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Effect of Aerobic Training with Blood Flow Restricting on Static Balance, Lower Extremity Strength, and Thigh Hypertrophy in Females with Multiple Sclerosis

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Abstract

Introduction: Multiple sclerosis (MS) is the most common neurological, progressive and debilitating disease in young adults. The purpose of this study was to investigate the effect of 8-week aerobic training with restricted blood flow on static balance, thigh strength, and thigh hypertrophy in females with MS.

Methods: 19 females with MS disease (age= 56.11±7.43 years and BMI= 22.78±1.78 kg.m^{-2}) were selected and divided randomly into four groups: aerobic training (A), blood flow restriction (BFR), combination aerobic training and blood flow restriction (COM), and control group (C). Before and after 8 weeks of aerobic training (45 min aerobic training with 50- 60% HRmax) and restricted blood flow; the balance, thigh strength and hypertrophy were measured. Paired sample t-test, two-way repeated measure ANOVA and Tukey's post hoc test were used to analyze statistical data (p≤0.05).

Results: The results showed significant difference between groups in balance (p= 0.02), thigh strength (p= 0.001), and hypertrophy (p= 0.04). Post hoc test showed a significant difference between the COM and C groups (p = 0.003) and COM and BFR groups (p = 0.03); but the COM group didn't have better balance scores than the A (p=0.37) and BFR (p=0.15) groups. Also in thigh strength there was a significant difference between the COM and A group (p = 0.008) and between the COM and C group (p = 0.001); but the COM group didn't have better thigh strength than BFR (p=0.08) group. Also there was a significant difference between COM and C group in hypertrophy (p = 0.02).

Conclusion: According to the results aerobic training with blood flow restriction leads to increased balance, strength and thigh hypertrophy in MS patients so this approach can be taken instead of traditional aerobic training to decrease disability in MS patients.

