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Effects of Short-term Exercise Training on Cardiorespiratory Fitness of Male Adults with Myocardial Infarction

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Abstract. [Purpose] The purpose of this study was to determine the effects of short-term exercise training on the cardiorespiratory fitness (CRF) of individuals suffering from myocardial infarction. [Subjects] A total of 60 participants were divided into experimental (EXP; n=30, mean age 56.7 ± 2.8 years, body mass 80.7 ± 10.7 kg, body height 171.9 ± 7.2 cm) and control (CON; n=30, mean age 56.5 ± 3.1 years, body mass 84.4 ± 12.4 kg, body height 171.5 ± 12.4 cm) groups. [Methods] The members of the EXP group took part in an organized daily physical exercise program (Monday through Sunday), for a period of 3 weeks. The exercise program consisted of 60 min daily specialized fitness exercises with an intensity ranging from 55–70% of the maximum heart rate, which was determined by test on a bicycle ergometer. The effects of the exercise were monitored by means of the following parameters: maximum oxygen uptake (VO2peak), resting heart rate, systolic blood pressure and diastolic blood pressure. [Results] The results indicate statistically significant post-exercise improvements in heart rate, relative oxygen uptake and systolic blood pressure, among the members of the EXP group. The results indicate that at the initial measurement of cardiorespiratory fitness no statistically significant differences were found between the groups at the multivariate level (Wilk's λ=0.83), while statistically significant differences in the cardiorespiratory fitness were found at the final measurement (Wil's λ=0.430). [Conclusion] The obtained results indicate that the exercise program, which lasted for a period of 21 days, though shorter in duration than other programs still led to statistically significant changes in the CRF of individuals suffering from MI.
Key words: Blood pressure, Functional capacity, Aerobic training

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INTRODUCTION

Diseases of the cardiovascular system are at the top of the scale of modern-day illnesses and are leading causes of death in most developed and developing countries. Cardiovascular disease, especially myocardial infarction (MI), is responsible for from one third to one half of all deaths and is the main cause of death among both men and women[1)]. Until the 1960s, bed rest and/or major limitation of exercise were considered beneficial for the majority of patients[2)]. However, the benefits of exercise training for patients with cardiovascular disease are now generally accepted as a nonpharmacological intervention for improve their fitness levels[3)].

Part of the rehabilitation of cardiovascular patients includes a physical activity program[4, 5)], which is especially important for people who have been diagnosed with MI[6)]. Today, various exercise programs such as cardiorespiratory endurance (aerobic) training, flexibility exercises, arm exercises and muscular resistance (strength) training, represent part of the recovery program for individuals suffering from MI[7)]. The rehabilitation of individuals suffering from MI is currently topic of great interest, not only due the frequency and increased number of MI occurrences, but also because of the very course the illness takes, which over time significantly reduces an individual's ability to work and leads to disability[8)]. The population of individuals who would benefit significantly from cardiovascular rehabilitation is not limited to people who have suffered an MI, but also includes individuals who suffer from peripheral blood vessel disorders, angina pectoris, hypertension and the like. Prior to the start of a physical exercise program, it is necessary to analyze an entire range of factors which are related to the individual who is considering joining the program. The following characteristics need to be taken into consideration: age, gender, prior physical activity levels, motivation for participating in the program, the status of the locomotor apparatus, and especially the residual functions of the cardiovascular system.

Cardiorespiratory capacity has been shown to improve during training in post-myocardial infarction patients[9)]. Exercises that are prescribed for individuals with MI have changed over the years, ranging from standard exercises

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meant for everyone, all the way to exercises tailored to each individual, which are created on the basis of risk factors, age and state of function. Proper dosing and controlled physical activity do not have negative effects, which has been proven in various research programs[10, 11]. It is not exercise itself that endangers the health of individuals suffering from MI, but primarily the way in which the exercise takes place and the extent of the load, both in the qualitative and quantitative senses. Certain authors have indicated that people who have suffered MI are able to run, even run marathons, which indicates that the functional abilities of these individuals, following the realization of certain exercise programs, can be quite great[7]. It is the recommendation of experts that all exercise programs contain dynamic work, which includes large muscle groups, and which lies at the basis of everyday physical activities such as walking, running, riding a bicycle, swimming and the like. Walking and riding a bicycle-ergometer have always been the most popular forms of exercise. Even walking at a relatively slow pace can be a sufficient stimulus for the improvement of the cardiovascular fitness (CRF) of individuals suffering from a cardiovascular disease[12].

