Research Paper:



The Effect of Muscle Endurance Training on Blood Pressure, Resting Heart Rate and Endothelin-1 Levels in Inactive Men

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ABSTRACT

Background and Aim: Sports activities play a protective and preventive role against heart diseases by reducing their risk factors. This study aimed to evaluate the effect of resistance training by muscle endurance method on blood pressure, heart rate, and plasma endothelin-1 levels of inactive healthy men.

Materials and Methods: In this quasi-experimental study, 30 middle-aged men (Mean±SD age: 47.03±2.12 years, Mean±SD height: 172.90±3 cm, Mean±SD weight: 80.70±3.1 kg, Mean±SD Body Mass Index: 27.47±3.66 kg/m², and Mean±SD waist to hip ratio: 0.98 0±1.27) were purposefully selected and then randomly divided into the control and experimental groups (each 15 members). The experimental group performed 8 weeks of resistance training, three sessions per week with an intensity of 40% to 70% of 1 repetition maximum. Plasma endothelin-1, systolic and diastolic blood pressure, and resting heart rate were measured before and after 8 weeks of exercise. The dependent t-test was used to examine intra-group changes, and the independent t-test was used for inter-group differences. The significance level was considered less than 0.05.

Results: Eight weeks of muscular endurance resistance training significantly reduced endothelin-1 plasma levels of inactive middle-aged men (P=0.002). Also, 8 weeks of resistance training significantly reduced their systolic blood pressure (P=0.001) and resting heart rate (P=0.01), but the decrease in diastolic blood pressure was not significant (P=0.0411).

Conclusion: Based on the present study results, muscular endurance resistance training as a preventive factor can decrease the risk of hypertension and heart disease in healthy middle-aged men by reducing plasma endothelin-1 levels, systolic blood pressure, and resting heart rate.

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1. Introduction

igh blood pressure is one of the most critical risk factors for cardiovascular diseases such as coronary artery disease, stroke, and heart failure [1]. It usually refers to a state of systolic and diastolic blood pressure in the resting conditions above 140 and 90 mm Hg, respectively [1]. Accord-

ing to studies, approximately 25%-35% of the population over 18 is affected by hypertension. With increasing the number of older people, the incidence of this complication will increase [2]. The prevalence of this disease in Iran was 17.37% [3]. The cause of increased blood pressure in most cases is not clear, but it can be controlled effectively by modifying weight, observing a healthy diet, and doing regular physical activity [2].

Researchers have examined different mechanisms involved in hypertension, including an imbalance in peptide protection devices (endogenous), a ligand for type 1 angiotensin-like receptor [4]. Vascular endothelial cells play an essential role in regulating vascular activity by producing vessel activating compounds, such as endothelin 1 [5]. Endothelin is one of the main factors of vascular contraction and has three different types of 1, 2, and 3, among whom endothelin 1 is higher than the rest of the concentration. Endothelin 1 is the strongest known vascular constrictor, and its contractile effect is ten times higher than angiotensin 2, vasopressin, and neuropeptide Y [6]. This substance reacts with two types of receptors in the cell membrane, including type A (ETA) receptors and type B (ETB) receptors [7]. Also, endothelin 1 is involved in the development and progression of atherosclerosis [8]. In addition to plasma, endothelin-1 is present in the lungs and is mainly secreted in the endothelium of the pulmonary arteries and vascular smooth muscle cells, and the epithelium of the airways [9].

In many studies, the effect of exercise on changes in heart hormones and blood pressure following various aerobic and anaerobic exercises has been studied. However, different cardiovascular responses due to various resistance training are among the most controversial challenges among researchers and sports medicine professionals [10]. Besides, cardiovascular responses after common resistance exercises may be essentially different according to age, sex, and individual health status [11]. In other words, these exercises have different effects on functional indicators such as systolic blood pressure and heart rate, and endothelin-1 concentration [12]. In this regard, Meada et al. studied 6 healthy young men of 26 years of age. They reported that 8 weeks of resistance training, three days a week, reduced endothelin-1 concentration [13]. Ramezani et al. concluded that 8 weeks of circular resistance training, three days a week, reduces systolic blood pressure and endothelin-1 in older adults [4]. In another study, Hedayati et al. concluded that lower extremity exercise improves systolic, diastolic blood pressure, and heart rate in people with hypertension [1]. However, some studies have shown that plasma endothelin-1 concentration increases with age [7].