Keywords: Multiple Sclerosis, Blood Flow Restriction, Training

Introduction

Multiple sclerosis (MS) is the most common neurological, progressive and debilitating disease in young adults (1). This affects the white substance of the brain and the spinal cord. The process of this disease causes inflammation, demyelination, and ultimately sclerosis (1). The cause of this disease is unknown, according to the researches; 2.5 million people in the world suffer from MS (2). According to the MS Society in 2016, there are about 70,000 MS patients in Iran, with an estimated prevalence of approximately 9 per 100,000 people; considering the high contribution of patients with MS in the country and its high prevalence, the concern about the future of these patients is very important. On the other hand, due to the development of neurological disorders, it can impair life quality (3). The disease is more common in young adults aged 20- 40 years and among women, and is the third leading cause of disability among adults (4). Balance disturbance is one of the most common and prevalent symptoms in patients with multiple sclerosis, which with other factors, can increase the risk of falling (5). These abnormalities often prevent the daily activities in patients. More than 85% of these patients suffer from walking problems. Individual motor ability has been affected by several factors such as weakness, imbalance, fatigue, spasticity and environmental conditions (5). Kasser *et al.* showed that the cause of recurring falls in patients is the progression of the MS and factors such as asymmetric walking and weakness of flexors and extensors in legs (6). Sosnoff *et al.* examined spasticity, mobility, and balance in MS patients. This study showed that spasticity of great muscles affects the mobility and balance of these individuals, as well as treatment for reducing spasticity, improved the balance in these patients (7). From benefits of exercise therapy for patients with MS can mention improving the physical condition of patients, doing better their daily activities and their mental health (8, 9). Varied exercises such as endurance and resistance (10, 11). Pilates (12), water therapy (13), aerobic and yoga (14) were recommended for MS patients. For example, Kileff and Ashburn assessed the effect of 12 weeks endurance training on eight MS patients. The exercise protocol intensity was 60- 80 % of maximum heart rate. The time of 10-meter walking was unchanged but distance travel of 6-minute walking 16% increased (15). Van den Berg *et al.* investigated the effect of four weeks aerobic walking on treadmill on improving motor ability and fatigue in MS patients. Subjects trained for 30 minutes on a treadmill with an intensity of 55-85% of maximum heart rate with three rest periods. The results showed a 17 % decrease in walking time of 12 meters and a significant increase in walking distance of two minutes (16). Also Taylor *et al.* examined the effect of six weeks of resistance training on nine MS patients. The exercise protocol included three upper and lower extremities exercises on the gym, in two sets with 10 to 12 repetitions, intensity of 80-60% One-repetition maximum (1RM). Results showed an increase of 32% in the press and 10% in the press of the chest. In performance tests, at 10 m walking time, there was a 6% increase, but this change was not significant and there was no significant change in the test of climbing the stairs (17). De Souza-Teixeira *et al.* examined the effect of resistance training on 13 patients with MS, and showed a significant increase in muscle strength, hypertrophy and motor function (18). Also Dalgas *et al.* examined the effect of 12 weeks of strength training on improving muscle strength and motor function in patients with MS. The results showed an increase of 15.7% and 21.5% in knee extensor muscle strength and motor function (19). Up to the present, no study was found to investigate the effect of blood flow restriction on the strength, balance, and muscle hypertrophy in MS patients. On the other hand, the scientists note the new and effective exercise training program and intervention to decrease the MS patient limitations. One of these new exercise training programs is training with blood flow restriction (BFR), known as the Katsu Exercise, which was first introduced in Japan as a common exercise (20). An important trait of limiting blood flow in an organ is with low intensity exercise, it can be triggered significant increase in muscle mass and strength. BFR exercises, lead to decrease blood flow so the flow of oxygen will decrease; therefore, the power produced by the fast twitch muscle fibers have an important role to increase muscle strength and muscle hypertrophy. In other words, in exercises with blood flow restriction, fibers that have more potential to increase muscle growth (fast twitch) and they are the main source of power and strength in muscle, are recruited (20). Considering the fact that rare research has been done about the effect of aerobic training with restricted blood flow on balance, lower extremity strength and lower extremity hypertrophy in MS patients, and today we face the prevalence of this disease. In the present study, researchers are seeking the answer to these questions that dose the restricting lower extremity blood flow affect the balance, strength and hypertrophy of hamstrings and quadriceps muscles of MS patients and does the combined effect of aerobic training with blood flow restriction lead to change in the balance, lower extremity strength and hypertrophy of patients with MS?

Methods

This research is a semi-experimental pretest-posttest designed research and its statistical society is females with MS disease in Isfahan. The subjects were selected randomly from all patients referring to MS clinics associated with Isfahan University of Medical Sciences. Forty subjects were selected and after obtaining consent and the physician's permission, were assigned randomly into four groups: aerobic training (A), blood flow restriction (BFR), combination: aerobic training with blood flow restriction (COM), and control group (C). After one week of familiarization with aerobic training and blood flow restriction, a pretest was performed. Then eight weeks of aerobic training with restricted blood flow were performed and 24 hours after the last training session (to neutralize the acute effects of training), the post-test was conducted. The control group had not any specific exercise activities, and they were only doing their daily routine. The subjects completed the protocol for eight weeks and two sessions per week (21). The time for each session was 45 minutes. Aerobic training was performed in three stages: 1) warming, 2) main exercises with ergo line GmbH Type: RR 900 Rehab ergometer made in Germany (training intensity was fixed according to the feeling of pressure about to 50- 60 % maximum heart rate) and 3) return to the initial state (Three minutes pedaling without resistance) (21). Blood flow into the active muscle during training by restricting a flexible rubber cuff or cache (Tourniquet) was limited in the proximal both thighs region for 45 minutes. In this research, a combination of one eight cm wide cuff and a manual pressure barrel were used to limit the flow of blood in the hip area. By closing the cuff at the highest point of the throat, and pushing the pressure gauge on the throat to limit its blood flow to the desired pressure (22). When the subjects performed training with BFR, the proximal portions of their thighs were compressed at the pressure of 150–160 mmHg by electronically controlled air pressure belts (23). Balance-Berg scale was used to evaluate the balance of MS patients. It tests the performance of balance on the basis of 14 instance that are used in the life, such as simple movement (moving, standing without support, standing up, etc.), and difficult movement (360 degrees of turning and Standing on one leg, etc.). The total score of the test is 56, which shows the balance at an excellent level. The scale includes 5 points and range from 0 to 4. The zero score is used for the lowest level of performance and 4 for the highest level. The score of the subject is calculated based on the sum of the points that are awarded to each section (24). The maximum isometric strength of the lower limb muscles, including quadriceps and hamstrings, was evaluated by using a dynamometer (13). Based on the fatigue associated with MS (24), muscle test was performed only once. The patient held the test posture for only five seconds (26). To evaluate the hypertrophy of quadriceps and hamstring muscles, after the training period, the muscle cross-sectional evaluation method was used. As indicated in the below formula, at first, the fat spot point of the thighs was measured by the caliper and then the circumference of the thigh (exactly below the hip) with the strip meter was evaluated, and placed in the formula, then the muscle cross section indicated total thigh hypertrophy muscle hypertrophy (27).