The most important determinants of exercise in patients suffering from MI, which should always be taken into consideration, include the following: intensity, duration and frequency[13], and the type of physical load. The intensity of the exercise should be greater than the intensity of everyday activities, and below the level which leads to bad clinical symptoms or the occurrence of pain, in order to achieve positive changes. In addition, attention must be paid to the intensity of the exercise, keeping it above the lower threshold of intensity, as otherwise the exercise would not have any desired effects.

Scientific reports[14, 15] have recommended various types, durations and frequencies of different levels of physical activity load for individuals suffering from MI. The intensity should range from 40–45% to 60% of the maximum heart rate (HRmax) achieved during a load test[16]. Some authors have stated that exercise intensity should not exceed 70% HRmax[17–19], while other institutions and researchers have reported that exercise programs for the improvement of the CRF of individuals suffering from MI should be performed at an intensity between 60 to 80% HRmax[20, 21]. The duration of the exercise, according to some researchers, should last from 4 to 6 weeks[18], or from 10 to 12 weeks[21, 22], with varying exercise frequencies and individual exercise duration. There are even some studies with exercise programs that lasted up to 24 weeks[23].

Kargarfart et al.[2] showed that a 2-month exercise rehabilitation program for post-MI patients is useful for improving both blood pressure and exercise capacity, and they opined that it should be more commonly used. Previous studies[9, 18, 19] have also shown that exercises, if undertaken at moderate intensities, can result in improvements in health and aerobic capacity. After acute MI, aerobic exercise promotes a decrease in percentage body fat[23], HRmax[19], reduces blood pressure[22], and increases VO-2peak[23]. However, despite its importance, there is still controversy regarding the level and format of exercises that can yield optimal beneficial effects. Indeed, studies[2, 9, 13, 18, 19] of the effects of exercise training of cardiorespiratory fitness in patients after MI have mainly focused on long-term aerobic training. To our knowledge, practical issues such as the optimal intensity, volume and modalities of short term training effects are still unclear. Therefore, this study was carried out with the aim of determining the effects of a physical exercise program on the CRF of individuals suffering from MI. We hypothesized that short-term aerobic training would improve the cardiorespiratory fitness of patients after myocardial infarction.

SUBJECTS AND METHODS

Subjects

Sixty of 73 male participants finished the training program and participated in the initial and final testing. Ten participants dropped out from the experimental group and 3 from the control group. Participants dropped out from the experimental group due to cardiac arrhythmia (n=2), lack of motivation to exercise (n=4), and lack of availability to participate in the study (n=4); three participants in the control group died. The sample of 60 males, with an average age of 56.15 ± 2.95 years belonged to one of two groups, an experimental (EXP) or a control (CON) group; all participants had suffered a MI. The EXP group consisted of 30 participants, with an average body mass of 80.67 ± 10.7 kg, body height of 171.92 ± 7.2 cm, and BMI of 27.20 ± 3.80 kg/m^2. The CON group consisted of 30 participants with a body mass of 84.41 ± 12.4 kg, body height of 171.55 ± 12.4 cm, and BMI of 28.66 ± 4.10 kg/m^2. Inclusion criteria were: male between 50 and 60 years old; myocardial infarction; ability to pedal independently on a static bicycle; physical independence − able to walk without assistance, and lack of cognitive impairment or dementia, assessed as a score of more than 24 points for the educated and 18 points for the unqualified respondents in the mini-mental state evaluation[24]. Excluded from the study were patients with poor exercise tolerance (working capacity, less than 1 W/kg body wt), heart rhythm disturbances greater than Lown[25] classification IVa, or orthopedic difficulties that prevented them from participating in the exercise program. The EXP group was involved in an exercise program which consisted of calisthenics exercises, walking and riding a static bicycle, which lasted for a period of three weeks. All three types of exercises were performed daily. The experimental exercise program was carried out in the facilities and on the fields belonging to the Institute For Treatment and Rehabilitation "Niška Banja" (Niš, Republic of Serbia). The members of the CON group did not take part in any organized forms of exercise. The members of both groups continued their prescribed pharmacological therapy, as they had done prior to the study.