On the other hand, the results of some studies are different. For example, Maeda et al. examined the effects of short-term lower extremity muscle resistance training on arterial function in older adults. They found that vascular stiffness and plasma endothelin-1 concentration do not change significantly after resistance training [14]. However, one of the possible reactions to any kind of regular physical activity is to reduce the risk of cardiovascular disease, as well as positive and beneficial effects on vasomotor function [15]. Studies show that improving vascular vasomotor function following exercise reduces cardiovascular disorders, especially in healthy elderly and patients with hypertension, and increases endothelial-dependent vasodilation [16]. Although no clear consensus still exists on the effect of different types of exercise, especially resistance training on changes in endothelium-1 levels and blood pressure, resistance training is recommended due to the variety of movements performed and the reduction of mental fatigue caused by aerobic exercise on the one hand, as well as more emphasis of health-related organizations such as American Heart Association and American College of Sports Medicine on the other hand [7]. Because of the increasing prevalence of blood pressure in Iran, its consequences, and the effect of resistance training on reducing its risk factors, we decided to investigate the impact of 8 weeks of muscular endurance resistance training on blood pressure, resting heart rate, and plasma endothelin-1 levels in inactive middle-aged men.

2. Materials and Methods

This research is a quasi-experimental study and has a pre-test, post-test with a control group design. Thirty healthy middle-aged men were purposefully selected to take part in this study. Before the study, the volunteers were introduced to the objectives, conditions, and research stages. They were asked to sign a form containing information about the study and the conditions for voluntary participation. The sample size (30 people) was based on previous studies in this field and the estimation of G Power software, with an effect size of 0.5, the error type 1 of 0.5, and error type 2 of 0.1. Then, according to

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the experimental protocol, the subjects were randomly divided into resistance training groups (15 people) and the control (15 people). The inclusion criteria included being 45-50 years old, not smoking, lacking cardiovascular or specific diseases, not participating in regular physical activity in the last six months, and not having blood pressure above 130/90 mm Hg. The exclusion criteria included the occurrence of any disease that prevents them from participating in more than 30% of training sessions, leaving the study, having any chronic diseases such as cardiovascular disease, diabetes, thyroid, and respiratory diseases based on the doctor's diagnosis and examination. After collecting demographic information and examination by a physician, the participants were permitted to exercise. Then the participants' height, weight, Body Mass Index (BMI), and daily average systolic and diastolic blood pressure (with a sphygmomanometer, Omron M6 AC, made in Japan with an accuracy of 0.1 mm Hg) were measured. Also, a physician measured their resting heart rates at 8 to 9 AM at the training site. The subjects' subcutaneous fat was measured at three points (thigh, triceps and upper hip) with a metal caliper (model SH5020, made in South Korea). Measurements were repeated three times for each individual, and the average result was recorded. Then, using Jackson and Pollack Equation, the fat percentage of the subjects was calculated [5].

Measurement of endothelin-1

Forty-eight hours before and after 8 weeks of resistance training, 5 mL of blood was taken from each volunteer from the anterior vein of the right arm by a physician. Blood sampling was performed at 8 AM and after 12 hours of fasting. The collected blood samples were sent to the laboratory immediately before the resistance training program and once again after 8 weeks of resistance training. According to the instructions of the specialized kit used, the plasma was separated by centrifugation and kept at -70 °C. In the end, the samples were sent to the medical diagnostic laboratory for one-time analysis, and the concentration of plasma endothelin-1 was measured using human ELISA kits (Cayman Company, made in the USA), with an accuracy of 1.5 pg/mL, which had a coefficient of variation within the test of less than 5%.

