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EFFECT OF PHYSICAL EXERCISE ON MUSCLE STRENGTH, STATIC AND DYNAMIC BALANCE AND RESILIENCY IN WOMEN WITH MULTIPLE SCLEROSIS

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ABSTRACT

Exercise is an essential component in the management of multiple sclerosis (MS). The purpose of this study was to evaluate the effect of a combined aerobic and resistance training programme on muscular strength, static and dynamic balance and resiliency of women with MS. Twenty participants aged 20-40 years with an expanded disability status Scale Level of 2 to 5 were selected. Participants were randomly divided into two groups: Experimental Group (age=36.1±2.2 years) and Control Group (age=34.3±5.4 years). The experimental group performed combination training that included aerobic and resistance exercises for eight weeks, three times a week, with an intensity of 40% to 55% heart rate reserve. The strength of knee flexor and extensor muscles, dynamic and static balance and resiliency level using Connor-Davidson were assessed. There were significant ($p \leq 0.05$) changes in all measured parameters for the Intervention Group, no significant ($p>0.05$) changes were found from pre- to post-test in the Control Group. Eight weeks of combined training improved significantly ($p \leq 0.05$) for muscle strength, balance and resiliency level in the Experimental Group when compared to the Control Group. Combined training may inevitably aid daily functioning and mental health in individuals with MS.

***Keywords*:** Concurrent training; Endurance training; Multiple sclerosis; Physical exercise.

INTRODUCTION

Multiple sclerosis (MS) is a chronic, debilitating disease that can damage the nerves of the spinal cord and brain, and also the optic nerves. Symptoms of this disease include a wide range of symptoms, from muscle control disorder and imbalance to optic and speech problems (Taggart, 1998; Miller & Dishon, 2005; Kargarfard *et al*., 2010). The most common complications of this disease are fatigue, physical weakness, tremors, muscle cramps, imbalances in walking, asymmetric or double vision and walking disorders (Leocani *et al*., 2001; Kargarfard *et al*., 2012).

There is no known therapeutic treatment for MS thus far. However, several treatments can assist in the management of the motion systems and to prevent disease progression (APT, 1997). Treatments include medication and rehabilitation treatments (regular physical activity training based and hydrotherapy) that can improve the symptoms of the disease (Beckerman *et al*., 2010; Sangelaji *et al*., 2017). Physical activity can improve an MS patient's activities of daily living, mental health, social relationships and self-reliance (Comi *et al*., 2001; Corvillo *et al*., 2017; Hakakzadeh *et al*., 2019; Shariat *et al*., 2019). Given the negative motion consequences and also the medicinal costs of treating MS, sport and rehabilitation activities are an effective, inexpensive and side effects free management tool in the treatment of MS patients (Kargarfard *et al*., 2018).

When investigating the effect of exercise on physical fitness parameters related to health in MS patients, some studies have only used resistance exercise protocols (DeBolt & McCubbin, 2004; Dalgas *et al*., 2007) and showed that resistance training with moderate intensity could be useful to improve the function of patients with MS , while others have used only aerobic exercise programmes (Kileff & Ashburn, 2005; Newman *et al*., 2007; Rampello *et al*., 2007).

Another study done in 2015, showed that doing a regular pattern of Tai Chi Chuan is effective on balance of patients with MS (Azimzadeh *et al*., 2015). In a similar study done by Amiri *et al*. (2019), the positive effects of core stability training was shown on balance of patients with MS. Physical activity, whether resistance or aerobic has been shown to ameliorate MS functional impairments. However, it is unknown whether a combination of these two modalities would provide synergistic benefits or create an interference effect limiting their efficacy (Shaw *et al*., 2009a; Grazioli *et al*., 2019). As such, further investigation into the effects of combined training on MS patients should be assessed.

PURPOSE OF STUDY

This study aimed to evaluate the effect of aggregation of aerobic and resistance training programme on muscular strength, static and dynamic balance and resiliency of MS patients.