The Ethical Committee of the Faculty of Sport and Physical Education, University of Nis, certified that this investigation conformed to all ethical standards regarding scientific investigations involving human participants according to the Declaration of Helsinki. Participation in the study was voluntary and each of the participants could withdraw from the study at any time. All participants were fully informed about the risks and benefits that this research would have for their age group before they signed a consent form.

Methods

Beside the results, the basic anthropometric parameters (body height and body weight) were recoreded in the study protocol. The initial testing took place before the beginning of the training program, and the final testing was performed after 21 days of intervention. To prevent unnecessary fatigue accumulation, the participants were instructed to avoid exercise for a 24-hour period before each testing session. During testing, the air temperature ranged from 22 °C to 27 °C. The testing always commenced at 10 a.m. and was completed by 1 p.m. The assessments and part of the exercise sessions (calisthenics and riding a static bicycle) took place in the therapy room at the participants' rehabilitation center while walking activities took place on outdoor paths under the supervision of a researcher, a chartered therapist qualified to prescribe and oversee such exercise. The heart rate of the participants was monitored during the exercise and any adverse events were recorded on the exercise data collection sheet.

Body weight was assessed to the nearest 0.1 kg using a SECA Beam Balance Scale 700 (SECA GmBH & Co, Hamburg, Germany) with the participants wearing minimal clothing. Body height was assessed to the nearest 0.1 cm using a portable SECA Stadiometer 282 (SECA GmBH & Co, Hamburg, Germany). The stadiometer and scale were calibrated periodically during the study. Body mass index was calculated using the formula: BMI=body weight (kg) / (body height (m))^2.

For the purpose of evaluating the CRF, the following measures were used: maximum oxygen uptake (VO2peak), and relative oxygen uptake (relative VO2peak), calculated using the submaximum standardized load test on a static exercise bicycle (Ergometer AX1; Heinze Kettler, GmbH & Co, Germany). We also monitored heart rate (PC-15; SIGMA Elektro, Gmbh & Co, Germany), resting heart rate (beat/min), systolic arterial blood pressure (mmHg), and diastolic arterial blood pressure (mmHg).

Maximal oxygen uptake. Sub-maximal exercise testing was carried out on a static cycle ergometer (Ergometer AX1; Heinze Kettler, GmbH & Co, Germany) at a submaximal workload using the Astrand-Rhyming protocol[26]. The test protocol was started after a rest period of 10 min in the supine position. The test comprised of a 3-min warm-up at a workload of 50 W, followed by a constant workload at 100–130 W for 6–7 minutes until the participants met the steady-state heart rate. This was followed by a 3-min recovery period with workload set at 50 W, followed by a 10-min rest period in the supine position. The load chosen in each case was determined by the weight and age of the person, or heart rate during the first minute of the test. We determined the VO2peak indirectly using Astrand's nomogram due to the high correlation between directly and indirectly measured VO2peak[27]. This method has previously been decribed in detail[28].

Systolic and diastolic blood pressure. Evaluation of blood pressure was conducted by an automatic digital device OMRON M4-1 (OMRON Healthcare Europe BV, Netherlands). The cuff was positioned around the forearm of the seated male and female subjects about three centimetres above the elbow. The results were read in mmHg. Before the measurement, the subjects rested in a seated position. Three minutes of rest was taken by the participants between three successive readings of blood pressure. Although the three readings were different with the largest value being the first reading and the smallest being the third reading on average, these differed by no more than 2 mmHg of systolic blood pressure, and no more than 4.5 mmHg of diastolic blood pressure. We chose to take the average of the second and third readings as recommended by the World Health Organisation[29] in order to increase the degrees of freedom for the mean.