Resistance training program

After getting acquainted with resistance training and assessing the level of physical fitness of the subjects, the experimental group participated in resistance training for 8 weeks, three 65-min sessions per week. The exercise program included 15 minutes of warm-up with various stretching and flexing movements, and then 6 movements of the machine head, chest press machine, armpit from the front with a wire machine, foot press machine, front foot machine, and standing back leg machine. The participants first did upper body movements and then lower body movements. At the end of the exercise, the participants performed the cooling down by doing light stretching movements. To observe the principle of overload training, the intensity of training started from the first to the fourth week with 40%-45% of 1 repetition maximum, three sets with 20-30 repetitions, and continued from the sixth to the eighth week with 55%-70% of 1 repetition maximum, three sets with 15-20 repetitions. The following formula was also used to determine 1 repetition maximum [17].

[number of repetitions until fatigue \times 0.0278) - 1.0278] \div weight shifted = (kg) one Repetition Maximum (1-RM)

It should be noted that the training protocol of this study was performed according to the current protocols and instructions of the American College of Sports Medicine (2014) to improve the function of the cardiovascular and neuromuscular systems of individuals [5]. During the training, all stages of training were performed by a special trainer of physical fitness and bodybuilding and under direct supervision.

Statistical analysis

The results were expressed as the mean and standard deviation for each group. For statistical analysis, after confirming the normality of the data, the Shapiro-Wilk normality test was used. A dependent t-test was used to examine intra-group changes, and the Independent t-test was used to determine the inter-groups changes to measure the difference between pre-test and post-test. Data analysis was performed using SPSS version 22. The results were evaluated at a significance level of less than 0.05.

3. Results

According to Table 1, the variables of age, height, weight, BMI, and Waist to Hip Ratio (WHR) of the subjects in this study in the experimental and control groups were not significantly different (P \ge 0.05), indicating that the randomization of the two groups is well done.

According to Table 2, the results of the dependent ttest showed significant differences between pre-test and post-test variables of plasma endothelin-1 concentration (P=0.002), systolic blood pressure (P=0.002), resting heart rate (P=0.02), and mean arterial blood pressure

Madakia	Mean±SD			
variable –	Control Group (n=15)	Experimental Group (n=15)		
Age (y)	47.40±2.05	48.67±1.19		
Height (cm)	137.51±2.48	172.30±3.52		
Weight (kg)	80.37±53.08	81.04±3.13		
BMI (kg/m ²⁾	27.85±3.21	27.09±4.12		
Waist to hip ratio	0.98+0.14	0.99±0.4		
		Complexity of Medical Sciences		

Table 1. Descriptive characteristics of the subjects in the experimental and control groups

(P=0.01), in the experimental group, but this difference in systolic blood pressure (P=0.056) was not significant. Also, the results of the Independent t-test showed significant differences between the experimental and control groups in the post-test variables of plasma concentration of endothelin 1 (P=0.002), systolic blood pressure (P=0.001), resting heart rate (P=0.01), and mean arterial blood pressure (P=0.02), but this difference was not significant regarding diastolic blood pressure (P=0.411).

