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Effect of four types of sub-maximal aerobic exercises on variations of systolic and diastolic blood pressure among the patients with hypertension

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ABSTRACT

The aim of this study was to investigate and compare the effect of four types of sub-maximal aerobic exercises (front crawl swimming, running, bicycle riding and rhythmic movements) on the variations of systolic and diastolic blood pressure during and after the exercise in middle-aged males with hypertension. The present article was a semi-experimental study. The statistical population used in this study included 1500 middle-aged male patients (40 to 55 years old) with drug-dependent mild hypertension, from among whom 16 patients were randomly selected as the participants of the study. The participants used medications under the supervision of a physician and they did not have any cardiac or diabetic diseases. All four types of single-session sub-maximal aerobic exercises were carried out with 60-70% of their maximal heart rate for about 20 min. The time interval between each exercise was 2 days.
Investigation of the obtained results demonstrated that all the four types of selected exercises caused considerable variations in systolic and diastolic blood pressure during and after exercises. Systolic blood pressure during and after bicycle riding had the least variation relative to other exercises while systolic blood pressure during and after the rhythmic movements had the largest variation relative to other exercises. Variations of systolic blood pressure during and after running and front crawl were in an average range compared with other exercises. In all four types of exercises conducted in the present study, there was a significant decrease in the diastolic blood pressure during the exercise and this pressure drop was almost the same among all the exercises. Diastolic pressure drop after stopping exercises in the running exercise and rhythmic movements was lower and higher than other exercises, respectively.

Keywords: Blood hypertension, Sub-maximal aerobic exercise, Systole, Diastole

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INTRODUCTION

Sedentary lifestyle is the origin of many dangerous factors such as premature aging, high blood pressure and diabetes, which significantly increase the risk of cardiovascular diseases[1, 2].The results of studies have underlined that patients with hypertension have more rigid arteries than that those of normal people[3]. Also, people with lower level of activities have more rigid arteries than those with a higher level of activities[4]. More than 30 long term studies on humans and 20 studies on animals have investigated the effect of long term exercising on blood pressure. Most of them have demonstrated that long term exercises not only improve physical fitness but also decrease resting blood pressure. The results have also shown that dynamic and regular exercises decrease blood pressure by about 5 to 10 mmHg. However, static exercises are harmful for the patients with hypertension since blood pressure reflexively increases to higher degrees at the time of isometric contraction [5-7].

Since long ago, medical and sports circles have been encouraging the patients with hypertension or cardiovascular diseases to do sports activities. However, it should be noted that different exercises have different effects on the patients’ blood pressure. Some exercises such as soft running and swimming are mainly isotonic while others such as lift weighting are mainly isometric; but, many sports have different proportions of these two types. Therefore, there are different cardiovascular responses to these activities. Isotonic exercises cause a high increase in cardiac output and oxygen consumption and decrease in the resistance of systemic vessels. In contrast, isometric exercises severely increase systemic pressure and have a negligible effect on cardiac output and oxygen consumption[8, 9]. Therefore, isometric exercises create more increase in blood pressure than isotonic exercises, which can be attributed to the pressure increase at the time of exercising due to neural reflex and pressure increase inside the rib cage which reduces blood return to heart[4].

Since about 5% of heart attacks happen right after heavy exercises and 30% of them lead to death, the patients with hypertension should do exercises that cause the least increase in their blood pressure. Thus, the necessity finding the optimum exercise intensity and its type and characteristics are vital for the patients with hypertension.

Therefore, the aim of this study was to identify whether different types of sub-maximal exercises (front crawl, aerobic running, bicycle riding and rhythmic movements) with 60 to 70% intensity of maximum heart rate can cause a different effect on systolic and diastolic blood pressure of middle-aged males with hypertension.

MATERIALS AND METHODS

This study was a practical, semi-experimental research with pre-test, mid-test and post-test.