Total thigh hypertrophy= (4.68 × circumference of the thigh)-(2.09 × fat spot point of the thigh)-80.99

Normality of data was tested using Shapiro Wilk's test. Then, to compare the results of the groups and to examine the change from the pretest, post-test and interactive effects, paired sample t test and two-way repeated measure ANOVA and Tukey's post hoc test were used at the significance level of $p< 0.05$.

Results

Table 1 shows the demographic characteristics of subjects. The Shapiro Wilk's test indicated no significant difference between the groups in these variables. Table 2 shows the mean and standard deviation of the variables in the pre-test and post-test. The results of paired sample t test showed significant changes on balance in three experimental groups of A (t=-8.65, p=0.001), BFR (t= -11.61, p=0.001) and COM (t= -50.20, p=0.001) but not in C group (t=0.43, p=0.67). Also the results showed significant changes on thigh strength in groups of A (t= -5.95, p=0.001), BFR (t= -3.75, p=0.005) and COM (t= -12.36, p=0.001) but not in C group (t=0.38, p=0.71). Also the results showed significant changes on thigh hypertrophy in groups of A (t=-11.25, p=0.001), BFR (t= -12.12, p=0.001) and COM (t= -57.53, p=0.001) but not in C group (t=1.09, p=0.30). The results of two-way repeated measure ANOVA showed significant differences between groups in balance ($F_{3,36}$=3.62, p=0.02), thigh strength ($F_{3,36}$=8.63, p=0.001), and hypertrophy ($F_{3,36}$=3.05, p=0.04). The results of Tukey's post hoc test for balance showed a significant difference between the COM and C groups (p=0.003) and COM and BFR groups (p = 0.03); that the COM group hadn't better balance scores than the A (p=0.37) and BFR (p=0.15) groups (table 3). Also, the results of post hoc test for thigh strength showed that there was a significant difference between the COM and A groups (p = 0.008) and between the COM and C groups (p = 0.001) that the COM group hadn't better thigh strength than BFR (p=0.08) (Table 4). Also, there was a significant difference between COM and C group in thigh hypertrophy (P = 0.02) (Table 5).