Ten days after myocardial infarction, participants were included in the training program. The exercise program lasted for a period of three weeks (Table 1), and the 21 exercise sessions were divided into three parts, each including: calisthenics exercises; walking along fitness trails with an asphalt surface, 800 to 2000 m in length, with a 2% incline; and riding a static bicycle. The 3-week daily (Monday

Table 1. The exercise training program

		Week		
		I	II	III
Calisthenics exercises	Duration of the exercise	20 min	20 min	25 min
	Rest interval (second)	15 s	15 s	10 s
	Number of exercises	23	23	30
	Repetitions of individual exercises	10	10	10
Walking	Duration of the walk	3×5 min	3×5 min	4×5 min
	Tempo (step/min)	70–80	70–80	80–100
	Movement speed (km/h)	2.5–3.0	2.5–3.0	3.5–4.0
	Rest intervals (min)	1 min	1 min	1 min
Static bicycle exercises	Duration of the exercise (min)	2×5 min	2×5 min	3×5 min
	Duration of rest interval (min)	5	5	5
	Pedal turning speed (number/min)	50	50–60	60
	Workload (Watt)	25	25	50

through Sunday) training consisted of the following activities.

Morning sessions: Activities included walking on paths graded to the capacity of the patients according to the score achieved during the initial test and calisthenics exercises (23–30 exercises for different muscle groups). Each calisthenics exercise was repeated 10 times. During the walking activity patients had 2–3 active rest pauses (breathing exercises).

Afternoon sessions: Participants rode a static bicycle for 10 minutes in the first and second weeks and for 15 minutes in the third week. The workload was 25 W in the first and second weeks and 50 W in the third week of the training program. All sessions had equal duration of work and rest interval (5 vs. 5 minute).

The overall duration of the daily exercise sessions ranged from 45 minutes in the beginning up to 60 minutes at the end of the program. The exercise intensity progressively increased from 55% to 70% HRmax based on the results that were achieved during the previously carried out standardized load test on the bicycle-ergometer. Training was monitored daily by a heart rate monitor (PC-15; SIGMA Elektro, Gmbh & Co, Germany) and blood pressure recordings were made before and after each training session.

Data analysis was performed using STATISTICA 6.0 (StatSoft. Inc., Tulsa, OK, USA). Descriptive statistics were calculated for all experimental data. In addition, the Kolmogorov–Smirnov test of the normality of distribution was performed for all variables before the analysis, the homogeneity of variance was tested by the Levene test. To determine whether statistically significant differences existed between the means of the EXP and CON groups' initial and final measurement, we used a multivariate and univariate analyses of variance (MANOVA/ANOVA). The differences between the initial and final measurements of the EXP and CON groups were determined using the t-test. For the purpose of determining the effects of the exercise following the completion of the exercise program, a multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA) were used. Statistical significance was accepted for values of $p<0.05$.

RESULTS

The Kolmogorov-Smirnov test showed that the data were normally distributed. Levene's test showed no violation of homogeneity of variance. The results of the MANOVA indicate that at the initial measurement of the CRF no statistically significant difference was found between the groups at the multivariate level (Wilk's λ=0.83; F(5.54)=6.22; p=0.066), while statistically significant differences in the CRF were determined at the final measuring (Wilk's λ =0.430; F(5.54)=14.41; p=0.000) (Table 2).

Statistically significant intergroup differences were found for the relative VO2peak between the initial (p=0.000) and final measurements (p=0.045). The members of the EXP group showed lower numerical values in almost all the measurements used to evaluate the CRF, except resting heart rate, which showed numerically greater values both at the initial and final measurements of this group of participants.

The differences between the initial and final measurements of the EXP group indicate that there was a statistically significant increase in the relative VO2peak from an initial 21.23 mL/min/kg to a final 23.19 mL/min/kg ($p<0.01$) following the completion of the exercise program. A numerical increase between the initial and final measurements was also found in VO2peak of the EXP group, but it was not statistically significant. In the case of the other measurements for the evaluation of the CRF of the EXP group, the resting heart rate and arterial blood pressure, were both lower, which in this case constitutes a better result.

Statistically significant differences ($p>0.01$) were not found between the initial and final measurements of any of the variables used to evaluate CRF in the case of the CON group, even though the measured values differed numerically. At the final measurement of the CON group showed greater numerical values for the variables used to evaluate oxygen uptake, while the values of resting heart rate frequency and arterial blood pressure were lower compared to the initial ones.

