

Title: Comparing endurance- and resistance-exercise training in persons with multiple sclerosis: a randomised pilot study

Authors:

Nicole M. Sabapathy¹

Clare L. Minahan¹

Grant T. Turner²

Simon A. Broadley³

Authors affiliation:

1. School of Physiotherapy and Exercise Science, Griffith University,
Queensland, Australia

2. Gold Coast Community Health, Queensland Health, Queensland Australia

3. School of Medicine, Griffith University, Queensland, Australia

Corresponding author:

Nicole Sabapathy

School of Physiotherapy and Exercise Science

Gold Coast campus

Griffith University,

Australia, 4222

Telephone: 617 5552 8281

Facsimile: 617 5552 8674

Email: n.sabapathy@griffith.edu.au

Abstract

Objective: The purpose of this study was to compare adaptations in functional and quality of life measures following endurance- and resistance-exercise training in persons with multiple sclerosis.

Design: Cross-over design with an 8 week washout period

Setting: Community health centre

Subjects: 16 individuals with multiple sclerosis

Intervention: Subjects completed both an 8 week endurance- and an 8 week resistance-exercise training program in a randomised order. The exercise training was comprised of individualised progressive programs that were completed twice weekly in a supervised group setting.

Main measures: Grip strength, Functional Reach, Four Step Square, Timed Up and Go and Six Minute Walk Tests, Multiple Sclerosis Impact and Modified Fatigue Impact Scales, Becks Depression Inventory and the Health Status Questionnaire Short Form-36.

Results: 16 of 21 (76%) subjects completed the study. Subjects attended 13.2 ± 1.6 endurance- and 15.8 ± 1.9 resistance-exercise training sessions. No adverse events were reported. No significant differences ($p < 0.05$) in any outcome measures were observed between the two exercise training programs either at baseline or following the completion of both training programs.

Conclusion: Both endurance- and resistance-exercise training were well tolerated and appear to provide similar effects for persons with multiple sclerosis, however larger studies are required to confirm these findings.

Keywords: aerobic exercise, cross-over design, exercise intervention, neurological disorder, strength training, quality of life

Multiple sclerosis is a progressive or relapsing neurological disorder of the central nervous system. Physical symptoms including fatigue and mobility impairments can contribute to a reduction in functional capacity and interfere with the patient's ability to perform activities of daily living. The activities of daily living that are most affected in persons with multiple sclerosis are those tasks that could be classified as mobility-related and physically demanding (e.g. housework, gardening) (1). In persons with multiple sclerosis a reduced ability to complete activities of daily living is associated with higher depression scores and decreased quality of life (2). Currently, multiple sclerosis has no cure and pharmacological interventions are limited in their ability to slow/prevent the progression of physical disability (3). Therefore, alternative evidence-based interventions that can improve functional capacity, as well as increase quality of life in persons with multiple sclerosis must be explored.

Research examining adaptations to exercise in persons with multiple sclerosis have predominately focused on endurance-exercise training programs (see Dalgas et al, 2008 for review (4)). Endurance-exercise can be described as moderate-intensity continuous exercise that involves the use of large skeletal muscle groups and predominately uses aerobic metabolism to sustain the activity (5). Examples of such activity are exercises like treadmill walking, or stationary cycling. While there is some evidence to suggest that endurance-exercise training may improve mobility and cardiorespiratory fitness in persons with multiple sclerosis (6, 7), endurance-exercise training may have little impact on

muscular strength (8, 9), or balance (6). Thus, exercise training adaptations from endurance-exercise training may not translate to the greatest improvements in functional capacity in persons with multiple sclerosis.