4. Discussion

This study aimed to evaluate the effect of 8 weeks of muscular endurance resistance training on blood pressure, resting heart rate, and plasma endothelin-1 concentration in inactive middle-aged men. The present study results showed that the plasma endothelin-1 concentration level significantly decreased after 8 weeks of training protocol in the experimental group. The results of the present study are consistent with the findings of some studies [4, 7, 13, 18-21]. Ramezani et al. showed that a circular resistance training period significantly reduces endothelin-1 concentration in older men [4]. In a study of healthy middle-aged men, Ballard et al. found that a period of intermittent exercise at different times of the day had a significant effect on lowering plasma endothelin-1 levels [19]. However, the results of some studies are not consistent with the present findings. Tagawa et al. reported that plasma endothelin-1 concentration did not change significantly after resistance training [22]. In another study on the effects of aging and acute exercise on vascular diameter reduction of endothelin-1 in rat skeletal muscle vessels, an association was found between aging and gastrocnemius muscle vascular diameter reduction response and endothelin-1 sensitivity in healthy endothelial capillaries. Besides, exercise had no significant effect on reducing endothelin-1 in the vessels of the soleus or capillaries of the gastrocnemius muscle [14]. Regarding the role of exercise on endothelin-1 sensitivity in coronary arteries, it was found that the contractile sensitivity of coronary arteries to endothelin-1 is affected by sex-dependent physical activity, and the concentration of endothelin-1 is likely to increase with exercise [23]. This difference in the results can be due to the differences between the study groups in terms of physical conditions and level of physical fitness, the health or lack of health of the subjects, and finally, the type of training protocol. Thus most studies that have examined the longterm effects of exercise, such as this study, have reported a decrease in plasma endothelin-1 levels in their results. However, the acute effect of exercise on endothelin-1 appears to increase or not alter its concentration. The exact mechanism for reducing plasma endothelin-1 after resistance training is unclear. It seems that the regulation of tropical hormones in the body due to physical activity or changes in body weight and total fat mass, as well as increasing the strength and power of skeletal muscles around blood vessels, all reduce the body's need for vascular endothelial cell function. As a result, the material secreted by these cells in the plasma is also reduced [7, 24].

This study also showed that 8 weeks of muscular endurance resistance training significantly reduced systolic blood pressure in inactive middle-aged men. However, their diastolic blood pressure decreased slightly (not statistically significant). This finding is consistent with the results of some researchers. Meada et al. studied 6 healthy 26-year-old people who were doing resistance training three days a week for 8 weeks. This training significantly reduced their systolic blood pressure, but no changes were observed in their diastolic blood pressure [13]. Also, Heidari et al. studied the effect of aerobic exercise on hypertension in the elderly [25], and Hakimi et al. studied the impact of resistance and endurance training on endothelin-1, apelin, and hypertension in middle-aged men. They concluded that exercise

Variable	Group	Levels	Mean±SD	t	P Intergroup	P Intergroup
Resting heart rate (Beats per minute)	Experimental	Pre-test	74±3.12	2.20	0.02*	0.0*
		Post-test	70±15.21			
	Control	Pre-test	75±10.22	-0.14	0.264	
		Post-test	77±09.35		0.204	
Plasma endothe- lin-1 (pg/mL)	Experimental	Pre-test	2.3±0.38	3.23	0.002*	0.002 ⁺
		Post-test	1.5±0.10			
	Control	Pre-test	2.5±14.20	-0.58	0.495	
		Post-test	2.5±18.48			
Mean arterial pressure (mm Hg)	Experimental	Pre-test	108.20±0.4	3.87	0.01*	0.02*
		Post-test	106.10±0.22			
	Control	Pre-test	108.01±0.15	0.27	0.154	
		Post-test	108.50±0.35			
Systolic blood pressure (mm Hg)	Experimental	Pre-test	128.020±0.12	-2.34	0.002*	0.001 ⁺
		Post-test	111.635±0.50			
	Control	Pre-test	127.532±19.32	0.31	0.173	
		Post-test	129.298±20.55			
Diastolic blood pressure (mm Hg)	Experimental	Pre-test	87.201±0.15	2.08	0.056	0.411†
		Post-test	86.384±0.68			
	Control	Pre-test	88.110±05.45	1.87	0.082	
		Post-test	87.483±42.12		0.002	

Table 2. Investigation of intra-group and inter-group changes of variables in the studied groups

