

Original research papers

THE EFFECT OF UNSTABLE RESISTANCE TRAINING WITH BLOOD FLOW RESTRICTION ON SHORT-TERM MEMORY, STRENGTH AND DYNAMIC BALANCE IN OLDER ADULTS

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Abstract

Introduction. The aim of the present study was to investigate the effect of unstable resistance training with blood flow restriction (URT with BFR) on short-term memory, strength and dynamic balance in older adults. **Material and Methods.** A total of 27 male older adults (age = 62 ± 1.5 years) were randomly divided into two experimental groups: URT with BFR, URT without BFR, and a control group. The training program for the experimental groups consisted of bodyweight Scott exercise (three sessions a week for four weeks). The first two weeks included three sets, each set consisted of 15 repetitions at 60-second intervals. The second two weeks included four sets, with each set consisting of 15 repetitions and the use of weight constituting 5% of each person's body weight (mean = 3.5 ± 1.5 kg). To restrict blood flow, an 8-cm wide elastic band was used at 72 ± 9 mm Hg arterial pressure. All subjects performed Wechsler memory, 30-sec chair stand test, and timed up and go test (TUG) before and after the intervention. Data analysis was carried out using analysis of covariance (ANCOVA) and Bonferroni post hoc test. **Results.** The results showed that URT with BFR was significantly superior to other groups in the variables of strength ($p = 0.001$), dynamic balance ($p = 0.0001$) and short-term memory ($p = 0.04$). **Conclusions.** These findings suggest that URT with BFR can be a useful training method for older adults.

Key words: aging, physical fitness, cognitive function, resistance training, blood flow restriction

Introduction

Aging is associated with cognitive, physical and functional changes that can negatively affect people's health status [1]. Memory is regarded as the ability to store information and experiences and use them in subsequent interactions with the environment. Decreased memory performance due to factors such as changes in neuroplasticity [2] occurs as a consequence of "normal" aging. These structural changes in the nervous system are accompanied by other changes, especially in the locomotor system and motion control. In this regard, aging leads to a significant decrease in muscle strength, especially lower extremity muscles due to the decrease in the number and activity of motor units and also muscle breakdown [3], which, along with cognitive impairment [4], leads to restricted motor activity and imbalance [5]. Imbalance accounts for 10% to 25% of falls among older adults, so 1.3% of people aged over 65 years of age experience falls at least once a year [6]. Overall, atrophy of fast-twitch muscles [7] and decreased muscle strength are among the causes of aging-related imbalance [8]. Many studies have linked the decrease in muscle strength with poor cognitive function [9].

Physical exercise, especially resistance activities, is one of the most promising non-pharmacological strategies to delay or prevent some of the harmful effects of age-related cognitive, physical, and functional changes. High-intensity resistance training (HIRT) is one of the training methods that improve cognitive function [10], increase strength [11] and improve balance [12] in older adults. In this regard, Coelho-Junior et al. and

Wu et al. referred to 50-80% 1RM resistance exercise training as effective training methods to delay short-term memory loss in older adults [13, 14]. Tsai et al. also observed an improvement in short-term memory following 75% 1RM resistance training [15]. Also, the results of studies by Blocquiaux et al. showed that HIRT leads to a change in the size of fast-twitch muscle fibers, an improvement in muscle strength and dynamic balance, and ultimately a reduced risk of falls among older adults [11].

Despite the positive effects of HIRT on physical and cognitive function, some older adults are unable to perform it due to previous injuries, orthopedic limitations, and other diseases in order to reap the benefits of this training. Thus, manipulating training variables such as creating motor challenges using unstable surfaces or combining resistance training with blood flow restriction (BFR) will not only reduce injury in older people, but will have benefits similar to HIRT [1].