Subjects

After the public call for research and coordination with cardiologists and hypertension specialists in city of Kashan, 1500 middle-aged males with the age range of 40 to 55 years old who were living in Kashan and were suffering from drug-dependent mild hypertension were identified. From among them, 16 patients voluntarily participated in the research after approving the consent form for research participation. According to their related medical files and physician advice, none of the participants had any acute cardiovascular diseases and diabetes (Table 1).

Table 1: General characteristics of the participants

Statistical Index / Variable	Mean	Mode	Variance	Minimum	Maximum
Age	42.95	40	18.85	41	56
Weight	84.46	82	71.54	70	101

Physiologic Measurement

Before, during and after exercises, the participants' systolic and diastolic blood pressures were measured using a pressure gauge made in Japan which was done by a measurement technician.

Schedule of the Physical Exercise

First, the participants' maximum heart rate was calculated using the equation (220-age); then, between 60 and 70% of their maximum heart rate was considered according to each person’s exercise intensity and heart rate.

The participants performed the physical activities in the following order: front crawl, aerobic running, bicycle riding and rhythmic movements, with the interval of 2 days between each. During the exercises and under the supervision of the physician, the participants used amlodipine, which decreases resting blood pressure and does not prevent from blood pressure increase while exercising.

Test Stages

The participants arrived at the laboratory 10 min prior to the test start-off. In pre-test stage, their resting blood pressure was measured and recorded in two stages of 15 and 5 min before starting the exercises by the laboratory technician. Then, the participants performed the desired exercise, during which their blood pressure was measured in two stages of 10 and 20 min after starting the exercises; the blood pressure for the mid-test stage was calculated as the average of these two numbers. Finally, their blood pressure was measured and recorded 5 min after the end of the exercise for the post-test stage.

Sub-maximal Front Crawl Exercise

The sub-maximal front crawl exercise was performed in a swimming pool with the ambient temperature of 29 degrees Centigrade and water temperature of 28 degrees Centigrade, which included a warm-up program by performing stretching movements outside the water and 10 min of walking inside the water. Then, the participants performed front crawl swimming with the intensity of 60 to 70% of their maximum heart rate for about 20 min. Those participants who could not do front crawl swimming walked in the shallow part of the pool while doing the hand movement of front crawl and moving their feet like front crawl by holding the pool bar.

Sub-maximal Running Exercise

The running exercise was performed on a TechnoGym treadmill made in Italy and included a warm-up exercise of doing stretching movements and 10 min of walking. Then, they performed the running exercise for about 20 min at 60 to 70% of their maximum heart rate. Intensity of this exercise was monitored by a Polar pulsometer which was attached to the participants during the exercise.

Sub-maximal Bicycle Riding Exercise

This exercise was performed on a MATRIX ergometer bicycle made in the USA and included a warm-up program of stretching movements and 10 min of walking. Then, the participants performed cycling for about 20 min at 60 to 70% of their maximum heart rate. Intensity of this exercise was monitored by a Polar pulsometer attached to the participants during the exercise.

Sub-maximal Rhythmic Movements

This exercise started by a few minutes of stretching warm-up exercise and 10 min of walking. Then, the participants performed rhythmic movements for about 20 min at 60 to 70% of their maximum heart rate. Rhythmic movements more included the ones which required less coordination of nerve and muscle.

Statistical Methods

To ensure normal distribution of the data, Kolmogorov-Smirnov test was used; to investigate within-group differences, Analysis of Variance (ANOVA) with repeated measures was used in accordance with Greenhouse-Geisser (GG) correction. In the case significance, the dependent t-test considering Bonferroni correction was used to determine the within differences. Moreover, one-way Analysis of Variance (ANOVA) was applied for investigating between-group differences and, in the case of any significant differences, post-hoc Scheffe test was used for determining the location of the between-group difference. The statistical operations of this research was done by $SPSS_{15}$ software and the significance level of α <0/05 was considered.