Table 1. The demographic characteristics of subjects

Variables	Aerobic Training	Blood Flow Restriction	Aerobic Training with Blood Flow Restriction	Control
Age (year)	43.6±9.3	48.42±2.6	45.31±11.4	51.11±6.4
Weight (kg)	70.21±13.82	78.72±6.91	81.12±14.7	75.21±11.51
Height (m)	1.87±0.9	1.83±0.8	1.81±0.15	1.82±0.11
BMI (kg/m^2)	20.15±2.76	23.42±1.43	24.73±1.03	22.83±1.92
EDSS (%)	2.1 ± 0.7	3.1±0.9	2.8 ± 1.2	1.9±0.5

Table 2. The results of paired sample t- test for compare the research variables in per- test and post- test

Variables	Groups	Pre test Mean± SD	Post test Mean± SD	t	p
Balance (score)	A	32.91±4.18	41±2.70	8.65	0.001*
	BFR	34.71±3.59	37.70±3.41	11.62	0.001*
	Com	32.30±3.34	46.21±3	50.20	0.001*
	C	34.20±2.46	35.22±2.81	0.43	0.676
Thigh strength (kg)	A	71.60±7.85	77.40±8.60	5.95	0.001*
	BFR	74.91±6.25	79.71±7.70	3.75	0.005*
	Com	76±5.94	92.42±6.31	12.36	0.001*
	C	70±3.8	70.41±4.62	0.38	0.714
Thigh hypertrophy (cm^2)	A	145.41±25.79	161.11±23.51	11.25	0.001*
	BFR	144.20±22.61	158.32±23.22	12.12	0.001*
	Com	144.11±20.72	198.50±20.40	57.53	0.001*
	C	143.90±24.21	141.91±23.81	-1.09	0.304

A: aerobic training group, BFR: blood flow restriction group, COM: aerobic training with blood flow restriction group, C: control group. *: $p\leq0.05$

Table 3. The results of Tukey post hoc test for compare the balance between groups

Groups		Mean Difference	Sig
A	BFR	0.7500	0.65
	COM	-2.3000	0.17
	C	2.2500	0.19
BFR	A	-.7500	0.65
	COM	-3.0500	0.03*
	C	1.5000	0.11
COM	A	2.3000	0.27
	BFR	3.0500	0.03*
	C	4.5500	0.003*

A: aerobic training group, BFR: blood flow restriction group, COM: aerobic training with blood flow restriction group, C: control group. *: p≤0.05.

Table 4. The results of Tukey post hoc test for compare the tight strength between groups

Groups		Mean Difference	Sig
A	BFR	-2.8000	0.12
	COM	-9.7000*	0.008*
	C	4.3000	0.08
BFR	A	2.8000	0.12
	COM	-6.9000	0.03*
	C	7.1000	0.06
COM	A	9.7000*	0.008*
	BFR	6.9000	0.03*
	C	14.0000*	0.001*

A: aerobic training group, BFR: blood flow restriction group, COM: aerobic training with blood flow restriction group, C: control group. *: p≤0.05.

Table 5. The results of Tukey post hoc test for compare the thigh hypertrophy between groups

Group		Mean Difference	Sig
A	BFR	1.9392	0.77
	COM	-16.6058	0.10
	C	14.3412	0.13
BFR	A	-1.9392	0.77
	COM	-18.5450	0.08
	C	12.4020	0.15
COM	A	16.6058	0.40
	BFR	18.5450	0.08
	C	30.9470*	0.02*

A: aerobic training group, BFR: blood flow restriction group, COM: aerobic training with blood flow restriction group, C: control group. *: p≤0.05.