The primary aim of resistance-exercise training is to improve muscular strength and/or muscle endurance. Adaptations vary depending upon the workout protocols used (5). Few studies have investigated the effect of resistance-exercise training on persons with multiple sclerosis (see Dalgas et al, 2008 for review (4)). While previous studies suggest that resistance-exercise training may improve strength, the impact of resistance-exercise training on functional capacity in persons with multiple sclerosis is still inconclusive (4). A recent study which specifically investigated the impact of progressive resistance-exercise training on muscular strength and functional capacity in persons with multiple sclerosis, found that progressive resistance training improved muscular strength and functional capacity (10). Dalgas et al. reported a 21.5% increase in functional capacity in 19 persons with multiple sclerosis (10). Participants in the Dalgas et al. study improved their performance on the following functional capacity tasks; Chair Stand, Ascending Stair Climbing, Ten Meter Walk and Six Minute Walk Tests (10). Further investigation is required to confirm the impact of resistance training on functional capacity in persons with multiple sclerosis.

The impact of exercise training on quality of life in persons with multiple sclerosis is inconclusive. A meta-analysis examining the impact of exercise training on

quality of life in persons with multiple sclerosis, concluded that although endurance-exercise training significantly improved quality of life, there was insufficient evidence to draw conclusions on the effect of non-endurance-exercise training (such as resistance-exercise training) on quality of life in persons with multiple sclerosis (11).

No previous study has directly compared endurance- and resistance-exercise training in the same cohort of persons with multiple sclerosis. Thus, it remains unclear as to which mode of exercise training will elicit optimal physical and psychological improvements in this clinical population. The aim of this pilot study was to compare adaptations in grip strength, balance, mobility, fatigue, depression and quality of life following endurance and resistance-exercise training in persons with multiple sclerosis.

Methods

Experimental design: The present study was a cross-over design where 16 subjects completed 8 weeks of endurance-exercise training and 8 weeks of resistance-exercise training (Figure 1). Participation in the two programs was separated by an 8-week interval. Program order was randomised using a coin toss. Eleven subjects performed resistance-exercise training first. Outcome measures were assessed before and after the endurance- and resistance-exercise training programs. The primary outcomes in this study were mobility, fatigue and quality of life. The secondary outcomes were grip strength, balance,

disease impact and depression. Two of the four assessors were blinded to the order subjects completed the training program. This study was approved by the Griffith University Human Research Ethics Committee and the Queensland Health Research Ethics Committee.

Subjects: Twenty-one individuals with multiple sclerosis responded to a “call for volunteers” flyer displayed at local Community Health Centres and were accepted to participate in the program. Subjects with multiple sclerosis were included in the study if they could ambulate independently either with or without the use of walking aid. Over the course of the study, five volunteers withdrew from the study for various reasons including difficulties with time commitments, moving house, and ill dependants. Analyses were performed on data collected from twelve female and four male subjects aged 47 to 66 years. Disease severity was assessed by a registered physiotherapist using the Disease Steps Scale (12). Subject demographic and clinical characteristics are presented in Table 1. Subjects obtained approval for participation in the training programs from their General Practitioner and each subject gave their written informed consent to participate in the study.

Measures of physical ability:

Several measures of physical ability were used to provide an indication of functional capacity. Grip strength was assessed using a hand-held dynamometer (North Coast Medical hand dynamometer 800-821-9319). This test was

performed in the seated position with the subject's arm held out straight and parallel to the ground at shoulder height. Subjects were instructed to squeeze the hand dynamometer with maximal force. Balance was assessed using the Functional Reach (13), and Four Step Square Tests (14), and the Timed Up and Go (15) and Six Minute Walk Tests (16) were used to provide a measure of mobility. The Six Minute Walk Test was administered in accordance to the guidelines outlined by the American Thoracic Society (16), with the exception that a 25 m, rather than a 30 m track was used in the present study (due to space constraints). In all measures of physical ability, two trials of each task were performed with the best performance used in the data analysis.

Questionnaires:

Disease impact was assessed using the Multiple Sclerosis Impact Scale (17). The Multiple Sclerosis Impact Scale assesses the individual's view of how their multiple sclerosis has impacted upon their daily functioning during the previous 2 weeks. The higher the score, the greater the impact of the disease on the patient over the 2-week assessment period.

