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Original Article

The Effects of Aerobic Training and Blood Flow Restriction Training on the Stride Length and Balance of Women with Multiple Sclerosis

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Abstract

Introduction: Multiple sclerosis (MS) is an autoimmune disease that causes damage to the myelin of the central nervous system. The purpose of this study was to investigate the effects of aerobic training and blood flow restriction training on the stride length and balance of women with multiple sclerosis (MS).

Methods: 24 volunteer patients with disability scale of 1- 4 (age: 37.08 ± 8.23 years; weight: 61.54 ± 8.58 kg and height: 159.5 ± 7.27 cm) were randomly divided into two groups including aerobic training group (n=12) and blood flow restriction (BFR) training group (n=12). Both groups pedaled on aqua cycle (3 sets of 6 minutes with 1 min of rest between sets and 60-65% HRmax) for 6 weeks and 3 sessions in a week. To restrict the blood flow, the cuff on the upper part of the foot with a pressure of 96 ± 10 mmHg was implemented. The stride length and balance were measured by employing cameras and berg balance scale, respectively. To analyze the data, analysis of covariance (ANCOVA) and Bonferroni's post-hoc test were used at a significant level of $P < 0.05$.

Results: The results showed that both types of training significantly increased the left step length ($p < 0.05$) and balance ($p < 0.05$) in patients with multiple sclerosis, but significantly decreased the right step length ($P < 0.05$).

Conclusion: It seems that both aerobic training and BFR training caused improvement in the balance of patients with multiple sclerosis, however, more deliberation is needed in relation to their effects on the stride length.

Keywords: Training, Balance, Multiple Sclerosis, Blood Flow Restriction

Introduction

Multiple Sclerosis (MS) is a progressive autoimmune disease in the central nervous system (CNS) (1). The onset of the disease is usually early in adolescence, and mainly women are more at risk for the disease, including motor weakness, changes in sensory perception, visual impairment, and fatigue (2). Axons, myelin or the myelin producing cells, oligodendrocytes, are the primary targets of the attack, whose damage interferes with the communication between brain-given messages and muscle activity (3). Neuromuscular disorder impairs the physiological function and ability and leads to a cumulative reduction in the daily activities and quality of life. The personal and economic costs of neurological disorders create problems for public health (4). Natural imbalance and vestibular action are commonly known as MS symptoms and have been reported as an initial symptom (5). Despite the high incidence of imbalance in MS patients and its negative effect on functional ability, relatively little attention has been paid to improving the balance in this population. A lack of normal walking (reduced speed, reduced stride length, and prolonged dual support phase) and defective posture control have been found in people even with MS with minimal disorder (2). Balance and walking capacity are completely related to each other, and most falls occur during walking activity (6). Patients with MS experience a loss of balance due to reduced muscle strength, reduced exercise tolerance and reduced reaction speed (7). One of the biggest problems for MS patients is an impairment of walking capacity and independent walking, which is due to spasticity, muscle weakness and fatigue, reduced vision, and reduced nerve stimulation in the organs of the body. Compared to the healthy people, MS patients are faced with a decrease in the length and frequency of the steps, decrease in speed and walking distance, decrease in the pelvic rotation as well as knees and ankles and increase in trunk flexion during walking, and the most important result of such disorders is balance disorder, fall and collapse of the patient (8). The problem of quick movement in patients with MS is along with spending high energy and effort during walking as well as poor endurance and tolerability; this abnormal energy intake can be a major contributor to leg fatigue during exercise (9, 10). The rate of walking disorder depends on the severity and progression of the disease, decreased strength and muscular endurance, level of spasticity, degree of instability, and degree of sensory impairment (11). Although drug therapy can reduce the number and severity of attacks that result in falls, fatigue, muscle weakness, and balance and walking problems persist. This situation reduces the daily activities and quality of life of the patient (3). Exercise is known as a mechanism for maintaining health, preventing disease, and rehabilitating MS. Evidence has shown that engaging in exercise can increase muscle strength, increase walking speed and improve time and balance control (7). Resistance trainings lead to the development of neurological adaptations such as improving motor activity and muscle coordination, which is desirable for MS patients (12). Aerobic trainings also increase cardiovascular fitness and physiological changes in the body (13). Because MS patients are allergic to heat and exercises can increase the patient's body temperature, we run it in an aquatic environment. Aquatic training is performed in a controlled aquatic environment and recommended for neurological rehabilitation (7). Water allows the patient to practice his or her therapy with less fear of falling (14). Moreover, the hydrostatic pressure created by the aquatic environment creates supportive power and reduces the production of gravitational force that can facilitate postural control (15). In addition, the hydrostatic pressure and forces provide different perceptions and sensory feedback on the ground, thus affecting the posture and balance control system (7). Hence, aquatic training creates an optimal environment for rehabilitation programs for MS patients (14). In a study the effects of aquatic and land training programs were compared. There was more efficiency in balance, walking, fatigue and muscle strength in the aquatic training group, but no significant improvement was found in land training (14). Improvement after aquatic training can be attributed to the aquatic flotation in support of body weight and increased capacity to move. Water turbulence and its resistance can also be a good environment for exercising balance and walking (16). Rodgers *et al.* (1999) found that aerobic training improves cardiovascular fitness while walking mechanics remain unchanged (13). Considering that achieving resistance training goals such as hypertrophy and neural adaptation is essential for MS patients to maintain balance and perform daily activities, also increased muscle strength requires an increase in training intensity, and tolerating increased training intensity is hard for patients with MS, in the present study, the BFR method with aerobic training was implemented. The BFR method involves reducing blood flow to the muscle by applying an external limiting device such as cuff in the given muscle (17). The BFR method alone has been shown to reduce muscle atrophy during inertia, and considering the physiological effects that aerobic training with BFR can have on improving muscle neuromuscular adaptation and muscle strength (18), in the present study of, the effects of two methods of aerobic training and BFR in water on the stride length and balance of women with multiple sclerosis are investigated.