Discussion

The purpose of this study was to investigate the effect of eight weeks aerobic training with restricted blood flow on static balance, lower extremity strength and thigh hypertrophy in female with multiple sclerosis. The results of the study showed a significant difference in thigh hypertrophy between groups. In BFR training, low blood flow results in a decrease in the oxygen supply to the active muscle; therefore, in this kind of training, the force generated by fast-twitch muscle fibers plays an important role in increasing muscle strength and hypertrophy, since the flow of oxygen to muscle tissues was restricted the fibers with less oxygen consumption were recruited and their glycolysis and phosphocreatine dominant energy systems were working. In other words, in training with a restricted blood flow, fibers with more potential for muscle growth (fast twitch) are the main source of muscle strength and power (20). Takashi *et al.* investigated the effects of daily physical activity combined with Kaatsu, they examined the acute and chronic effects of walk training with and without Kaatsu on MRI-measured muscle size and maximum dynamic (one repetition maximum) and isometric strength, along with blood hormonal parameters. Nine men performed Kaatsu-walk training, and nine men performed walk training alone (control-walk). Training was conducted two times a day, 6 days/wk, for 3 wk using five sets of 2-min bouts (treadmill speed at 50 m/min), with a 1-min rest between bouts. MRI-measured thigh muscle cross-sectional area and muscle volume increased by 4- 7 %, and one repetition maximum and maximum isometric strength increased by 8- 10 % in the Kaatsu-walk group. There was no change in muscle size and dynamic and isometric strength in the control-walk group (28); It seems that the different nature of the exercises is the reason for the difference between the results of the present research and the above-mentioned research (29). Karabulut *et al.* in a study conducted on 37 adult males for six weeks, showed that the knee flexural strength training group with an intensity of 80 % 1RM had the same increase in muscular strength with a knee flexion strength training group of 20 % 1RM with blocked vessels the result of this study is consistent with above-mentioned research (30). Takarada *et al.* studied the strength of knee extensor on rugby male player for eight weeks. Six subjects completed training program with 50 % 1RM with vascular obstruction and six subjects with the same intensity training and without obstruction of the vessels. The results indicated strength and muscular endurance increased only in the training group with vascular occlusion the result of this study is consistent with above-mentioned research (31). In our study increasing strength in the combined group can be due to muscle hypertrophy. Another reason for increased strength can be increasing anabolic hormones such as testosterone and growth hormone. Since testosterone has several anabolic effects, cause to increase the bone matrix and calcium retention (32). In addition, testosterone elevates the base metabolism, which is the result of the indirect effect of testosterone on protein anabolism that in practice causes the formation of muscle after puberty. Therefore, increase in strength through exercise before and after puberty may be due to changes in muscle hypertrophy (32), but this effect is more significant in men. May *et al.* performed a study about blood flow restriction that led to muscle strength adjustment in the activated arm. The results showed that 1RM in the experimental group increased. Also the increase in 1RM of knee extension in the experimental groups with blood flow restriction was twofold compered the control group, but knee flexion and cross-sectional strength were not significantly different between the two groups (33). Based on the results of this study, there was a significant difference in the static balance between groups and also between the combination and control groups. Cattaneo *et al.* investigated the effects of resistance training on the balance of women with MS. Results showed a significant improvement in the balance of these patients (34). Instability of postural, spasticity and weakness of muscle tone are from the biggest problems for the balance and mobility of daily activities of MS patients, which are due to the loss of myelin in the nervous system in the brain and the spinal cord. The cerebellum is one of the most commonly vulnerable areas in this patients that cause impairments in movement, balance and reduce the directional control stature. This leads to poor quality of life for these patients (35), leads to fall down, reduce balance, (36) severe muscle weakness, tingling, and numbness. Researchers suggest that these patients due to fatigue, lack of coordination, nervous impairments, vestibular and vision systems impairments have many problems with walking (35). Two main factors for equilibrium in standing conditions are: the alignment of body components with each other and muscle tones; therefore, in the present study, improving the body alignment and enhancement of muscle tones as well as increasing muscle strength may improve the balance. It should be noted that the researcher was not able to control the level of activity during the time out of study time. It is suggested that to compare the effect of resistance training with aerobic training and blood flow restriction in MS patients.

Conclusion

The results of this study showed that aerobic training along with blood flow restriction lead to increase balance, strength and thigh hypertrophy in MS patients. Therefore, aerobic training with restricted blood flow can be used instead of traditional aerobic trainings to improve the life conditions of MS patients.

Ethical issues

Not applicable.

Authors' contributions

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

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