Depression was assessed using the Beck Depression Inventory. The Beck Depression Inventory is a twenty-one itemed questionnaire with higher scores indicating more severe depression (18).

Fatigue impact was assessed using the Modified Fatigue Impact Scale (19). This questionnaire provides an indication of the impact fatigue has on an individual in three domains: physical, cognitive, and psychosocial. Higher scores indicate that fatigue has a greater impact on the individual.

Quality of life was assessed using the Health Status Questionnaire Short Form-36. The Health Status Questionnaire Short Form-36 provides scores for eight dimensions which are combined to produce two summary scales: i) a Physical Component Summary Score, and ii) a Mental Component Summary Score; on all scales higher scores indicate a higher quality of life (20).

Exercise training

Both the endurance- and resistance-exercise training programs were 8 weeks in duration and consisted of two exercise sessions per week. All training sessions were supervised by two Exercise Physiologists. Before all training sessions, subjects completed a 5-min warm-up comprised of walking at a self-selected speed. Progression through the exercise training programs was at the discretion of the Exercise Physiologists and was based upon the subjects rating of difficulty for each activity. For both the endurance- and resistance-exercise training programs, subjects rated the difficulty of each exercise using the Borg Category Ratio Scale (21) immediately after completing each exercise during the training session . This rating was based on the subject's level of exertion. The intensity/difficulty of each activity was adjusted in order to maintain a rating of 3-5

(moderate-hard). The training sessions were concluded with 15-20 min of supervised static and dynamic stretching of the major upper- and lower-body muscle groups. In order to minimise the effect of overheating, oscillating pedestal fans and water spray bottles (on request) were used. All testing and training sessions were performed at Queensland Health facilities (Bundall or Helensvale Community Health Centres).

Endurance-exercise training program:

The endurance-exercise training program involved a circuit of eight exercise stations comprising of six different activities. Subjects exercised for 5 min at each station and rested for 2 min every 10 min (i.e. after the completion of every two activities). The eight exercise stations were: 1) step ups (step height 10-20 cm), 2) arm cranking (ADPE Duo Bike), 3) upright cycling (Tunturi F35 Competence or York Magnaforce 5000 HRC), 4) arm cranking, 5) recumbent cycling (Vision Fitness R2250 HRT), 6) cross-trainer (Octance Fitness Q35), 7) treadmill walking (Elite DX726 or Pacer 3701), and 8) arm cranking. The exercise-intensity of each activity was increased throughout the program by adjusting resistance and/or cadence. Additionally exercise time was progressively increased over the 8-week endurance-exercise training program for those subjects who initially were unable to complete 5 min of continuous activity.

Resistance-exercise training program:

The resistance-exercise training program consisted of three upper-body and three lower-body exercises as well as one core-strength, and one stability exercise (Appendix 1). For each exercise, subjects commenced and progressed through a series of exercises dependent upon the individual's initial level of strength and rate of improvement. Subjects performed 2-3 sets, comprised of 6-10 repetitions of each exercise per set. Subjects were instructed to have a minimum of 30-60 s rest between each exercise set. Progression through the resistance-exercise training program was facilitated by increasing the resistance of Therabands and/or weights used on applicable exercises (Appendix 1) and by progressing through a series of exercises. The progression for each exercise is presented in appendix 1.

Data analysis

To determine if there were significant differences in baseline measures between training modes and the order the training programs were completed, a mixed factor ANOVA with baseline values as the within subject variable and training order as the between subject variable was conducted using Bonferroni adjustments. Results suggested that there was no carry over effect of the two programs and that values for the dependant variables prior to commencing endurance- and resistance-exercise training were similar. Therefore, data in this study were analysed as endurance- versus resistance-exercise training irrespective of the order participants completed the training programs.