METHODOLOGY

Design and participants

Seventy early adult (20-40 years) women, diagnosed with MS from the MS Society of Tehran, Iran were initially identified for participation in this study. Of these, 40 did not meet the inclusionary criteria, eight declined to participate and two failed to respond to the request to participate in the study. The remaining 20 women were randomly assigned using a random number generator based on the selection criteria and were divided into two equal groups with 10 participants each using a dice. Participants were required to meet the following inclusionary criteria prior to participation in the study: early adult aged 20-40 years (Gross *et al*., 1997), Expanded Disability Status Scale (EDSS) between 2 and 5 (Kargarfard *et al.*, 2018), regular menstrual cycle, no known cardiovascular and orthopaedic diseases, no participation in regular exercise, and ability to walk without assistance and auxiliary accessories.

Instruments and procedures

All Experimental and Control Group participants underwent the same resilience, static and dynamic balance, and muscular strength and power assessments to determine baseline and if any changes took place at post-test. Participants underwent testing at an indoor centre where the air temperature ranged from 22°C to 25°C by the same qualified Sports Medicine Specialist.

Resilience testing

The Conner-Davidson Resilience Scale is a 25-item instrument that measures resiliency using a five-point Likert scale (Shin *et al*., 2018). With zero representing "completely inaccurate" and five representing "always correct". The minimum amount that can be scored was zero and the maximum 100. A 5-point Likert scale was used (0=not true at all, 4=true all the time). The total score ranges from 0 to 100, with higher scores indicating higher levels of resilience. The mean score of the scale was 52. As such, if a participant scored more than 52 it signified high resiliency, while a score closer to zero signified less resiliency.

Static and dynamic balance assessments

To measure static and dynamic balance, the Biodex device (model 590-32, Neclear Medicine, UK) was used. This device consisted of an adjustable plate underfoot (reliance level), stable level (static) and unstable level five to eight was used to measure static and dynamic balance and the duration was for one minute. The score of each test consisted of overall, anterior-posterior (AP) and medial-lateral (ML) indexes. The lower scores indicated superior balance. The American Biodex Company has previously confirmed the validity of the device (Drouin *et al.*, 2004).

Isokinetic muscular strength and power assessment

This test followed the protocol as proposed by Shaw *et al*. (2009b) and took place following a 5-minute warm-up of light pedalling (heart rate <100 beats per minute) on a stationary cycle ergometer (Monark 828E, USA) and 5 minutes of quadriceps and hamstring stretching (Shaw *et al*., 2009b). This was followed by positioning the participants on the isokinetic dynamometer (Biodex Isokinetic Dynamometer, IPRS Mediquipe, UK). Stabilising straps were used to secure each participant and right knee was aligned with the axis of rotation of the dynamometer using a line passing transversely through the femoral epicondyles of the dominant knee (Magee & Currier, 1986).

The knee/hip adapter pad was positioned three centimetres proximal to the medial malleolus. Participants were then asked to put their arms across their chest for the duration of the protocol in order to isolate the muscle acting on the knee, and to eradicate any extraneous pelvic movement that might arise as a result of a participant using her arms to generate additional force. Each participant's anatomical zero, range of motion and gravity effect torque was determined according to the parameters of Cybex International (1997). The Cybex Norm System dynamometer was set at a damp setting of '2', to lessen torque overshoot occurring from participants trying to 'catch up' to the speed of the dynamometer. Each participant was limited to 100 degrees of range of motion, with the entire range of motion lying between 5° and 105° of knee flexion (Shaw *et al*., 2009a).

Then, participants were familiarised with the equipment and warmed-up by performing one set of five progressive familiarisation repetitions of concentric contractions (con-con). This was followed by familiarising with the equipment and warmed-up by performing one set of five progressive familiarisation repetitions of concentric contractions (con-con) at 60 degrees per second ($^{o}.sec^{-1}$) (Ford *et al*., 1994). The familiarisation repetitions consisted of two repetitions at 50% effort, two repetitions at 75% effort and one repetition at 100% effort (Ford *et al*., 1994). Upon completion of the familiarisation repetitions, participants commenced with the test items after a one-hour rest. The trials consisted of five pairs of maximal (100% effort), intermittent, reciprocal, eccentric contractions (ecc-con) 60 degrees per second ($^{o}.sec^{-1}$) and the mean was selected. No verbal encouragement was given during all trials and the computer monitor was positioned one metre from each participant at chest level to standardise visual feedback. This procedure was repeated for $180^{o}.sec^{-1}$ subsequent to a 2-minute rest.