Methods

The present study is a quasi-experimental design with a pretest and posttest design and two intervention groups. The statistical population included all women with MS with a range of 18- 50 years of age and disability scale of 1- 4 of the MS society of Tehran, among whom 24 were selected. Subjects then filled out individual questionnaire, individual medical records and satisfaction form. The criteria for inclusion of the subjects were involvement with MS with a disability scale of 1.4, no history of cardiovascular disease, lack of epilepsy, lack of mental illness and lack of exercise. Subjects were then divided into two groups including aerobic training group (n = 12) and Blood flow restriction training (in water) group (BFR, n=12). The stride length and balance of participants in both groups were evaluated before and after the training period. To do this, two cameras were used in two different views, one in the side view and another one in the back view of the designated area for the subjects' walking. To identify the important points and patterns for the subject's walking, 20 light reflective markers were used on subject's bodies, where they were positioned as follows: in the side view on the metatars, ankles, knees, hips and shoulders, and in the back view on the heel of the legs, ankles, shins, knees and pesis. After placing the markers and getting prepared for the test, the subject attended the specified place and started walking and the filming was simultaneously started. Each subject at least 3 and at most 6 times covered the desired path for walking, of which two full walking cycles were selected for analysis, and the one repetition maximum (1 RM) was determined. Both training groups trained for 6 weeks, 3 sessions a week. The aerobic training protocol included 5 minutes of warm- up, 40 minutes (3 sets of 6-minutes with one minute rest between the sets) pedaling on aqua cycle (Made in Iran, ROBIMAX AUABIKE) in the water at 60 % maximum heart rate and 5 minutes of cooling. The intensity of training was controlled by a polar heart rate monitor (made in Germany) during training. The BFR aerobic training protocol was similar to that of the aerobic training protocol, with the exception that there was a blood flow restriction on the blood vessels (by the German pressure gauge). The cuff pressure was 96 ± 10 mmHg during the test on the upper part of the right and left feet. The cuff size was 13 cm. To introduce the subjects, the blood flow restriction started at 65 mmHg in the first week, and each session 10 mmHg was added to the thigh straps pressure until the fourth session it reached 96 mmHg, and it then remained constant until the end of the protocol. The Berg balance scale was used to measure the subjects' balance. This test is a clinical test for static and dynamic balance in neurological patients, and is considered as a gold standard test to examine functional balance. The scale includes 14 different prompts, which are performed consecutively. The tools needed included a ruler, two standard armchairs (one handle and one without a handle), a stool or staircase, a chronometer and a tape meter. It took about 15 to 20 minutes to complete this test. The minimum score for each test was zero and the maximum score was 4. Zero means inability to do the quest, and four means normal operation, and the total score of the questionnaire was 56. Kolmogorov-Smirnov test (K-S) was used to check the normal distribution of data. Based on mean and standard deviation, all data were reported. Analysis of covariance (ANCOVA) was used to determine the effect of blood flow restriction (BFR) on the results of the study. In this model, the pre-test was controlled to eliminate the effect of the differences in the first day data on the last day data. In case of a significant difference, Bonferroni's post-hoc test was used to determine the point of the difference. The significance level for all statistics was considered as p <0.05. All statistics were performed using SPSS software version 22. Also, to draw figures, Microsoft Excel version 16 was employed.