RESULTS

The obtained results in this study demonstrated a significant difference between systolic blood pressure during and after front crawl swimming, running, bicycle riding and rhythmic movements and diastolic blood pressure before exercises. Thus, swimming, running, bicycle riding and rhythmic exercises cause variation in systolic blood pressure during and after exercises. Also, there was a significant difference between their diastolic pressure during and after swimming, running, bicycle riding and rhythmic exercises; therefore, swimming, running, bicycle riding and rhythmic exercises affect diastolic pressure during the exercise. But, no significant difference existed between their diastolic blood pressure before and after swimming and running exercises while a significant difference existed between their diastolic pressure before and after bicycle riding and rhythmic movements.

Also, one-way Analysis of Variance (ANOVA) along with post-hoc Scheffe test showed that, in the resting period, no significant difference existed between diastolic (p= 0.665) and systolic (p=0.694) blood pressure of different exercises. Furthermore, during the exercises, significant difference was observed between the participants' systolic blood pressure (p=0.0001) of different exercises in a way that systolic blood pressure of swimming and running exercises was significantly different from that of bicycle riding (p=0.000) and rhythmic movements while no significant difference existed between swimming and running exercises in this stage (p=0.982). Also, significant difference existed between systolic blood pressure in bicycle riding and rhythmic exercises and other exercises during the activities (Table 2).

Significant difference existed between systolic pressure in rhythmic movements and other exercises at the significance level of 0.05.

No difference was seen in the participants' diastolic pressure (p= 0.993) in different exercises. According to the obtained results after the exercises, no significant difference existed with regard to the systolic (p= 0.337) and diastolic (p=0.645) pressures (Table 2).

Table 2

Variable	Groups	Pre-test (before exercises)	Mid-test (during exercises)	Post-test (after exercises)
Systolic blood pressure	**Front crawl swimming**	**128.5 ±4.91**	**155.8±9.28 ‡†§**	**117.6±5.93§**
	Aerobic running	**128.9 ±5.08**	**155.7±11.24 ‡†§**	**120.6±8.13 §**
	Bicycle riding	**128.7 ±5.47**	**139.7±9.08 ‡*+§**	**120±7.07 §**
	Rhythmic movements	**130.3±3.84**	**164±10.98 †*+§**	**116.7±6.23 §**
Diastolic blood pressure	**Front crawl swimming**	**85.7±4.11**	**87.8±5.11 §**	**83.5±5.15**
	Aerobic running	**85.9±5.15**	**79.3±3.81 §**	**84±4.12**
	Bicycle riding	**86±4.37**	**79±6.57 §**	**82.9±6.27 §**
	Rhythmic movements	**87.5±4.62**	**79.1±3.29 §**	**80.9±9.16 §**

† *Significantly different from bicycle riding* ‡ *Significantly different from rhythmic movements*

* *Significantly different from swimming* **+** *Significantly different from running*

§ *Significantly different from pre-test stage*

DISCUSSION

According to the obtained results of this study, mean systolic pressure considerably increased during exercising in the four types of considered isotonic activities increased, which had significant difference in each of the exercises compared with other exercises.