Unstable resistance training (URT), as one of the resistance training methods, as compared to stable resistance training, can increase coordination between the agonist and antagonist muscles, increase information of muscle afferents and neuromuscular adaptation by creating more challenges on the nervous and muscular system [16]. In this regard, Vera-Garcia et al. stated that URT is considered as an important part of a good exercise program that is closer to daily activities and leads to more adaptations in response to exercise [17]. Eckardt also referred to the role of URT in improving strength and balance among older adults [18]. The results of previous studies also showed that URT is not only physically challenging, but may also increase cognitive function by affecting cortical plasticity [19]. In this regard,

Eckardt et al. investigated the effect of URT on the memory performance in older adults [20]. The results showed that the use of resistance training in combination with URT improved memory performance in older adults.

Blood flow restricted resistance training (BFRRT) is another new training method that has replaced HIRT. BFRRT increases muscle metabolites and acidity by reducing oxygen supply, thereby leading to changes in fiber recall patterns, neuromuscular adaptation, and improved muscle strength [21]. BFRRT is also thought to increase blood flow and oxygen transport to the brain and improve cognitive function [1]. Törpel et al. also stated that increased brain activation following BFRRT, as compared to traditional resistance training, affects the cognitive function [22]. In this regard, Sardeli et al. investigated the effect of BFRRT on cognitive function in older adults, and the results of the Stroop test showed an improvement in cognitive function among older adults [23].

Considering the positive effects of BFRRT and URT alone on the physical and cognitive functions in older adults, it seems that the combination of BFRRT and URT can have a greater effect on strength, balance and memory performance in older adults, but there has been no relevant study. Therefore, the aim of the present study was to investigate the effect of twelve sessions of BFRRT+ URT on strength, dynamic balance and short-term memory in older adults.

Material and Methods

G-power software ver. 3.1.9.2 was used to determine the sample size. A total of 27 elderly men aged 60 years and older participated in the present study. Inclusion criteria included no acute and advanced cardiovascular diseases, no specific diseases (diabetes, hypertension), psychological, neurological, orthopedic injuries and neuromuscular injury, non-use of walkers and crutches, no participation in regular exercise program during the last six months as well as lack of cognitive problems (using MMSE test). Exclusion criteria also included being absent from one training session, personal unwillingness to continue training, injury and extracurricular activities. After explaining about the training interventions and possible muscle pain, each of the subjects completed a written informed consent form. The demographic characteristics of the subjects in each group are presented in Table 1.

Table 1. Individual characteristics of subjects separated by group

Variable	RT	BFRRT	Control group
Height (cm)	0.78 ± 167.75	2.07 ± 168.78	2.43 ± 168.56
Weight (kg)	3.64 ± 81.4	1.2 ± 74.01	4.32 ± 75.11
BMI (kg/m ²)	1.3 ± 28.26	1.18 ± 25.94	1.36 ± 26.42
Round the hip (cm)	1.15 ± 54.33	0.89 ± 51.78	1.78 ± 50.33

In the present study, 8-cm wide elastic bands were used. To determine the BFR level, the subjects were lying on their backs and the pneumatic cuff was fastened in the upper part of the right thigh. The cuff was inflated until there was no arterial pulse in the inner ankle of the right thigh, which could be detected using a pulse-Doppler instrument (DC8-EXP, China). The cuff pressure was then slowly decreased to detect the first arterial pulse. Therefore, the highest pressure at which the arterial pulse was no longer detectable was considered as the maximum BFR pressure, which was applied during 50% of the maximum

pressure (72 ± 9 mm Hg). In the present study, the pressure of 72 ± 9 mmHg applied by 8-cm wide elastic bands using the Doppler ultrasound device was similar for each subject (63, 64). Also, the pilot results showed that the use of elastic bands creates more satisfaction for the subject.

30-sec chair stand test: 30-sec chair stand test (30CST) was used to measure the strength of lower extremity muscles. Jones et al. referred to the above test as a reliable tool for measuring lower extremity strength among older adults. The maximum number of complete sitting sessions over a period of 30 seconds on a 45-cm high armless chair with the hands resting crosswise on the chest was considered as the final score in this test ($0.84 < R < 0.92$) [24, 25].