Intervention

Only the experimental group participated in an eight-week exercise programme, three times weekly with each session lasting 40-45 minutes. Each session was supervised by a qualified sports physiologist and rehabilitation specialist. In an attempt to obtain the benefits of both modalities, the intervention programme utilised a combination of resistance and aerobic training (Shaw *et al*., 2009a; Shaw *et al*., 2015). The combined exercise programme used was designed in accordance with the principles of the International Society of MS with low to medium intensities according to the status of MS participants' disability and based on 10 maximal repetitions.

Balance (standing using one leg) and flexibility (proprioceptive neuromuscular facilitation) exercises for 5 rounds and each round for 1-1.5 minutes were used in the warm-up and cool-down phases (Kargarfard *et al*., 2018). The resistance training component consisted of leg press, chest press, knee flexion, knee extension and seated pulley row, for two to four sets and eight to twelve repetitions with a three to four-minute rest between sets.

The aerobic component consisted of walking/running at a moderate intensity of 40 to 55% heart rate reserve (Cox *et al*., 2001; Ronai *et al*., 2011). Heart rate reserve was calculated using the following formulae: $HR_{reserve}=HR_{max} – HR_{resting}$, where $HR_{max}=206.9 - (0.67 \text{ x age})$. Due to the disability level, the aerobic component consisted of three to eight intervals with one to two minutes of rest between the intervals. Since individuals with MS are at an increased risk of sustaining exercise-related fatigue, intensity was progressively increased over the eight-week period, every week, based on personal improvement and abilities, and not using pre-determined specific percentage increases (Halabchi *et al*., 2017).

Experimental group participants were required to complete 22 of the 24 possible sessions (92% compliance) to be included in the final analysis. Participants' attendance at each of the supervised sessions was recorded by the supervising sports physiologist. The Control Group did not participate in any prescribed exercise training programme and were instructed to continue with their normal activities for the duration of the experimental period.

Ethical considerations

This study was conducted in compliance and in the spirit of the declaration of Helsinki and the study was approved by the University of Tehran's Ethics Committee (IR.UT.Sport.REC. 1398.047). All participants completed and signed an informed consent form prior to participating in the study. The physical health of the participants was assessed by a neurologist and their disability criteria were determined.

Data analysis

Kolmogorov-Smirnov test (K-S) was used to determine normality and Levene's test was used to investigate the homogeneity of variables in the study groups. Dependent and independent t-tests were utilised to determine if any changes occurred at post-test both within- and between-groups, respectively. Significance levels were set at $p \leq 0.05$. Cohen´s d was used to determinate the effect size (the value of 0.1 for small effect, 0.3 for medium effect, and 0.5 for large effect).

The data were analysed with the statistical analysis programme Statistical Package for Social Sciences (SPSS) version 20 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

All 20 of the sampled participants completed the study. Demographic and baseline characteristics of participants in each group are shown in Table 1.

Dependent t-tests indicated significant ($p \leq 0.05$) changes from pre- to post-test in the intervention group for quadriceps peak torque at 60º.sec-1 (p=0.001), quadriceps peak torque at 180º.sec-1 (p=0.012), hamstrings peak torque at 60º.sec-1 (p=0.014), hamstrings peak torque at 180º.sec-1 (p=0.021), overall static balance (p=0.001), anterior-posterior static balance (p=0.011), medial-lateral static balance (p=0.022), overall dynamic balance (p=0.001), anterior-posterior dynamic balance (p=0.001), medial-lateral dynamic balance (p=0.016), and resiliency level (p=0.001).

No significant ($p>0.05$) changes were found from pre- to post-test in the Control Group with regard to quadriceps peak torque at 60º.sec^{-1} (p=0.431), quadriceps peak torque at 180º.sec^{-1} (p=0.810), hamstrings peak torque at 60º.sec^{-1} (p=0.623), hamstrings peak torque at 180º.sec^{-1} (p=0.057), overall static balance (p=0.059), anterior- posterior static balance (p=0.071), medial-lateral static balance (p=0.059), overall dynamic balance (p=0.061), anterior-posterior dynamic balance (p=0.074), medial-lateral dynamic balance (p=0.081) and resiliency level (p=0.075).