Pre- and post-exercise training scores for all outcome measures were assessed using a repeated measures ANOVA with Bonferroni adjustments. Data are presented as the mean \pm standard deviation. For all analysis, statistical significance was accepted at $p < 0.05$. All tests were two-tailed. Data were analysed using the statistical analysis software package SPSS version 15.0.

Results

No adverse effects to exercise training were reported during either training program. Both training programs were well attended. Of the 16 sessions in the training program, subjects attended 13.2 ± 1.6 endurance- and 15.8 ± 1.9 resistance-exercise training sessions.

Measures of physical ability

Pre- and post-training results for the measures of physical ability are presented in table 2. No differences between training modes (endurance- vs resistance-exercise training) were found for any of the measures of physical ability.

However, with the exception of grip strength, analysis of the data found that all measures of physical ability significantly improved with 8 weeks of exercise training (Table 2).

Questionnaires

Pre- and post-training results on the questionnaires assessing disease impact, fatigue, depression and quality of life are presented in table 3. No difference in

training modes were found on any of the questionnaires utilised in this study. When changes in pre- and post-exercise training scores were examined, significant improvements on the physical scale of the Multiple Sclerosis Impact Scale, and the physical and psychosocial scales of Modified Fatigue Impact Scale were observed. We found no significant changes in the psychological scale of the Multiple Sclerosis Impact Scale, cognitive scale of the Modified Fatigue Impact Scale, Becks Depression Inventory, or the Health Status Questionnaire Short Form-36.

Discussion

The aim of this study was to compare changes in grip strength, balance, mobility, fatigue impact, depression and quality of life following 8 weeks of endurance- and resistance-exercise training in persons with multiple sclerosis. When the two modes of exercise training were compared, neither the resistance- or endurance-exercise training elicited greater improvements in any of the outcome measures used in this study.

Measures of physical ability

When pre- and post- training scores were examined improvements in balance and mobility were observed following both the endurance- and resistance-exercise training programs.

The finding that resistance-exercise training was associated with improved balance is in contrast to the findings of a previous study. De Bolt et al.(22) reported no improvements in balance after a home-based resistance-training program in persons with multiple sclerosis. The supervised exercise setting used in the present study, when compared to the home-based training described in the study by De Bolt et al. (22), may explain the discrepancies in balance adaptations observed following resistance-exercise training. Similarly, a recent meta analysis on walking mobility in persons with multiple sclerosis, found that walking mobility improved with exercise training when conducted in a supervised environment, but not when the training was home-based (23).

In the current study, like the resistance-exercise training program we observed that performance on the Functional Reach and Four Step Square Tests improved following endurance- exercise training. These results are supported by two previous case studies that have reported improvements in balance in persons with multiple sclerosis following regular treadmill walking (24, 25).

The type of endurance-exercise training performed may be of importance in determining balance outcomes. A study conducted in older adults with balance deficits investigated different types of endurance-exercise training and found that balance improved when the activities performed “stressed” the subject’s balance (26). That is, those activities during which the individual was required to maintain their centre of mass over their base of support in response to either an internal or

external perturbation. These authors reported that cycling did not improve balance, whereas walking and aerobic-exercise classes did (26). In the present study, our endurance-exercise training program was comprised of six different activities. It is possible that the activities that stressed balance (treadmill, cross-trainer and step-ups) contributed to the improvement in balance observed. However this is an area that requires further investigation.

In agreement with previous investigations, this study reported improvements in mobility following both endurance- and resistance-exercise training (23). The mechanisms through which endurance- and resistance-exercise lead to improvements in mobility have not yet been determined. A previous 3-week balance training program reported improvements in both the Berg Balance Scale and Dynamic Gait Index Score and suggests that balance training improved both balance and mobility in persons with multiple sclerosis (27). Additionally a relationship between postural sway and brisk walk time in persons with multiple sclerosis has been reported (28). It is possible that the improvements in mobility observed in the present study are secondary to improvements in balance. However other factors such as improved gait kinematics (gait pattern) and cardiorespiratory fitness can not be ruled out.