Results

Characteristics of subjects in both groups of study are presented in Table 1. Data on the length of the right and left feet and the balance are reported in Table 2 based on mean and standard deviation. The results of the analysis of covariance showed that training independent of its type caused a significant decrease in the stride length of the right foot (F = 6.6, P = 0.019, μ = 0.227). However, no significant difference was found between the effect of two types of training (F = 0.144, P = 0.708, μ = 0.007). Aerobic training caused 5.9% and blood flow restriction training caused 5.9% reduction in the stride length of the right foot (Fig. 1). On the other hand, the results of the analysis of covariance showed that in the stride length of the left foot, independent training of its type caused a significant increase (F = 6.88, P = 0.015, μ = 0.238). However, no significant difference was observed between the effects of two types of training (F = 0.026, P = 0.847, μ = 0.001)). Aerobic training caused 7.33% and blood flow restriction training caused 4.5% increase in the stride length of the left foot (Fig. 2). The results of the analysis of covariance showed that the subjects' balance was also affected by the training factor, so that during the training period, regardless of the type of training, the level of subjects' balance increased significantly (F = 30.17, P = 0.001, μ = 0.578). However, no significant difference was observed between the effects of two types of training (F = 2.38, P = 0.137, μ = 0.098). Aerobic training caused 15.37% and blood flow restriction training 77.22% increase in the level of balance (Fig. 3).

Table 1. Characteristics of subjects in the aerobic training group and blood flow restriction (BFR) training group

Group	Age (Year)	Height (cm)	Weight (Kg)	Body Mass Index	Disability Status Scale
Aerobic training *	39.25±8.41	155.87±6.91	59.12±8.82	24.12±2.9	1.87±0.83
Blood flow restriction (BFR) training	36.5±6.63	162±8.75	62.35±10.64	23.62±3.62	1.75±0.88

* Data reported based on mean and standard deviation.

Table 2. The subjects' length of right and left feet and balance in the aerobic training group and blood flow restriction (BFR) training group

Group	Length of Right foot step (m)		Length of left foot step (m)		Level of Balance	
	pre-test	Post-test	pre-test	Post-test	pre-test	Post-test
Aerobic training	1.17±0.16	1.10±0.15*	1.09±0.15	1.17±0.13*	40.66±6.70	46.91±5.97*
Blood flow restriction (BFR) training	1.19±0.15	1.12±0.10*	1.11±0.13	1.16±0.08*	45±6	50.25±7.05*

Data reported based on mean and standard deviation.

* Significant difference compared to pre-test.

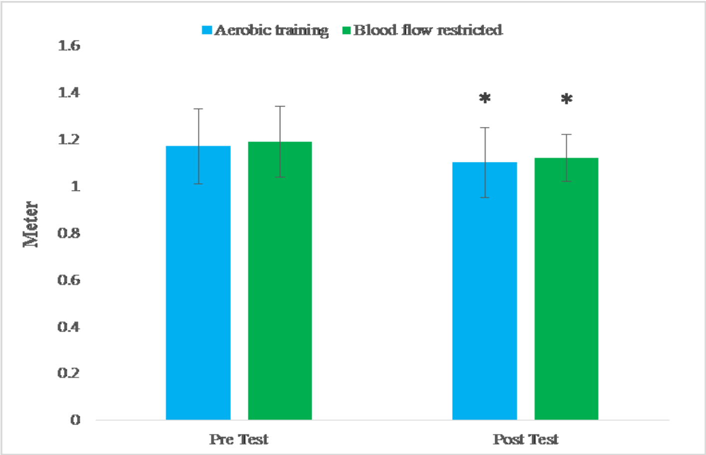

Figure 1. Right stride length in aerobic training group and blood flow restriction training group
Data reported based on mean and standard deviation.
* Significant difference compared to pre-test.