Timed up and go Test (TUG): TUG test was used to measure dynamic balance. The reliability of this test is reported to be 99% in older adults [26]. The test consists of six steps that must be performed consecutively. First, the subject stands up from an armless chair without using his/her hands, then walks three meters away and turns around the conical barrier, and finally, goes to the chair and sits on it. Test time is recorded as score ($0.96 < R < 0.99$) [27]. Two tests were performed with three-minute time intervals and the best time was used [28, 29].

Wechsler Memory Scale: The Wechsler Memory Scale is considered as a reliable objective scale for assessing adult memory. This test includes seven sub-tests that assess short-term memory, concentration, attention, orientation and recall of long-term memory ($R = 0.74$) [30]. In the present study, subscales of logical memory, digit repetition, visual memory and associative learning were used to assess short-term memory.

This was an applied study in terms of its purpose with pre-test-post-test research design (two experimental groups and one control group).

Prior to the present four-week training program, participants were randomly divided into two experimental groups (URT with BFR and URT without BFR) and one control group (no resistance training). Afterwards, the participants of the experimental groups got acquainted with research interventions (including URT with BFR and URT without BFR), and then a pre-test was performed. Height and weight were measured and 30CST (30-sec chair stand test), TUG (Timed up and go Test) and WMS (Wechsler Memory Scale) were performed. After the pre-test, the training program, including bodyweight squats on an unstable surface with and without BFR, was started for the two experimental groups (three sessions per week for four weeks). The first two weeks of the training program consisted of three sets, with each set consisting of 15 repetitions with 60-sec time intervals. To observe the overload principle, the second two weeks of the training program consisted of four 60-sec time interval sets, with each set consisting of 15 repetitions and also the use of weight constituting 5% of each person's body weight (Tab. 2). Prior to BFRRT, an elastic band was tied to the proximal part of the thigh, so that participants maintained 72 ± 9 mm Hg

Table 2. Unstable resistance training with and without blood flow restriction

Week	1-2	3-4
Sets	3	4
Number of repetitions	15	15
Rest between the sets (s)	60	60
Number of sessions per week	3	3
Overload	body weight	1.5 kg ± 3.5

pressure during each set. In order to ensure the amount of pressure applied by the elastic band to block blood flow, in addition to using a pneumatic cuff in each session, at the end of the first two weeks of training, an ultrasonography device was also used and the elastic bands were changed if necessary.

A 6-cm diameter foam was used to create an unstable surface. Subjects in both experimental groups performed general body warm-up (stretching and flexion exercises) for 10 minutes before the interventions and then performed cool-down exercises for 10 minutes after the exercises. The subjects in the control group participated only in the pre-test and post-test and received no exercise. After the 12 session-training program, the subjects of all three groups performed 30-SCST (strength) and TUG (balance) and WMS tests again.

Descriptive statistical analysis was carried out using mean, standard deviation and graph. The normal distribution and the equality of variances were also assessed using Shapiro-Wilk and Levene's tests, respectively. Inferential statistical analysis was also performed using ANCOVA (pre-test as a covariate) and Bonferroni post hoc test in SPSS software (version 23.0). P-value < 0.05 was also considered as a significance level.

Results

The results of descriptive statistical data analysis of pre-test and post-test stages for strength, dynamic balance and short-term memory variables in the three control groups, i.e. URT with BFR, URT without BFR, and control, are reported in Table 3.

In the present study, repeated measures ANOVA was used to investigate the intra-group effect of different levels of independent variables on strength, dynamic balance and short-term memory (Tab. 4). It should be noted that statisticians believe that using multivariate analysis instead of univariate analysis, while providing reliable results, does not require the sphericity assumption as one of the main assumptions of univariate analysis.