Table 1. **PARTICIPANT DEMOGRAPHICS AT BASELINE**

Variables	**Experimental group** (n=10)	**Control group** (n=10)
Age (years)	36.10±2.20	34.30±5.40
Height (cm)	163.80±7.20	158.90±8.90
Weight (kg)	61.50±6.70	60.20±9.30
Resiliency level (score)	6.24±2.47	6.24±4.28

Values=mean±standard deviation cm=centimetres kg=kilogrammes

Independent t-test results indicated that when compared to the Control Group, the eight-week combination training programme significantly increased quadriceps peak torque at 60º.sec^{-1} (p=0.001) and 180º.sec^{-1} (p=0.014) and hamstrings peak torque at 60º.sec^{-1} (p=0.001) and 180º.sec^{-1} (p=0.023). In addition, when compared to the Control Group, the Experimental Group displayed a significantly increased overall static balance (p=0.001), anterior-posterior (p=0.032) and medial-lateral indexes (p=0.001), overall dynamic balance (p=0.002), anterior-posterior (p=0.001) and medial-lateral (p=0.004) indexes. When compared to the Control Group, the resiliency level of the Experimental Group improved significantly from pre- to post-test (p=0.001) (Table 2).

Table 2. **MUSCULAR STRENGTH, STATIC AND DYNAMIC BALANCE AND RESILIENCY OF WOMEN WITH MULTIPLE SCLEROSIS FOLLOWING COMBINED AEROBIC AND RESISTANCE TRAINING**

	Experimental group (n=10)		**Control group (n=10)**		**Between groups**	**Effect**
Variables	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**p-value**	**Size**
Quadriceps peak torque (60º.sec^{-1}) (N.m^{-1})	80.60±1.3	84.80±3.20*	77.6±8.4	76.4±7.3	0.001$^{\#}$	0.57
Quadriceps peak torque (180º.sec^{-1}) (N.m^{-1})	54.90±4.8	58.11±6.60*	50.8±7.6	50.3±10.7	0.014$^{\#}$	0.61
Hamstrings peak torque (60º.sec^{-1}) (N.m^{-1})	22.60±6.6	25.80±1.30*	22.4±5.9	22.8±6.1	0.001$^{\#}$	0.65
Hamstrings peak torque (180º.sec^{-1}) (N.m^{-1})	20.80±3.2	23.90±4.70*	20.7±6.3	20.3±7.9	0.023$^{\#}$	0.60
Overall static balance	3.59±1.23	3.10±1.96*	3.47±2.52	3.41±1.27	0.001$^{\#}$	0.69
Anterior- posterior static balance	2.27±1.34	1.95±1.40*	2.29±1.64	2.25±1.7	0.032$^{\#}$	0.54
Medial-lateral static balance	1.65±0.65	1.32±0.34*	1.63±0.41	1.68±0.52	0.001#	0.66
Overall dynamic balance	6.24±2.47	5.85±3.14*	6.24±4.28	6.29±3.12	0.002$^{\#}$	0.70
Anterior-posterior dynamic balance	5.81±2.15	4.74±2.63*	5.62±3.42	5.66±2.21	0.001$^{\#}$	0.59
Medial-lateral dynamic balance	3.31±1.12	3.01±2.18	3.42±2.64	3.47±2.36	0.004$^{\#}$	0.62
Resiliency level	33.6±17.4	45.4±12.30	30.6±11.3	32.3±19.9	0.001$^{\#}$	0.61

Values are mean±standard deviation * Significant difference ($p \leq 0.05$) between pre- and post-test within-group $^{\#}$ Significant difference ($p \leq 0.05$) between Experimental and Control Group Value of 0.1 for small effect, 0.3 for medium effect, and 0.5 for large effect) º.sec^{-1}: Degrees per second N.m^{-1}: Newton metres

DISCUSSION

According to the findings of the present study, eight weeks of combined aerobic and resistance training significantly improved the strength of the flexor and extensor muscles of the knee joint, dynamic and static balance and resiliency in women with MS. The significant improvement in muscle strength is in line with the results of previous research (DeBolt & McCubbin, 2004; Wens *et al*., 2015). However, it is not consistent with the findings of Harvey *et al*. (1999), who did not report a significant change in the muscle strength of participants with MS. This was likely as a result of the indecorous population used in their study (Harvey *et al*., 1999).