Resistance-exercise training has previously been shown to improve gait kinematics in persons with multiple sclerosis (29). This may enable patients to walk quicker and further without tiring. Similarly, endurance-exercise training may

improve efficiency through gait kinematics, although this relationship has not yet been examined in multiple sclerosis. Alternatively, endurance-exercise training may improve exercise tolerance in persons with multiple sclerosis by improving cardiorespiratory fitness (7, 30). Improved cardiorespiratory fitness may enable the patient to ambulate quicker (or exercise at a higher intensity), as well as improve walking endurance. However, as we did not analyse gait kinematics or directly measure cardiorespiratory fitness in this study we are unable to examine or comment on these relationships.

Of the measures of physical ability examined in this study, the only measure in which we did not observe an improvement with exercise training was grip strength. It is possible that grip strength was not influenced in the current study, as neither program focused on activities which involved the forearm extensor and flexor muscles.

Questionnaires

In the current study we found that fatigue impact in the physical and psychosocial domains decreased following exercise training. Surprisingly, we found that neither endurance- or resistance-exercise training was associated with improvements in depression or quality of life.

Fatigue in multiple sclerosis is defined as *“A subjective lack of physical and /or mental energy that is perceived by the individual or caregiver to interfere with*

usual or desired activities" (31). Previous studies have produced conflicting results on the impact of exercise training on fatigue. An overall score >38 on the Modified Fatigue Impact Scale (score when 3 subscales are combined) has been suggested as a cut-off score for determining fatigued and non-fatigued patients (32). Based on this cut-off, 8 of 16 subjects before endurance-exercise training, and 6 of 16 subjects before resistance-exercise training were classified as experiencing significant fatigue in the present study. This decreased to 4 of 16 subjects following both endurance- and resistance-exercise training.

Fatigue pathology in multiple sclerosis is complex. It may result from the disease pathology itself, caused by secondary factors including medication use, sleep disturbance or depression, or may be the consequence of physical deconditioning caused by physical inactivity (33). It is likely that underlying fatigue pathology is largely responsible for the variability in results observed in different exercise intervention studies. As exercise modality was not found to elicit different effects on fatigue impact in the present study, we believe that both endurance- and resistance-exercise training may be useful strategies in the management of fatigue in persons with multiple sclerosis. Most importantly this study suggests that exercise training does not exacerbate fatigue in persons with multiple sclerosis.

Previous cross-sectional studies have suggested a relationship between physical activity levels and a reduced incidence of depression in persons with multiple

sclerosis (34). In this study we found no changes in depression following exercise training. However, our ability to investigate depression was limited due to the small number of subjects in this study who suffered from depression. Based on previous establish criteria (Beck Depression Inventory score ≥ 13) (35, 36), only 3 of the 16 subjects in this study experience depression prior to both the endurance- and resistance-exercise training programs. Therefore we are unable to make any interpretation on the different effect of the two training programs on depression.

In the current study we observed no changes in quality of life following either endurance- or resistance-exercise training. A score of 50 ± 10 on both the Physical and Mental Component Summary Scores represents normative quality of life scores in the general population (37). Although scores for the subjects in the current study indicated a reduced quality of life in the physical domain, the Mental Component Summary Score was similar to that of the general population. Therefore, we would not expect to see large changes in the Mental Component Summary Score, restricting our ability to examine the impact of exercise training on this outcome measure.

Previous studies investigating the impact of exercise training on quality of life in persons with multiple sclerosis have reported conflicting results. Some studies have reported improvements in quality of life with exercise training (30, 38) while other studies have not (39-41). Overall, as indicated by a recent meta-analysis

(11), the literature does seem to suggest that exercise training is associated with a small improvement in quality of life in persons with multiple sclerosis.