A statistically significant difference at the multivariate level between the members of the EXP and CON group was found (p=0.020). The results of the ANCOVA test for the EXP and CON group at the final measurement (Table 3) indicate that there were statistically significant differences between the groups in Heart Rate (p=0.031) and relative

Table 2. Differences in the cardiorespiratory fitness between the groups at the initial and final measurement

Variables	Initial Mean (SD)		Final Mean (SD)	
	EXP	CON	EXP	CON
Heart Rate (b/min)	71.80 (5.5)	69.20 (5.8)	68.66 (7.6)	68.20 (6.4)
Systolic BP (mmHg)	130.33 (16.6)	132.00 (13.0)	123.36 (15.8)	126.17 (10.9)
Diastolic BP (mmHg)	80.55 (9.6)	83.33 (8.0)	76.83 (8.7)	80.83 (7.6)
VO2peak (l/min)	1.70 (0.3)	1.85 (0.3) **	1.87 (0.3)	1.90 (0.2) *
VO2peak (ml/min/kg)	21.23 (2.7)	21.70 (4.0)	23.19 (2.9)	23.36 (3.7)
	Wilk's λ =0.83, F(5,54)= 6.22, p= 0.066		Wilk's λ =0.43, F(5,54)= 14.41, p= 0.000	

BP-blood pressure, VO2peak-maximal oxygen uptake, RVO2max-relative oxygen uptake, EXP- experimental group, CON − control group, the level of significance, * $p< 0.05$, ** $p< 0.01$

VO2peak (p=0.041). In the case of Systolic BP, a statistically significant difference was found between the groups ($p<0.01$). The completed exercise program most likely contributed to the positive changes that the EXP group experienced. The members of the EXP group had better results at the end of the exercise program than those of the members of the CON group.

DISCUSSION

The primary purpose of the current study was to determine the short-term effect of a physical exercise program on the CRF of individuals suffering from MI. We observed that the 3-week training program led to significant improvements in measurements of VO2peak, systolic BP, heart rate, but had no discernible effect on dyastolic BP. On the basis of the results of the initial and final measurements of the CON group, decreases were noted for Heart Rate, Systolic BP and Diastolic BP at the final measurement. Heart Rate was reduced by 1 beat/min, Systolic BP by 5.83 mmHg, while Diastolic BP was decreased by 2.50 mmHg. In the case of the members of the control group at the final measurement, the VO2peak showed a higher numeric value than the initial measurement. The improvement in the VO2peak can be explained by the "spontaneous" improvement in functional aerobic capacity, which can occur during regular recovery periods, which allows greater daily work activities unrelated to regular physical exercise[30]. Even in the values for relative VO2peak a mild increase was noted at the final measurement in comparison to the initial one. Similar results have also been noted by other authors[23, 31]. These authors concluded that the improvement in the functioning of the cardiovascular system took place due to improvement in sympathetic nervous activity, along with an improvement in heart function, which are not related to exercise. The results of participants tended to increase, irrespective of whether they took part in exercise programs or not.

The values of heart rate in the EXP group at the final measurement, compared to the initial one, were reduced (though not in a statistically significant manner) by 3.14 beats/min. Changes to the heart rate were most likely the result of the influence of the exercise program; that is, the exercise led to a lower heart rate following the completion of the program. One group of researchers[18] have reported that following the completion of an exercise program, a decrease can occur in heart rate of 5 beats/min. A decrease in heart rate following the completion of an exercise program, has been noted by other authors[32–35].

The decreases in systolic BP of 7 mmHg and diastolic BP of around 4 mmHg were not statistically significant, but are in agreement with previous research, confirming there is a decrease in arterial blood pressure following the completion of a physical exercise program. These decreases in systolic BP and diastolic BP can range from 5 to 10 mmHg[36]. In an analysis of 22 studies[37] it was determined that physical exercise programs lead to decreases in systolic BP of 6.4 mmHg and diastolic BP of 6.9 mmHg. The positive effects of physical exercise on the decrease in arterial blood pressure have also been confirmed in meta-analysis[39]. The authors of the meta-analysis reached the conclusion that properly programmed and dosed physical activity undoubtedly leads to a decrease in arterial blood pressure (3.84 mmHg for systolic and 2.58 mmHg for diastolic blood pressure). In the meta-analysis[39], which included 54 randomly selected controlled studies comprising 2419 individuals, it was determined that physical exercise programs of an aerobic character, which lasted for a period of at least two weeks, resulted in significant decreases in arterial blood pressure. The decreases in systolic and diastolic BP, following physical exercise programs has been reported by other studies[40, 41]. The reduced values of arterial blood pressure, both systolic and diastolic, are most likely the result of increased elasticity of the blood vessels.

