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The influence of physical rehabilitation on arterial compliance in patients after myocardial infarction

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Abstract

Background: *The aim of this study was to determine the effect of 6-week physical training on the mechanical properties of the arteries, in patients (pts) after acute myocardial infarction (MI).*

Methods: *The group under investigation consisted 119 pts after their first acute MI qualified for the second stage of post-hospital training. Only 64 pts (Group 1) underwent the training program. The remaining 55 pts (Group 2) could not participate in it. All the pts underwent an initial exercise test, an ultrasound cardiac scan and a pulse wave velocity (PWV) measurement by means of the COMPLIOR system. Group 1 underwent cardiac rehabilitation program according to Model A or B, depending on exercise tolerance at baseline. Then, both groups had another exercise test and another PWV measurement. Additional PWV measurements were taken in both groups after 6 months.*

Results: *Both groups were comparable with respect to demographic data, the site of MI, the method of treatment, left ventricular function, mean exercise time, the workload attained and mean PWV values at baseline (12.8 ± 1.6 m/s vs. 12.2 ± 2.7 m/s). In group 1 a significant increase in exercise capacity was observed: from 6.46 ± 2.7 to 8.95 ± 2.16 MET, and the PWV values were significantly lowered from 12.8 ± 1.6 to 8.7 ± 1.8 m/s. Group 2 showed only a slight lowering of PWV from 12.2 ± 2.7 to 10.8 ± 2.3 m/s.*

Conclusions: *Controlled physical training after MI significantly improves systemic arterial compliance, probably through improving the endothelial function.* (Cardiol J 2007; 14: 366–371)

Key words: physical rehabilitation, arterial stiffness

Introduction

Cardiac rehabilitation is a safe and effective way of increasing the exercise tolerance of patients after a myocardial infarction (MI). Properly selected exercises and physical training result in a lower demand for oxygen, slower resting and exercise heart activity, a higher stroke volume, increased blood supply to the heart and the development of collateral circulation, an increase in HDL cholesterol fraction and increased exercise tolerance. The analyses of cardiac rehabilitation that are available have shown a significant decrease in mortality among patients who have followed a physical training programme after their myocardial infarction [1, 2]. Restoring the balance of the neurohumoral mechanisms and the normalisation of the reflexes

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from the baroreceptors can contribute significantly to a decrease in mortality from cardiovascular causes [3, 4].

Recent studies have demonstrated that the development of cardiovascular complications is also linked to increased stiffness of the large arteries [5]. Arterial distensibility plays an important role in determining exercise capacity because increased arterial stiffness leads to a greater cardiac workload. Pulse wave velocity (PWV) provides an indirect non-invasive measurement of the mechanical properties of the arteries. Arterial compliance is affected by many factors, which can be modified by physical training. An improvement in arterial compliance could supplement the numerous benefits brought about by physical training in patients after an MI.

The aim of our study was to determine the influence of a 6-week physical training schedule on arterial compliance in patients after a MI.

Methods

The group under investigation consisted of 119 patients who had suffered their first MI and who had qualified for rehabilitation treatment. The patients fulfilled the following criteria:
— time from the infarction: 3–4 weeks;
— coronary stability;
— retained heart efficiency confirmed by clinical examination (class 2 according to the NYHA);
— in echocardiographic examination (EF > 39%);
— no complex aberrations of rhythm;
— exercise capacity in an exercise test > 5 MET.
All the patients underwent the following:
— a baseline exercise test on a treadmill (Case 15 Marquette Electronic Inc.);
— an ultrasound cardiac scan (Acuson 128XP/10C);
— a non-invasive PWV measurement (the COMPLIOR computer system).
The following were regarded as exclusion criteria:
— obesity: body mass index (BMI) > 30;
— atrial fibrillation;
— barely palpable pulse above the carotid or femoral artery.

During the exercise test, conducted in accordance with the AHA guidelines [6], the following factors were evaluated: exercise duration, the frequency of the heart rate, arterial blood pressure at rest and at exercise peak, the metabolic equivalent of workload (MET), changes in the ST segment, the appearance of angina and exercise-induced arrhythmias.