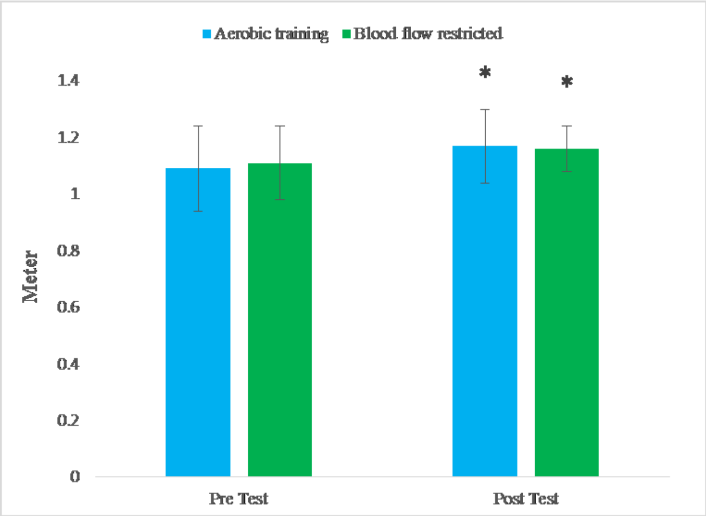

Figure 2. Left stride length in aerobic training group and blood flow restriction training group
Data reported based on mean and standard deviation.
* Significant difference compared to pre-test.

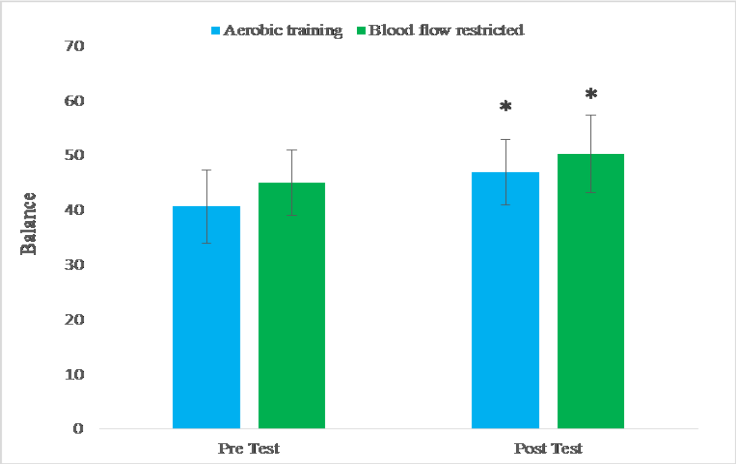

Figure 3. Level of balance in aerobic training group and blood flow restriction training group
Data reported based on mean and standard deviation.
* Significant difference compared to pre-test.

Discussion

Preserving musculoskeletal mass is an important factor for health, quality of life and everyday activities (19). Skeletal muscle plays a role in controlling glycemic index, stimulating glucose uptake, and oxidation of fatty acids (20, 21). Skeletal muscle also plays a role in maintaining daily activity and preventing falling. On the other hand, due to the connection between the nervous system and the muscles, maintaining and improving the compatibility and performance of these two parts in the life-span, especially for MS patients, is essential. In this study, we investigated the effects of aerobic training and BFR in water on the stride length and balance of women with multiple sclerosis. The results of this study showed that both methods of aerobic training and BFR training significantly reduced the length of the right foot and significantly increased the length of left foot and the balance of MS patients. There was no significant difference between the two training methods considering stride length and level of balance. Multiple sclerosis (MS) is defined by changing the direction in motor and sensory neural pathways caused by self-immune attacks on CNS system components. Axons, myelin or the cells producing myelin, oligodendrocytes, are the primary targets of the attack, whose damage affects the communication between the brain-given messages and the muscle activity (3); one of the consequences of such a disorder is failure to maintain balance and fall (22). Poor balance plays a role in falling and collapse. In addition, patients who experience falling are subject to the development of fear of falling and limiting physical activity (23). According to the U.S. Department of Health in 2010, despite the benefits of exercising in the prevention and treatment of chronic diseases, half of patients with chronic diseases such as MS do not participate in any exercise and recreational activities (24). The severity and frequency of MS symptoms can reduce individual participation in exercise programs, and this inactivity increases the risk of other illnesses associated with inactive lifestyle (25), also this situation is a threat to increase the inactive lifestyle of these people and increase their problems (26). Evidence has shown that patients with MS have fewer physical activity than healthy subjects, and this situation is a hazard for increasing the inactive lifestyle of this group of people and increasing their problems (26). Recent studies have shown positive effects of training therapy in relieving pains and improving movements in MS patients (26, 27). Excessive fatigue, poor balance and motor weakness are all harmful effects of inertia (3). The results of our study showed a significant increase in the length of the left foot and balance after both trainings. Therefore, our study confirms the previous report regarding the effect of exercise on improving the length of the left foot and the balance (7). On the other hand, the results of the present study on the effects of both aerobic training and BFR training on the length of the right foot are inconsistent with the results of other studies (25). Regular exercise improves bone and muscle strength, decreases depression and discomfort and improves oxidative capacity (3). Reduction in blood pressure, peripheral arterial resistance, and increased angiogenesis following training with BFR have been reported (28). In addition to vascular changes in the muscles, changes occur in hormones and nervous factors such as neurotrophins, for example, the expression or concentration of BDNF increases against certain intensities of exercise in MS patients (29). This factor plays a role in the neuronal differentiation and the formation of new capillaries from previous capillaries in the CNS, and so on. Studies have reported that the implementation of low intensity aerobic training combined with BFR facilitates muscle size and muscle strength the same as muscle hypertrophy due to resistance training (30). In addition, the sensitivity of MS patients to heat can be limited and improved during physical and post-exercise activity (3). According to