This study has several limitations that must be considered when interpreting the results of this study. This study is comprised of a small group of patients with mild-moderate multiple sclerosis and results will not necessarily translate to patients with more severe disability. The sample size in this study is small, increasing the chance of making a type II error. Further investigation with a larger sample of patients is required. Although standardised criteria was used in all pre- and post-testing, two of the four assessors were not blinded to the order the subjects had completed the training programs. Our process of randomisation (coin toss) lead to a larger number of subjects completing the resistance-exercise training program first. Also as no non-exercising cohort was investigated, we are unable to assess if exercise training is better than no exercise training. Finally, this study is subject to the limitations of a cross-over design. This study is based on the assumption that an 8 week period provided a sufficient period of time for a “washout” period to occur. Although statistical analysis of the data supported this, we cannot rule out that a type II error occurred (concluding that there was no carry over effect between the two programs when there was).

The results of the present study suggest that both endurance- and resistance-exercise training appear to provide similar benefits to persons with multiple sclerosis. However further investigation with a larger sample size is required to

confirm the findings of this study.

Clinical messages

- Both endurance- and resistance-exercise training is well tolerated by persons with multiple sclerosis.
- Endurance- and resistance-exercise training provides similar effects for persons with multiple sclerosis.
- Exercise training does not exacerbate fatigue in multiple sclerosis.

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Competing interests

We have no competing interests to declare.

Contributors.

NS: study design, conducting study, data analysis, writing and editing manuscript

CM: study design, data analysis, editing manuscript

GT: study design, conducting study, collation of data

SB: study design, editing manuscript

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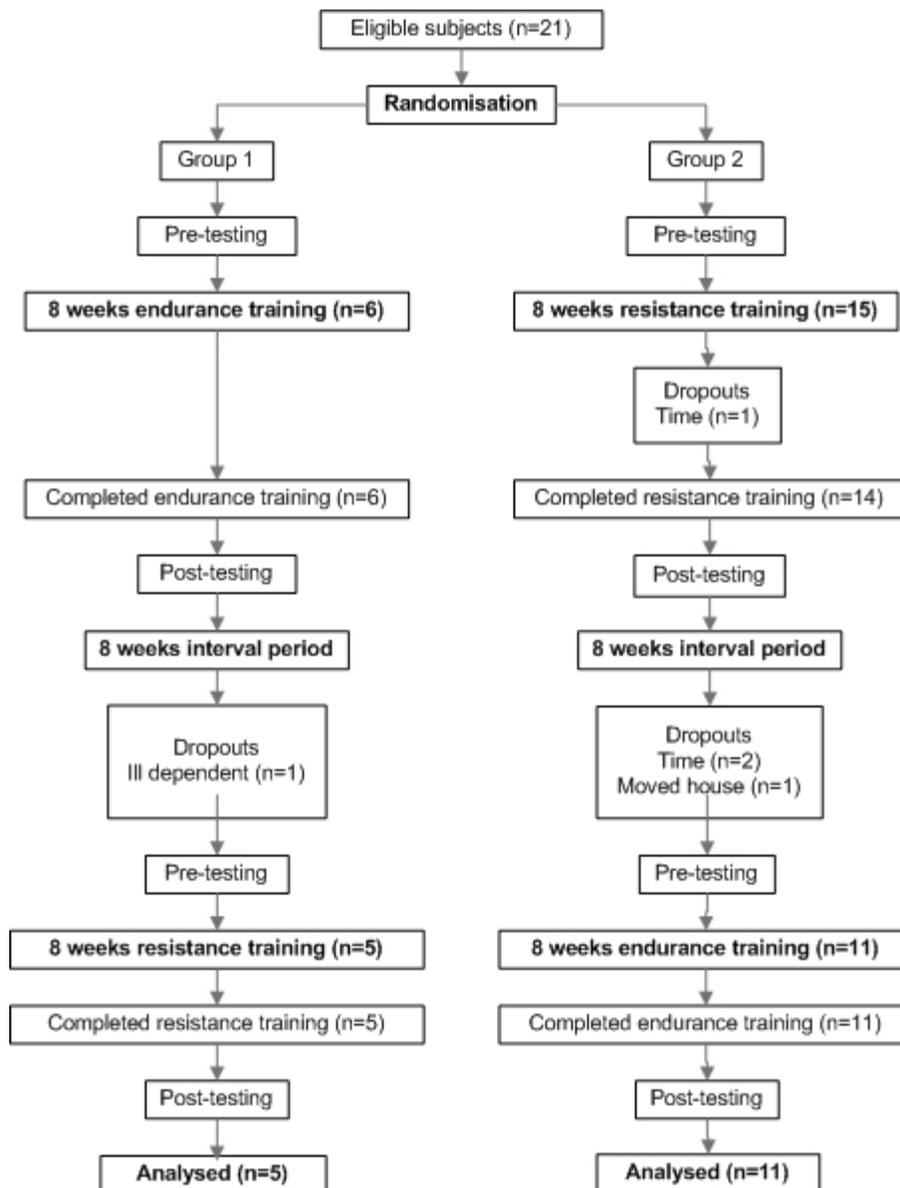