In the echocardiographic examination left ventricular function was evaluated by calculating the value of the ejection fraction (EF) by means of the Simpson method [7]. PWV was measured by means of an automatic device for measuring carotid-femoral transit or propagation of the pulse pressure wave (the COMPLIOR system). The method for assessing PWV velocity used in our work was described for the first time by Asmar et al. [8]. These authors have shown that measurements taken by means of the COMPLIOR instrument are characterised by considerable repeatability of the results between independent researchers (inter-observer reproducibility) and of the results obtained from the same patient by the same researcher (intra-observer reproducibility). Underlying the basic principle of measurement is the phenomenon of the propagation of the pulse pressure wave produced by the ejection of blood from the left ventricle along the aorta and the vessels branching off it. Calculations are based on the differences in pulse transit times between two points in the arterial system (the carotid-femoral artery). In our study we used TY-306 Fukuda pressure-sensitive transducers (Fukuda, Tokyo, Japan), placed where the pulse is best palpable above the carotid and femoral artery, recording and digitising at the sample acquisition frequency of 500 Hz. When the computer screen showed a pressure waveform of good quality, the calculating algorithm was initiated. The system calculated the PWV by dividing the distance between the transducers by the time the pulse wave needed to move from the carotid to the femoral artery. The final PWV value was the mean obtained from six measurements. The measurements were performed in the morning, with the patients in a recumbent position after 5 min of rest.

The patients were then qualified for the second stage of the post-hospital rehabilitation programme [9]. However, only 64 patients (Group 1) underwent the rehabilitation training. The remaining 55 patients (Group 2) could not participate in it for various (mainly family) reasons (Table 1). The patients from Group 1 underwent physical training on a cycle ergometer. On the basis of baseline exercise capacity of 7 MET or above, 28 patients were qualified for rehabilitation according to Model A. The remaining patients with exercise capacity below 7 MET underwent training according to Model B (Table 2) [10]. The rehabilitation period ranged from 4 to 9 weeks in length (mean length 6 weeks).

After this period patients from both Group 1 and Group 2 again had an exercise test and a non-invasive PWV measurement. Additionally, in the 6th month of the observation follow-up PWV measurements were taken in both groups of patients.

Table 1. Characteristics of the study groups before the rehabilitation.

	Group 1*	Group 2*
Mean age of patients	48.2 ± 2.3	51.3 ± 2.2
Sex (women/men)	24/40	30/25
Anterior wall infarction	26	22
Arterial hypertension	36	27
Diabetes	12	11
LVEF (%)	43.2 ± 9.8	41.4 ± 8.3
Primary PTCA (%)	88.5	85.3
Thrombolytic therapy (%)	12.5	15.7
Drugs administered		
Beta-adrenolytics	60	50
ACE inhibitors	56	48
Statins	57	49
Exercise workload [MET]	6.46 ± 2.7	6.05 ± 2.3
Pulse wave velocity [m/s]	12.8 ± 1.6	12.2 ± 2.7

*There were no statistically significant differences between Group 1 and Group 2; LVEF — left ventricular ejection fraction; PTCA — percutaneous transdermal coronary angioplasty

Table 2. The model of cardiac rehabilitation depending on baseline capacity.

	Patients	Type of training	Intensity
MODEL A Exercise capacity ≥ 7 MET	28	Interval or continuous training	60–80% reserve of heart rate
MODEL B Exercise capacity 5–6 MET	36	Interval training	60% reserve of heart rate

Statistical analysis

Statistical analyses were performed by means of the Statistica 5.0 software. The parameters under investigation are shown as mean values ± standard error of the mean of measurement (SEM). The significance of differences between continuous variables was estimated by means of Student's t-test for dependent samples. The differences were considered to be statistically significant when $p < 0.05$.

Results

Preliminary examination

When the groups were compared on the basis of the demographic data presented in Table 1, the site of infarction and the method of treatment, it can be seen that Group 2 was older (48.2 *vs.* 51.3) and that women predominated in this group, but these differences were not statistically significant. Similarly, the percentage of patients treated invasively was comparable in both groups (88.5% *vs.* 85.3%). The left ventricular function, as expressed by the value of the EF, was similar in the two groups (43.2 *vs.* 41.4%). The two groups were also similar with respect to NYHA classification and the frequency of occurrence of risk factors. In the exercise test, the mean duration of exercise and workload attained (6.46 ± 2.7 MET *vs.* 6.05 ± 2.3 MET) were comparable in the two groups (Tables 1 and 3).