Previous results of the studies inside or outside the country with regard to the mean increase of systolic pressure during exercising showed almost similar results, which were in good agreement with the results of this study[10-12]. The results of the study done by Frredson indicated that any kind of exercises can considerably increase blood pressure; this finding confirms the results of this study. Even relatively mild isometric exercises which use only 25% of maximum effort significantly increase this pressure. Furthermore, exercises that require more muscular mass and relatively high energy give a bigger response[12]. Thus, selecting the type of exercises for patients and those who are not ready for these types of exercises is very important. Probably, more harmonic exercises with moderate intensity are better and more effective for these people. It seems that blood pressure increase during exercises depends on various factors. In harmonic muscular exercises such as soft running, swimming, bicycle riding and rhythmic exercises, vasodilatation in active muscles depends on various parameters including local regulators, direct nerving and peripheral regulators, which reduces peripheral resistance and increases blood flow in many parts of the peripheral vascular system[11, 13]. So, blood pressure is affected by the above-mentioned parameters during exercising. During sports activities, cardiac output is influenced by variables such as heart rate and pulsatile volume. On the other hand, one of the most considerable cardiovascular variations is heart rate increase which happens to increase cardiac output. The main reason for heart rate increase during physical activities is for the stimulation of sympathetic nervous system. During any sports exercise, sympathetic nervous system is more stimulated, which not only dilates blood vessels in active muscles and increases systolic power but also leads to increased cardiac contractility (post-load) and, as a result, blood pressure. Of course, decrease in the parasympathetic effect also contributes to the increase of exercising heart rate increase to some degree. On the other hand, during exercising, heart rate alone cannot provide the desired cardiac output. Moreover, due to the need of active muscle for more oxygen, regulation of internal body temperature, especially in long-term exercises, and returning carbon dioxide from active muscles to lungs in order to be discharged by urine have been shown to increase the end-diastolic volume and pulsatile volume, in which variable parameters such as heart pumping activity are involved. However, the most influential parameter in cardiac output increase is induced by Frank-Starling effect[14, 15]. Therefore, blood pressure is influenced by some factors during exercising. Since systolic pressure rapidly increases during rhythmic exercises with moderate intensity at the beginning minutes of exercises and then becomes flat, as a result of continuing exercises at uniform speed, systolic blood pressure may not increase and even decrease due to the dilation of muscle arterioles and decrease of vascular resistance to blood flow. During these types of exercises, the diastolic pressure is approximately constant or decreases [14, 16]. So, based on the above-mentioned discussion, the result of this study which stated equal increase of blood pressure during exercise periods was confirmed.

In this study, mean systolic pressure showed the most and least increase during bicycle riding and rhythmic movements, respectively. Also, no significant increase was observed in mean systolic pressure during running and swimming while systolic pressure increase during running and swimming was more than systolic pressure increase during bicycle riding and less than that during rhythmic movements.

Based on the obtained results in this study, increase in mean systolic pressure during cycling demonstrated less increase than other three exercises, which was in good agreement with the results of Brown, Conocie, dengel and Duncen[1, 9, 11, 17]. Most probably, this important result was due to the more application of lower limbs in this type of exercising. So during this exercise, increase in systolic pressure in lower limbs showed less increase compared with upper limbs due to more muscular mass and less vessels in this area.

Since, at a specific percentage of maximum oxygen consumption, systolic and diastolic pressures are considerably high so that activities are done by hands rather than feet, it may be possible that bigger muscular mass and vasculature of feet generate less resistance to blood flow compared with more delicate muscular mass and vasculature in hands. Hence, during exercising, blood flow toward the feet requires less systolic pressure peak. It is obvious that these exercises indicate less cardiovascular pressure since heart activity considerably decreases. According to this study, mean systolic pressure considerably increased during running and swimming. Considering that difference in the variations of systolic pressure for swimming and running were 27.3 and 26.8, respectively, it can be concluded that swimming could affect systolic pressure more than running, which might be due to nature of the activity. In fact, this difference was not significant at α =0.05 level.

Systolic pressure increases with dynamic sports[18]. Body condition has a considerable effect on blood circulation. The highest and most stable cardiac output and pulsatile volume are obtained when body is in a horizontal position. In this position, resting pulsatile volume is almost equal to the maximum value and has a little increase during the exercise. In contrast, in the standing position, gravitational force acts in the opposite direction or return direction of blood flow out of the heart, which causes decrease in pulsatile volume and cardiac output in this position. This effect of body position is important evident when comparing resting blood circulation in lying and standing positions. Nevertheless, with increasing the intensity of exercises in the standing position, pulsatile volume increases and reaches the maximum value in the lying position[5, 6, 14].

When the sports activity is done in the horizontal position such as swimming, the effect of increase in end-diastolic volume and pulsatile volume is more evident. Studies done on humans and dogs have demonstrated that, in sports which are done in the horizontal body position and at the maximum intensity, end-diastolic volume shows higher increase. Also, in isotonic exercises, with the increase in the cardiac output and pulsatile volume, increase in systolic blood pressure happens in parallel[9]. Hence, one of the main causes of blood pressure increase during swimming activities relative to other activities is its nature which increases the cardiac output and consequently the blood pressure.

