the band around your foot. Extend you leg and hold for 1 second and return to the starting position.**

From seated position, extend leg outward. Extend leg as straight as possible and return to starting position. Alternate to the opposite side and repeat the exercise.

I. Hip flexion with leg extension
II. Hip flexion with leg extension with resistance band.

NOTES:

7. Leg Abduction (outer thigh)



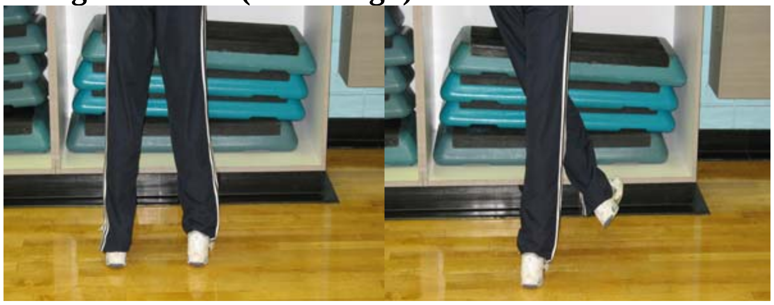
*** Set up: Untie the band from the previous exercise set up and tie it around a heavy and sturdy object. Stand sideways to that object and hook the band around the ankle that is furthest away from the object you are standing next to. Extend the leg away from the center of you body, lengthening the band.**

Start in a standing position and step to the side (laterally) with one leg while keeping the other foot in contact with the ground. Alternate to the opposite side and repeat the exercise.

I. Leg lift to side with resistance band
II. Side lunges with resistance band

NOTES:

8. Leg adduction (inner thigh)



***Set up: Same set up as previous exercise, hook the band around the leg closest to the object your standing next to and sweep the leg across your midline so that the band is lengthening.**

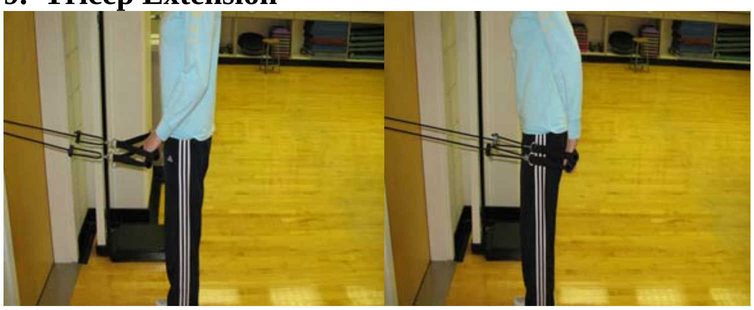
Start in a standing position and while keeping one foot in contact with the ground, sweep the other across your midline and hold for a count of one. Alternate to the opposite side and repeat the exercise.

I. Leg sweep with resistance band

NOTES:

Arm Exercise Name	Exercise Description

9. Tricep Extension



*** Set up: Hook the band around a door knob and double twist the band. Hold one end of the band in each hand, and bend your arms so that your elbow is at a 90 degree angle and elbows are resting against the sides of your body. There should be no slack in the band.**

Start in a standing position, with feet shoulder width apart. Bend arms, so that hands are just in front of each shoulder and elbows are resting against the side of the body. Hold one end of the resistance band in each hand and extend arms until they are straight and hands extend just beyond hips.

NOTES:

10. Biceps

*** Set up: Unhook the band from the previous exercise and find the center of the band. Sit down in the chair and step on the center of the band with one foot. Straighten your arm (the one that is on the same side as the foot that is stepping on the band), and take up the slack in the band. Band elbow, lifting your hand toward your shoulder (keep elbow at your side).**

Start in a seated position with both arms resting comfortably at your sides. Bend elbows and raise hands as close to your shoulders as possible and hold for a count of one second before returning to the starting position.

NOTES:

11. Shoulder/Chest


*** Set up: Hook the band around a door know and double twist. Set up your chair so that it is ~2.5 feet from the door and facing away from the door. Sit down holding one end of the resistance band in each hand. Start with elbows raised to shoulder height and back behind the shoulders (squeeze shoulder blades together). Maintain control when punching forward like a boxer.**

Start in a seated position, with arms bent and hands clenched near the shoulder. With one arm, punch like a boxer straight forward. Perform in an alternating pattern between the left and right sides.

I. Forward Punches with resistance band

NOTES:

12. Posterior Shoulder


***Set up: Same set up as previous exercise just turn your chair to face the door. Hold one end of the band in each hand and move your elbows back behind you, while squeezing your shoulder blades together.**

Start in a seated position with both arms bent 90 degrees at your side. Move both elbows backward, while pulling you shoulder blades towards each other (try not to raise your shoulders as you perform this exercise). Hold for a count of one and return to the starting position.

I. Shoulder retraction with resistance band

NOTES:

Core Exercise Name	Exercise Description

13. Trunk/Obliques

Lie on your back with hands at your sides and knees bent so that feet are on the ground. Lift your shoulders about 2 inches off the ground while rotating your upper body toward one side. The next repetitions will be to the opposite side.

NOTES:

14. Abdominals

Lie on your back with hands at your sides and knees bent so that feet are on the ground. Lift your shoulders about 2 inches off the ground while sliding your hands toward your heels.

NOTES:

15. Pelvic Lifts

Lie on your back with hands at your sides and knees bent so that feet are on the ground. Lift your hips about 2 inches off the ground and hold for 2 seconds.

NOTES:

Follow-up Questionnaire

Home-Based Activity Program

1. Are you actively engaged in exercise now?

    a) If so, are you utilizing the home based exercise program?

2. Was the home program educational/beneficial?

    a) If so, what did you learn that was important?

    b) If so, what benefits did you gain from the program?

3. What were your favorite exercises and why?

4. What were your least favorite exercises and why?

5. Do you think this program is valuable for others with MS?

6. How could the program be improved?