The remaining results of the test did not differ significantly between the two groups under investigation (Table 3). The mean value of PWV at baseline was comparable in the two groups (12.8 ± 1.6 *vs.* 12.2 ± 2.7) (Table 1).

The examination 12–16 weeks after the infarction

When analysing the exercise test performed 12–16 weeks after the infarction, we compared the results of those of Group 1 that had undergone physical training with those of Group 2 that had not been rehabilitated (Table 3). The patients who had undergone physical training showed better physical efficiency in comparison with those who had not taken part in the rehabilitation programme. In Group 1 the exercise time became significantly longer, from 6.21 ± 2.07 to 8.71 ± 2.63 min, $p < 0.05$, whereas in Group 2 no

Table 3. A comparison of results of an exercise test at baseline (B1) and 12–16 weeks after the myocardial infarction (B2).

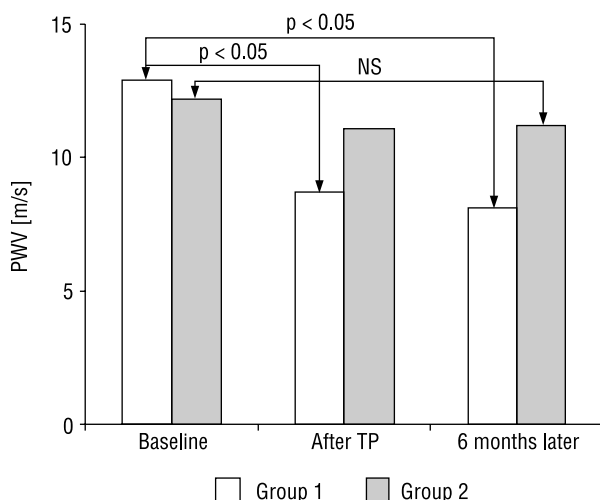|	Group 1			Group 2		
	B1	B2	p	B1	B2	p
Exercise duration [min]	6.21 ± 2.07	8.71 ± 2.63	0.05	5.89 ± 1.08	7.02 ± 1.23	NS
Exercise capacity [MET]	6.46 ± 2.7	8.95 ± 2.16	< 0.05	6.05 ± 2.3	7.35 ± 1.53	NS
Heart rate at rest (the number of heartbeats per min)	82.4 ± 15.1	67.5 ± 12.1	NS	80.2 ± 10.1	72 ± 9,3	NS
Heart rate at max. workload (heartbeats per min)	133.4 ± 17.2	145.6 ± 11.2	0.05	128.5 ± 9.3	135.4 ± 11.4	NS

Figure 1. The effect of the physical training programme (TP) on pulse wave velocity (PWV).

significant increase in exercise test time was observed. Similarly exercise tolerance in the trained group rose significantly from 6.46 ± 2.7 MET to 8.95 ± 2.16 MET ($p < 0.05$), whereas in the control group this increase, from 6.05 ± 2.3 MET to 7.35 ± 1.53 MET, was not statistically significant (Table 3). The results of the post-rehabilitation measurement of the PWV are shown in Figure 1. In patients from Group 2 there was a slight decrease in the value of PWV from $12.2 \pm \pm 2.7$ m/s to 10.8 ± 2.3 m/s. However, in patients from Group 1 after the completion of the physical training the PWV was significantly lowered from 12.8 ± 1.6 m/s to 8.7 ± 1.8 m/s ($p < 0.05$). In the examination performed after more than 6 months of observation it was observed that in Group 1 the values of PWV were still lowered, 8.4 ± 2.2 m/s, while in Group 2 these values were still higher at 11.2 ± 1.2 m/s.