In the present study, one-way ANCOVA was used to perform inter-group comparisons based on the variables of strength, dynamic balance and short-term memory, considering the pre-test scores as a covariate. Non-violation of covariance analysis test assumptions including normality (Shapiro-Wilk test, $p > 0.05$), linearity (scattering diagram and drawing of the best fitting line), homogeneity of variances (Levin's test, $p > 0.05$) and homogeneity of regression slope ($p > 0.05$) was investigated. After adjusting for strength ($p = 0.0001$), dynamic balance ($p = 0.0001$) and short-term memory scores ($p = 0.0001$) in the pre-test phase, there was a statistically significant difference between research groups in terms of strength $F(2, 23) = 21.75$ ($p = 0.0001$; partial eta squared = 0.65), dynamic balance $F(2, 23) = 60.2$ ($p = 0.0001$; partial eta squared = 0.84) and short-term memory scores in the post-test phase ($F(2, 23) = 22.62$; $p = 0.0001$; partial eta squared = 0.66). Table 5 shows the results of ANCOVA on research variables.

Since group had a significant effect on the variables of strength, dynamic balance and short-term memory (Tab. 5), the groups underwent pairwise comparison using Bonferroni post hoc test. The results showed a statistically significant difference between BFRRT and the control group in terms of strength ($P = 0.0001$), dynamic balance ($P = 0.0001$) and short-term memory ($P = 0.0001$) and BFNRT group in terms of strength ($P = 0.008$), dynamic balance ($P = 0.001$) and short-term memory ($P = 0.04$).

Table 3. Mean and standard deviation of strength, dynamic balance and short-term memory during pre-test and post-test stages in research groups

Variable	Group	Post-test mean $\pm$ SD	Pre-test mean $\pm$ SD
strength (the number of repetitions)	control	12.2 $\pm$ 1.3	12.1 $\pm$ 1.1
	URT with BFR	18.8 $\pm$ 0.8	14.3 $\pm$ 0.6
	URT without BFR	16.2 $\pm$ 1.2	13.8 $\pm$ 1.1
dynamic balance (s)	control	11 $\pm$ 0.8	11.1 $\pm$ 0.8
	URT with BFR	8 $\pm$ 0.3	10.4 $\pm$ 0.5
	URT without BFR	9.9 $\pm$ 0.7	11.4 $\pm$ 0.9
short-term memory	control	26.5 $\pm$ 2.4	22.1 $\pm$ 2.8
	URT with BFR	42.7 $\pm$ 3.5	30.2 $\pm$ 1.9
	URT without BFR	58.33 $\pm$ 2.9	29.1 $\pm$ 3.5

Table 4. Results of multivariate analysis (Wilks' lambda) and repeated measures ANOVA test to evaluate the intra-group effect of independent variables on strength, dynamic balance and short-term memory

Variable	Group	Value	F	Significance	Effect size (partial eta squared)
strength	control	1	0.0001	1	0.0001
	URT with BFR	0.12	59.98	*0.0001	0.88
	URT without BFR	0.16	39.2	*0.0001	0.83
dynamic balance	control	0.94	0.49	0.50	0.06
	URT with BFR	0.67	110.95	*0.0001	0.93
	URT without BFR	0.12	57.85	*0.0001	0.88
short-term memory	control	0.63	4.56	0.06	0.36
	URT with BFR	0.43	177.05	*0.0001	0.96
	URT without BFR	0.14	48.37	*0.0001	0.86

*- $p \geq 0.05$.

Discussion

The aim of the present study was to investigate the effect of URT with BFR and URT without BFR on short-term memory, strength and dynamic balance in older adults.