Based on the results obtained in this study, mean systolic blood pressure showed more increase during rhythmic movements compared with other three activities. This might be due to more movement of this exercise and also more coordination of nerve and muscle in these activities. Due to the harmonic movements, this type of exercises requires more attention and concentration on the part of the person in order to make higher coordination between the movements of hands and feet.

Among other results of this study was that, after doing one set of sub-maximal endurance exercises, systolic pressure temporarily fell below the level prior to the exercise. This result was also in agreement with previous studies. According to the studies done by Hannum in 1981, Kaufman in 1987 and Raglin in 1987, this issue has been confirmed in both groups of normal people and people with hypertension. This response of pressure drop to the exercise has done in recovery periods lasts for about 2 or 3 h. These findings support exercising as a defensive line without using any medication in order to treat hypertension; participating in several sessions of mild to moderate physical activities during different times per day has been approved[13, 16].

Precise mechanism of the effect of exercises on blood pressure decrease has not been known yet. However, this issue might be due to the reduction in catecholamine production caused by exercises [14, 16], as confirmed by Kiilavuori in 1999. In his studies, the amount of plasma norepinephrine decreased by 19% in resting condition [19]. This reaction has a role in the reduction of peripheral resistance to blood flow and consequently decrease of blood pressure. Also, exercise can facilitate sodium excretion from kidneys; thus, it can reduce liquid volume and blood pressure[11].

Probably, one of the reasons for blood pressure reduction after exercises might be due to ANP hormone secretion. According to the studies conducted inside and outside the country[15] it has been known that secretion of ANP hormone is regulated by dilating vestibule walls. And, the results of other studies have demonstrated that secretion of this hormone in response to exercise can be effective for patients with hypertension. Although the efficacy of this hormone is not accurately known, its efficacy includes interruption of cardiac sympathetic nerve stimulation and reduction of cardiac pre-load, increase in sodium excretion via urine and, consequently, increase in body water excretion and decrease in plasma rennin and aldosterone secretion; the set of these activities reduces blood volume and blood pressure[15].

Although the effect of regular exercise on the improvement of blood pressure conditions is not clear yet, the present study and previous investigations can be used to deduce that a regular aerobic exercise program can considerably decrease systolic blood pressure. These results were in good agreement with the results of studies done on the resting blood pressure of normal participants and patients with hypertension[4, 6, 9, 10, 20]. Also, other studies conducted by Cononie , Dengel and Raglin with regard to the reduction of mean artery blood pressure in middle-aged healthy men after exrcises confirm these results[6, 11, 16].

On the other hand, according to the results of this paper, drop of mean systolic pressure after all four exercises was in proportion to the pressure increase during exercises so that, in cycling, in spite of the least systolic pressure increase during the activity, systolic pressure demonstrated the least pressure decrease after the exercises while the highest increase in systolic pressure during rhythmic exercises and the greatest decrease in systolic pressure after the activity were observed in this type of exercises. Considering the findings of this article that pressure decrease after the exercises which are in proportion to increase of blood pressure during the exercise approved that further investigations should be done. In fact, the comparison of systolic pressure decrease after exercising in all four exercises showed no significant difference at α =0.05.

Based on the results of this article, mean systolic pressure during exercises in all four exercises considerably decreased with respect to the mean systolic pressure before the exercises. However, no significant difference existed as a result of comparison of systolic blood pressure drop in different exercises while exercising. This result was in agreement with some investigation, which revealed significant decrease in systolic blood pressure as a result of isotonic exercises and significant increase in diastolic pressure due to isometric exercises. Researchers have attributed the reduction in diastolic pressure during the activity to the reduction in norepinephrine level caused by sports activities[19].

CONCLUSION

According to the results obtained in this study, conservative suggestion is that, in order to control morbid hypertension, sports exercises are considered as the first defensive line in most medical programs. Previous studies have stated that, in the case of more severe hypertension, a combination of diet, weight loss, exercises and medical treatment might be necessary[4, 5, 8, 18, 20, 21].

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