Cardiovascular events observed within the 6-month period after the infarction

Of the patients in Group 1 who had undergone the physical training, one patient underwent coronary angioplasty. The revascularisation was not on the artery the patency of which had been restored during the infarction. In Group 2 one patient suffered another myocardial infarction, and three were hospitalised because of aggravation of coronary problems, two of whom required revascularisation by the percutaneous transluminal coronary angioplasty procedure.

Discussion

A cardiac rehabilitation programme is a recognised non-pharmacological method of treating patients with ischemic heart disease. The second phase of cardiac rehabilitation in patients after a myocardial infarction leads to improved exercise tolerance, decreases coronary risk and improves the general physical and mental state [1–3]. The available analyses concerning cardiac rehabilitation have shown a considerable decrease in mortality among patients who complete a physical training programme, mainly through a reduction in cardiovascular risk factors [11]. One of the independent prognostic factors of cardiovascular mortality is the PWV. The risk coefficient when the PWV is higher by 5 m/s is 1.34 for all-cause mortality and 1.51 for cardiovascular mortality [12].

In our study we evaluated the results of physical training in patients over a period of, on average, 12–16 weeks after infarction. This programme comprised the second stage of the post-hospital rehabilitation according to Model A or Model B. It was administered to a group of 64 patients, and the results were compared with those of the group of 55 patients qualified for rehabilitation, but who, for various reasons, were unable to participate in it. We compared the results of the exercise test and the measurements of the PWV for all the patients.

In Group 1 the effects of the physical training were increased exercise tolerance and a significant improvement in arterial compliance, expressed by a decrease in PWV from 12.8 ± 1.6 m/s to $8.7 \pm \pm 1.8$ m/s. This beneficial tendency was still observed in the examination performed in the follow-up (the 6th month of observation). Regular physical exercise increases the bioavailability of nitrogen oxide, reduces the synthesis of endothelin and reduces oxidative stress [13, 14]. Among the likely mechanisms accounting for the improvement in arterial compliance as a result of physical training is its influence on the vascular endothelium. The works by Safar et al. [15] and Guijarro et al. [16] show the significant role of the endothelium in regulating arterial compliance, and the PWV measurement has proved useful in evaluating endothelial function [17]. On the other hand, the effect of physical training on arterial compliance is far more complex in character and its influence on the endothelium may be additionally enhanced by the structural changes occurring in the wall of the vessel under the influence of physical training. In emphasising such a significant improvement in arterial compliance as a result of physical training, it must be stressed that some hypotensive drugs have an independent beneficial effect on the mechanical properties of the arteries, including the PWV. This influence is especially well documented in the case of ACE inhibitors and here mention must be made of the

results obtained in the Canadian [18] and Complior [19] studies.

Interesting results concerning the influence of simvastatin on arterial compliance were obtained by Kurpesa et al. [20], who have shown in their work that simvastatin reduces PWV in patients with arterial hypertension. Similar results showing a significant improvement in large artery compliance in patients treated with atorvastatin were published by Ferrier et al. [21]. In our study the two groups of patients who had had a myocardial infarction did not differ with respect to pharmacotherapy, but only Group 1 underwent regular physical training according to Model A and B. It therefore seems logical to infer that the second phase of cardiac rehabilitation had a significant influence on the decrease in PWV in patients from Group 1. It has also been shown in many studies that the stiffness of the aorta and of the large arteries increases with age [22–24]. In our work Group 2 was older and women prevailed in it, but these differences were not statistically significant. Similarly, the incidence of hypertension was comparable in the two groups.

The observations concerning the influence of physical training on arterial compliance may have significant clinical implications. Physical training, as a non-pharmacological method of treatment, supports the treatment of patients with ischemic heart disease by, among other mechanisms, improving arterial compliance. Progressing structural changes in the arterial part of the circulatory system decrease the blood flow in the arteries and on the level of the microcirculation. The possibility of slowing down this process can be a very important point in treating patients after a myocardial infarction, because it might decrease the risk of cardiovascular events such as infarction, stroke, or death.

Conclusions

1. In patients who have suffered a myocardial infarction controlled physical training improves exercise tolerance.
2. Physical rehabilitation has a beneficial effect on the compliance of the large arteries, probably through improving the function of the endothelium.

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