Results showed that URT with BFR (partial eta squared = 0.96) was more effective than URT without BFR (partial eta squared = 0.86) in improving short-term memory. In general, the results of the present study are consistent with studies by Coelho-Junior et al. [13] and Wu et al. [14] that showed resistance training improved short-term memory in older adults. Resistance training seems to lead to functional and structural changes in the brain by activating the nervous system and releasing neurochemicals such as BDNF, IGF-1. Resistance training also increases IGF-1 levels, decreases homocysteine, and increases hippocampal neurogenesis, thus improving the memory performance in older adults [31]. However, a review of previous studies shows that unstable surface resistance training provides a greater control challenge for the nervous system and has a greater impact on cognitive functions than stable surface resistance training [32]. In this regard, Eckardt et al. investigated the effect of unstable surface resistance training on the memory performance in older adults [20]. The results showed that un-

Table 5. Results of analysis of covariance of intergroup effects on variables of strength, dynamic balance and short-term memory in older adults

Variable		Sum square	df	Mean squares	F	Significance	Effect size (partial eta squared)
strength	pre-test (strength)	219.14	1	219.14	114.06	*0.0001	0.83
	group	83.60	2	41.80	21.75	*0.0001	0.65
	error	44.18	23	1.92			
dynamic balance	pre-test (dynamic balance)	94.67	1	94.67	428.72	*0.0001	0.94
	group	26.59	2	13.29	60.20	*0.0001	0.84
	error	5.07	23	0.22			
short-term memory	pre-test (short-term memory)	1343.5	1	1343.5	61.74	*0.0001	0.72
	group	984.7	2	492.35	22.6	*0.0001	0.66
	error	500.4	23	21.76			

*– $p \geq 0.05$.

stable surface improved memory performance in older adults by increasing neural plasticity.

BFR-induced localized hypoxia is also a relatively new strategy to increase the effectiveness of resistance training, especially among disabled people. In this regard, BFRRT plays an important role in improving cognitive functions by increasing blood IGF-I, BDNF and lactate levels compared to URT without BFR [22]. In this regard, Sardeli et al. in their pilot studies investigated the effect of BFRRT (stable surface) on the cognitive function in older adults [23]. The results showed that BFRRT increased oxygenated hemoglobin in the prefrontal cortex by increasing cardiac output and cerebral blood flow, thereby improving cognitive function in older adults. In this regard, the results of research by Cassilhas et al. showed that elevated IGF-I and BDNF may lead to improved short-term memory performance in older adults [33]. Similarly, Törpel et al. also considered the elevated IGF-I as one of the mechanisms of BFRRT on improving cognitive function compared to URT without BFR [22]. On the other hand, the results of previous research show that elevated blood lactate concentration after BFRRT would improve short-term memory [34].

Therefore, it seems that URT with BFR not only yields the benefits of unstable surface training (increased cortical plasticity and neurogenesis) but also BFR-related benefits (further increase in blood IGF-I, BDNF, and lactate levels), thus leading to greater effectiveness on short-term memory as compared to URT without BFR in older adults.

The results of the present study also showed that URT with BFR (partial eta squared = 0.93) also had a greater effect on improving dynamic balance in older adults compared to URT without BFR (partial eta squared = 0.88). Overall, these results are consistent with the results of research by Lopez et al. [36] and Blocquiaux et al. [11] who showed that resistance training leads to improved dynamic balance in older adults. In general, it seems that URT as one of the training methods is closer to daily activities and can cause more adaptations in response to training by stimulating the proprioceptive systems of the muscles and increasing the information of the muscle afferents. In this regard, the results of studies by Eckardt showed that URT improves balance status in older adults by increasing the intensity of muscle activity, muscle strengthening and increasing joint flexibility, which is somehow consistent with the results of the present study [18]. Studies have also shown that atrophy of fast-twitch type II fibers and decreased muscle strength are two important factors affecting balance distribution in older adults.

In addition to increasing strength, BFRRT leads to a further involvement of motor units, a change in the use pattern of motor units and the recall of motor units with a higher threshold (further recall of atrophy of fast-twitch fibers) [37]. Therefore, it seems that URT with BFR can be more effective on dynamic balance in older adults than URT without BFR by increasing lower extremity strength and preventing atrophy of fast-twitch muscle fibers.

Conclusion

In general, the present study showed that URT with BFR can be effective on short-term memory, strength and dynamic balance in older adults. Therefore, it is recommended for the elderly to use BFR in combination with URT to improve cognitive performance and physical fitness.

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