The results of this study showed that eight weeks of combined aerobic and resistance training significantly increased the resiliency in women with MS. This is likely as a result of the combined aerobic and the ability of resistance training to create a positive self-concept and self-esteem of a patient, making the patients more resistant to some of the movement problems and pain by making the patient more responsive with coping with stress, depression and/or anxiety (Malivoire *et al*., 2018).

The present study further demonstrated a significant improvement in the static and dynamic balance of women with MS following combined aerobic and resistance training. The improvement is essential since balance is directly affected by the destruction of cerebellar tissue in patients with MS, and its contributory factors are sensory disturbances, excessive fatigue, optic reduction and muscle weakness, especially in the lower-body musculature of MS patients (Kargarfard *et al*., 2018). Since there is a significant interdependence between balance and lower body muscle strength (Broekmans *et al*., 2011), the improvement in the flexor and extensor muscles could have contributed to the improvement in static and dynamic balance. The combined aerobic and resistance training programme effectively improved balance, possibly as a result of the variety of muscle involvement that activated the proprioceptive receptors. Also, aerobic training has shown to improve aerobic capacity, flexibility and neural activity, thereby improving balance (Hautala *et al*., 2009). Furthermore, the resistance training could have resulted in the improved balance through reducing muscle spasms, reducing sensory disorders and reducing muscle weakness in this sample of participants with MS (Broekmans *et al*., 2011; Callesen *et al*., 2019).

Muscular strength assessments and improvements are essential in MS patients, especially in the lower body. This is since MS patients suffer from especially weak lower-body muscle strength. This may be due to the neurological features of MS, such as impaired muscular tension, increased tension in transverse bridge mechanisms, nervousness flow obstruction and nervousness fatigue (Doesburg *et al*., 2019; Hakakzadeh *et al*., 2019). In addition, patients with MS are also generally found to be inactive (Doesburg *et al*., 2019; Hakakzadeh *et al*., 2019). Resistance training has been shown to improve neural adaptations, such as the use of motor units and motor neuron contractions (Shaw *et al*., 2016; Kargarfard *et al*., 2017).

The improvements in the flexor and extensor muscle strength in this study was likely due to the improved effectiveness of muscle function, increasing neuronal activation and changes in the communication between motor neurons. These changes lead to more simultaneity and recall of motor units, which improves the amount of power production and the capacity of sustained power (Shariat *et al*., 2017). Moreover, resistance exercise can block the inhibitory impulses from the Golgi tendon organs to allow the muscle to achieve a higher level of strength (Shaw *et al*., 2009a). Other neural factors, such as a reduction of agonist and antagonist muscle activation, could have contributed to the increased strength (Comi *et al*., 2001; Broekmans *et al*., 2011).

As this study used a purposive sampling procedure, generalisation to the entire MS population, and particularly males, should be performed with caution. In addition, only lower limb strength was assessed and cross education (force variability) between the lower and upper limbs was not assessed. As such, generalisations to possible improvements following upper body training should not be inferred (Krasilshchikov *et al*., 2011). Other psychological factors, such as stress and anxiety could have influenced resiliency, and each participant would have different levels of each. Stress and anxiety were not tested and that it is therefore a limitation. As with all self-reporting, this study’s use of self-reporting for resiliency may have been influenced by self-report bias, effectively under-/overestimating resiliency (Hill *et al*., 2019).

CONCLUSION

The results of the present study demonstrate that a combination of aerobic and resistance training over an eight-week period led to significant improvements in resiliency, static and dynamic balance, and muscular strength of lower limb in women with MS, which are all extremely important in a population with MS. Thus, our study supports the necessity of studies that includes specific muscular resistance training along with traditional aerobic programmes to slow the functional deterioration that accompanies MS, which would improve patients' ability to carry out daily living activities and their quality of life.

Disclosure statement

The authors report no potential conflict of interest.

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