Figure 1: Flowchart of study outline

Table 1: Subject demographic and clinical characteristics

Age (yr ± SD)	55 ± 7
Gender (male:female)	4:12
Disease duration (yr ± SD)	10 ± 10
Disease Steps Score (0-6 scale)	
1	n = 7
2	n = 5
3	n = 4
Disease Course	
Relapsing-remitting	n = 10
Secondary progressive	n = 3
Primary progressive	n = 3

Disease Steps Score: 0 = normal; 1 = mild disability, mild symptoms or signs; 2 = moderate disability, visible abnormality of gait; 3 = early cane, intermittent use of a cane; 4 = late cane, cane dependant; 5 = bilateral support; 6 = confined to a wheelchair

Table 2: Performance on functional measures following 8 weeks of endurance- or resistance-exercise training

	ENDURANCE TRAINING			RESISTANCE TRAINING		
	Pre-training	Post-training	Δ	Pre-training	Post-training	Δ
Grip Strength (kg)	32.4 ± 13.3	33.0 ± 13.0	0.6 ± 2.7	30.3 ± 14.2	31.6 ± 12.8	1.3 ± 7.8
Functional Reach Test (cm)**	38.6 ± 5.9	40.0 ± 5.3	-0.6 ± 9.6	35.8 ± 6.7	41.3 ± 5.2	7.4 ± 13.4
Four Step Square Test (s)**	8.8 ± 1.8	8.1 ± 1.9	-0.7 ± 0.9	9.5 ± 2.4	8.3 ± 2.1	-1.2 ± 1.8
Timed Up and Go (s)**	7.2 ± 1.7	6.7 ± 1.4	-0.5 ± 0.7	7.5 ± 2.2	6.8 ± 1.8	-0.7 ± 0.8
Six Minute Walk Test (m)**	484 ± 96	503 ± 100	18.6 ± 40.1	447 ± 111	486 ± 107	38.1 ± 70.0

Values represent mean (± SD). ** A within-within repeated measures ANOVA with Bonferroni adjustments revealed a significant main effect for pre/post difference, p<0.01.

Table 3: Fatigue, depression and quality of life scores following 8 weeks of endurance- or resistance-exercise training