Loenneke *et al.* (2012), a training load less than 60- 70 % of 1RM is not enough to increase muscle strength or muscle hypertrophy, but resistance training along with BFR and a load of 20- 30 % of 1RM increases strength (16). Therefore, BFR trainings can lead to similar effectiveness as normal resistance trainings and lead to improved muscle strength, muscle strength, explosive power and running speed (16). Forsberg *et al.* (2016) reported that 7 weeks of balance training improves walking speed and balance in patients with MS (31), which is consistent with the result of the present study. Nagahara *et al.* (2017) argued that aerobic training with BFR in healthy subjects increases the walking speed, which is associated with an increase in the stride length (32). Salem *et al.* (2011) examined the effect of 5 weeks of aquatic training on the balance of 11 patients with MS. Subjects performed 60 minutes aerobic, stretching, balance, flexibility trainings as well as walking in the water. At the end of the fifth week, the 10- meter walking test, the Berg balance scale, and the get-up-go test were taken from the subjects. The findings indicated improvement in balance over 5 weeks (33). Also, in another study, Shanazari *et al.* (2013), using the same training protocol, measured the quality of life and walking speed, and the results showed improvement in the quality of life and walking speed (34). In a study by Rampello *et al.* (2007), 8 weeks of aerobic training significantly increased the walking speed and distance in patients with MS (10), in which the stride length and balance are likely to be effective in increasing walking speed and distance. In a study, Bayraktar *et al.* investigated six-minute test of walking and standing on one leg, and Marandi *et al.* examined a stage test of six scales. The results showed that training in water improved posture control in patients with MS. Also, improvement in modified fatigue impact scale (MFIS), duration of training, walking speed and muscle strength have been reported (25). Probably, the implementation of both types of training in water has played a role in the activation of molecular mechanisms related to the nervous system and skeletal muscles to increase the strength of the lower muscles of the trunk. The reason for the effectiveness of water trainings on MS patients is due to the floating nature that facilitates physical activity for those with physical inability; on the other hand, in these patients, an increase in body temperature occurs, which training in water prevents this temperature rise. MS patients also have muscle weakness and spasm (35), which training in water increases muscle flexibility, reduces spasticity and reduces muscle aches. As a result, training in water increases muscle strength, balance and coordination. Concerning the cause of a significant decrease in right step length, it may be possible to point out the superiority of the right leg of the patients; the patient psychologically has distrustfulness to his non-dominant left leg and so is more attentive to his left foot while walking. On the other hand, improving balance is also evidence of the usefulness of both types of training in these patients. It has to be considered that muscle strength and muscle mass in either legs have not been measured and evaluated, and this is a limitation of the present study, which shows why significant reduction in the length of the right foot can't be accurately explained. Considering that most studies have examined the effect of training on walking speed, further enquiries and more accurate studies are required in this regard.

Conclusion

Both types of aerobic training and BFR training improve balance, and the implementation of trainings in MS patients improves walking capacity and level of balance and reduce falls in MS patients.

Ethical issues

Not applicable.

Authors' contributions

All authors equally contributed to the writing and revision of this paper.

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