Between the initial and final measurements of the members of the EXP group, a numerical increase was found in relative VO2peak (p=0.009). The overall increase of the EXP group was 9.1%, and this result is in accordance with the results of previous studies[23, 33, 42]. In one study[43] of individuals with cardiovascular diseases, increases of 15% to 20% of maximum oxygen uptake were observed, following the completion of a physical activity program. Other studies[40, 42] have reported that physical exercise can increase oxygen uptake from 11% to 36%. What is especially emphasized is the smaller increase in relative oxygen uptake of 21% of individuals who are in post-myocardial infarction period[44]. The percentage of improvement in VO2peak following the completion of a physical exercise program is equal in the case of men and women, but the greatest improvements have been found in people who initially had the worst aerobic abilities[42, 43]. These improvements are similar to those of the elderly or younger individuals who take part in various exercise programs[45].

The changes that took place among the members of the EXP group were also determined for VO2peak but they were not significant, only numerically greater. There was a statistically significant difference between the groups at the final measurement, and from this result we infer that the completed exercise program had a positive effect on the CRF of the members of the EXP group. Statistically significant differences were also found for heart rate, relative VO2peak and systolic BP. Heart rate and systolic BP were numerically smaller in the EXP group, which in this case

Table 3. Analysis of covariance between the EXP and CON groups at the final measurement

	Adj Means	
	EXP (n=30)	CON (n=30)
Heart Rate (beat/min)	71.94	98.31**
Systolic BP (mmHg)	131.19	135.41**
Diastolic BP (mmHg)	81.20	82.75
VO2peak (l/min)	1.79	1.71
VO2peak (ml/min/kg)	24.85	21.08*
Wilk's lambda 0.77, Rao's R 2.97, df1 5, df2 49, p=0.020*		

BP-blood pressure, VO2peak-maximal oxygen uptake, RVO2max-relative oxygen uptake, EXP – experimental group, CON – control group, Adj Means – adjusted means, the level of significance * p<0 .05, ** p< 0.01

constitutes a better result. The results are in accordance with the results obtained by other researchers[46, 47].

The decreases in arterial blood pressure of 4.2 mmHg for systolic and 1.6 mmHg for diastolic pressure are within the range of results that other researchers have reported[38, 48]. The possible mechanisms which induce a decrease in arterial blood pressure are indirectly related to the decrease in the effects of the sympathetic nervous system (the dominance of the vagus nerves over the sympathetic nervous system) and vasoconstriction among individuals who take part in physical exercise.

The present study had a number of strengths, including topicality, and a large number of participants. Besides that, we should note some specific study limitations. This study used an indirect estimation of the maximal oxygen uptake by the Astrand nomogram. Also, BMI was determined using a predictive equation instead of a more accurate measure such as bioelectrical impedance. Therefore, in future researches direct methods for estimating the VO2peak and body composition should be used. Consequently, future studies should deal with the influence of various exercises program on the CRF of patients suffering from MI. Also, longitudinal studies with several points of measurement, which would allow tracking and correction for changes in CRF, would provide greater insight into the relationship between exercises and MI.

The members of the EXP group had higher VO2peak and relative VO2peak values, indicating that positive changes occurred as a result of the exercise program. The members of the EXP group at the final measurement had higher values of VO2peak compared to the control group, but they were not statistically significant. A significant difference was determined for relative VO2peak. The results of the completed exercise program are in accordance with the results of previous research programs, which also had the aim of determining the influence of physical activity on functional abilities[49–52]. The results of these research programs indicate that proper dosing and controlled short-term physical exercise can have a positive effect on the cardiovascular function of individuals who exercise. In the early stages of the post-infarction period, there is a need for activities at an intensity and extent that would contribute to the improvement of cardiovascular functions[53].

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