*P≤0.05; †P≤0.05

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on systolic blood pressure had a significant effect, while they acknowledged the ineffectiveness of exercise on diastolic blood pressure [2]. However, the present study results are inconsistent with the results of some previous research [7, 12, 26, 27]. Arazi et al. studied acute resistance training on blood pressure in type 2 diabetic patients. They concluded that this type of training increases systolic and diastolic blood pressure after resistance training [28]. One of the reasons for the inconsistency of the recent study with the present findings is its training protocol. All studies that examined the long-term effects of exercise, such as this study, concluded that prolonged aerobic or moderate-intensity resistance exercise could have beneficial effects on lowering systolic blood pressure. But studies that have examined the acute effects of exercise all concluded that acute exercise and physical activity, with moderate to high intensity, increase blood pressure or do not affect lowering blood pressure. In this study, it can be seen that the highest increase in blood pressure is in acute resistance exercises with moderate to high intensity, which is confirmed in other studies that compared the effects of different exercises and shortterm and long-term exercises on hypertension [29]. Similar to the above studies, it appears that long-term moderate-intensity exercise, especially resistance training, can reduce systolic and diastolic blood pressure due to increased capillary network and vascular flexibility in active muscles, as well as by lowering vasoconstrictor hormones, including endothelin-1. This exercise is a good solution, along with taking blood pressure medi-

cations to reduce the use of these medications and their side effects. The exact mechanism by which exercise lowers blood pressure is not fully understood yet. One of the reasons for the decrease in systolic blood pressure in this study could be the decrease in endothelin-1. As shown, endothelin-1 receptors are both types A and B, which exercise increases the type B receptors, which in contrast to type A receptors, play a role in vasodilation and produce Nitric Oxide (NO). Therefore, it seems that one of the reasons for the decrease in systolic blood pressure after resistance training is the increase in endothelin-1 type B receptors and the increase in NO [2]. Also, some studies have reported a significant correlation between changes in endothelin-1 concentration and changes in systolic blood pressure. In other words, there is a direct relationship between endothelin-1 concentration and systolic blood pressure, but this correlation has not been seen in diastolic blood pressure [7].

Other results of the present study showed that 8 weeks of muscular endurance resistance training significantly reduced resting heart rate in inactive middle-aged men. In line with the present study, Mokhtari et al. examined the effect of 12 weeks of resistance training on plasma levels of apelin-12, nesfatin-1, and resting heart rate in older women and concluded that resistance training significantly reduces resting heart rate in older women [30]. Eghbali et al. studied older adults with hypertension. They concluded that Pilates exercises have a significant effect on reducing resting heart rate [31]. Regarding the reduction of resting heart rate, studies show that exercise may increase stroke volume. As a result, in the same resting cardiac output, a lower resting heart rate is required because increasing the stroke volume compensates for the decrease in heart rate [30]. Exercise has also been reported to improve left ventricular systolic function by improving the balance between the sympathetic and parasympathetic nervous systems. This condition increases the stroke volume and cardiac output during exercise and delays fatigue, and decreases resting heart rate [32]. They observed that regular exercise reduces vascular resistance by increasing vasodilatory capacity. Decreased arterial dilatation leads to the development of arterial hypertension, a process that can lead to left ventricular hypertrophy and decreased coronary blood flow [32]. All of these changes can increase heart function and left ventricular volume and decrease in resting heart rate.

5. Conclusion

A review of the overall results of this study shows that 8 weeks of muscular endurance resistance training could improve the endothelial function factors of middle-aged men. Thus, if regular and long-term physical exercise is performed, it can be a preventive factor in the occurrence of cardiovascular diseases in middle-aged men. However, more research is needed on other cardiovascular indicators in inactive middle-aged men to reach more definitive conclusions.

In the present study, the researchers always faced limitations and problems, such as not controlling the subjects' diet, excitement, and anxiety, and their differences in terms of genetic and hereditary characteristics and or mental and psychological states in the training sessions.

Ethical Considerations

Compliance with ethical guidelines

This research project was approved by the Ethics Committee in Biomedical Research of Qom University with (Code: IR.QOM.REC.1400.003).

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Authors' contributions

Conceptualization, research: Sajjad Ramezani, Seyed Abbas Biniaz; Methodology: Sajjad Ramezani, Seyed Abbas Biniaz, Mohsen Yaghoubi; Drafting: Sajjad Ramezani, Mohsen Yaghoubi, Mohsen Akbarpourbani; Data colle tion and analysis: Sajjad Ramezani, Mohsen Yaghoubi; Editing and finalization: All authors.

Conflict of interest

The authors declared no conflict of interest.

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