	ENDURANCE TRAINING			RESISTANCE TRAINING		
	Pre-training	Post-training	Δ	Pre-training	Post-training	Δ
MSIS Physical Score*	43.5 ± 12.4	39.1 ± 12.9	-4.1 ± 9.6	43.8 ± 15.3	39.3 ± 13.1	-6.3 ± 12.2
MSIS Psychological Score	19.6 ± 8.0	16.9 ± 6.1	-2.7 ± 6.5	20.0 ± 9.3	17.1 ± 7.2	-1.9 ± 8.2
Beck Depression Inventory	9.7 ± 11.6	10.3 ± 11.6	0.6 ± 3.9	9.8 ± 9.0	8.7 ± 7.7	-2.3 ± 5.4
MFIS Physical Scale*	19.6 ± 7.6	16.9 ± 5.5	-2.7 ± 5.3	18.3 ± 7.5	16.6 ± 7.1	-1.6 ± 3.3
MFIS Psychosocial Scale**	3.1 ± 1.5	2.4 ± 1.5	-0.8 ± 1.4	3.6 ± 1.8	2.4 ± 1.8	-1.6 ± 11.6
MFIS Cognitive Scale	15.8 ± 10.2	13.5 ± 10.0	-2.3 ± 6.0	14.4 ± 10.0	12.3 ± 9.5	-3.3 ± 7.8
SF-36 Physical Component Summary Score	37.8 ± 6.7	37.7 ± 7.7	-0.2 ± 6.8	36.1 ± 9.1	39.8 ± 7.3	3.7 ± 7.0
SF-36 Mental Component Summary Score	48.1 ± 13.3	50.4 ± 12.8	2.3 ± 10.6	53.2 ± 11.2	51.3 ± 12.9	-1.9 ± 9.7

Values represent mean (± SD). MSIS: Multiple Sclerosis Impact Scale, MFIS: Modified Fatigue Impact Scale, SF36: Health Status Questionnaire Short Form 36. * A within-within repeated measures ANOVA with Bonferroni adjustments revealed a significant main effect for pre/post difference, $p < 0.05$. ** A within-within repeated measures ANOVA with Bonferroni adjustments revealed a significant main effect for pre/post difference, $p < 0.01$.

Appendix 1: Progression of exercises during resistance exercise training

UPPER BODY EXERCISES			
	EXERCISE 1	EXERCISE 2	EXERCISE 3
Progression of exercises ↓	Chest Press with Theraband*	Seated Row with Theraband*	Shoulder abduction with Theraband*
	Chest Press with dumbbell*	Upright Row with dumbbell*	Shoulder abduction with dumbbell*
	Wall push-up Push-up on parallel bar Knee push-up on ground Full push-up		
LOWER BODY EXERCISES			
	EXERCISE 1	EXERCISE 2	EXERCISE 3
Progression of exercises ↓	Sit-to-stand	Static lunge with support (inside parallel bars)	Hip abduction
	Standing half squats with support (standing inside parallel bars)	Static lunge without support	Hip abduction with ankle weights*
	¾ ball squats (using Swiss ball)	Dynamic lunge with return	Lateral step-ups (increasing from small to medium to large step height)
	Full ball squats	Dynamic lunge with return off step (increasing from small to medium to large step height)	Lateral step-ups with ankle weights*
	Full ball squats with hand weights*	Dynamic lunge off step with ankle weights*	
CORE AND LOWER-LIMB STABILITY EXERCISES			
	CORE EXERCISE	STABILITY EXERCISE	
Progression of exercises ↓	Prone support (on hands and knees) with single leg extension	Tandem stance	
	Prone support with arm and leg extension of contralateral limbs	Tandem stance on foam mat	
	Laying supine on floor, knees bent with hip lift	Heel-to-toe walk along foam beam	
	Laying supine on floor, feet elevated on swiss ball with hip lift	Single leg stance	
	Front support on elbows and knees Front support on elbows and toes	Single leg stance on foam Standing on wobble board	

Participant's progression through the above series of exercises was dependent upon the individual's rate of improvement during the program. *Indicates that the Theraband or dumbbell/ankle weight used in these exercises was increased prior to progression to the next exercise. Four Theraband resistances were used (red, green, blue, black), dumbbell weights of 1kg, 2kg, 3kg and 4kg, and ankle weights weighing 1kg, 1.5kg, 2kg, 2.5kg and 5kg were utilised. This rate of progression was monitored and directed by an Exercise Physiologist.