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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

The effect of cycle ergometer exercise training on improvement of exercise capacity in patients after myocardial infarction

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Abstract

Background: Cardiac rehabilitation in patients after myocardial infarction (MI) is a component of secondary prevention that has an established role in the current guidelines.

Aim: To determine the effect of physical training on exercise capacity parameters determined on the basis of cardiopulmonary exercise test (CPET) in patients after MI. We also evaluated the relationship between the number of training sessions and exercise capacity.

Methods: We prospectively evaluated 52 patients after MI who underwent percutaneous coronary intervention of the infarct-related artery. At the start of the training, patients had no symptoms of heart failure and coronary artery disease. Electrocardiographic exercise test was performed 4 to 6 weeks after MI, followed by CPET in patients with a negative stress test. After determination of the initial exercise capacity, patients underwent 12 training sessions on a cycle ergometer with a workload determined on the basis of anaerobic threshold or heart rate reserve. After 12 training sessions, CPET was performed, followed by another 12 training sessions and a follow-up CPET.

Results: All patients showed a significant increase in exercise capacity parameters: energy expenditure during CPET increased from 9.39 to 11.79 METs, peak oxygen uptake (VO_2peak) increased from 32.32 to 39.25 mL/kg/min ($p < 0.001$), and oxygen uptake at the anaerobic threshold increased from 18.34 to 24.65 mL/kg min ($p < 0.001$). The initial 12 training sessions resulted in a statistically significant increase in VO_2peak from 32.32 to 36.75 mL/kg/min ($p = 0.003$), while subsequent 12 training sessions were related with an insignificant increase in VO_2peak from 36.75 to 39.25 mL/kg/min ($p = 0.065$).

Conclusions: Regular physical activity improves exercise capacity as measured by CPET. A statistically significant improvement in exercise capacity was seen already after initial 12 training sessions, while another 12 training sessions were associated with smaller benefits.

Key words: cardiac rehabilitation, exercise tolerance, myocardial infarction, cardiopulmonary exercise test

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INTRODUCTION

Cardiac rehabilitation in patients after myocardial infarction (MI) is a component of secondary prevention that has an established role in the current guidelines [1]. Each year, cardiovascular (CV) disease and their complications are the cause of more than 4 million deaths in Europe [2]. Annual direct and indirect costs of treating CV disease in Europe have been estimated at about 192 billion euro [3], and regular physical activity is associated with a 15–30% relative decrease in mortality [4, 5].

According to the guidelines on cardiac rehabilitation published in 2001 by the Section of Exercise Rehabilitation and Physiology of the Polish Cardiac Society, cardiac rehabilitation following MI should comprise 3 stages. The first stage is in-hospital rehabilitation in the intensive care units, postoperative surgical units, cardiology or general medical wards,

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or specialised cardiac rehabilitation units. The second stage lasts 4–12 weeks and may comprise in-hospital rehabilitation, early outpatient rehabilitation, or early home-based rehabilitation. The final stage is a lifelong late outpatient rehabilitation to allow for further improvement of exercise capacity, maintenance of previous treatment and rehabilitation effects, and reduction of the recurrence risk [6].

The aim of this study was to determine the effect of physical training on exercise capacity parameters determined on the basis of cardiopulmonary exercise test (CPET) in patients after MI. We also evaluated the relationship between the number of training sessions and the change in exercise capacity.

METHODS

The study was conducted prospectively. The study protocol, patient information form, and informed consent were approved by the Bioethics Committee at the Medical University of Warsaw (approval No. KB 19/2010). All patients gave written informed consent for participation in the study. The study included 52 patients hospitalised due to an acute MI in the First Chair and Department of Cardiology at the Medical University of Warsaw. All patients were treated according to the European Society of Cardiology (ESC) guidelines [7, 8]. Invasive coronary angiography and percutaneous coronary intervention of the infarct-related artery were performed in all patients. At the time when physical training was initiated, patients had no symptoms of heart failure and coronary artery disease.

The inclusion criteria were as follows: an acute MI diagnosed according to the ESC universal definition of MI [9], patients consent for study participation and cardiac rehabilitation, complete percutaneous revascularisation and drug therapy according to the ESC guidelines [7, 8].

The exclusion criteria included a history of musculoskeletal or neurological disorder precluding exercise; active myocarditis or a history of myocarditis; decompensated heart failure; uncontrolled, severe and/or symptomatic arrhythmia; uncontrolled hypertension; head trauma within last 3 months; advanced cancer; chronic inflammation as reflected by elevated blood inflammatory markers (leukocyte count, erythrocyte sedimentation rate, C-reactive protein level); and failure to meet any of the inclusion criteria.

A maximal electrocardiographic exercise test (Cambridge Heart® with TMX42® treadmill) was performed 4–6 weeks after MI. In patients with a negative result of the exercise test, this was followed by CPET (ZAN 800®) with resting spirometry. After determination of baseline exercise capacity, anaerobic threshold (VO_2AT), and heart rate reserve (HRR), patients were referred for exercise training using a cycle ergometer (ER900 REHA, Ergoline®). Workload was set based on HRR or VO_2AT. Before each training session, patients were evaluated by a physician (internist or cardiologist). Exercise was supervised by a physiotherapist, and after the session patients were again evaluated by a physician.

HRR was determined using the following formula: HRR = HR max – HR rest; where HRR — heart rate reserve; HR max — maximum heart rate recorded during the exercise, and HR rest — resting heart rate [10]. To determine target heart rate during training, the following formula was used: HR during training = HR rest + 50% HRR.

VO_2AT was determined using the V-slope method. By measuring changes in oxygen and carbon dioxide content in the expired air, VO_2AT may be determined based on the slope of the relationship between carbon dioxide output (VCO_2) and oxygen uptake (VO_2) during exercise. Then, ergospirometry data were used to determine heart rate at which anaerobic threshold was obtained and this value was used as the target heart rate during exercise training. Anaerobic threshold was determined independently by two physicians who regularly performed CPET.

Using Schiller software for exercise rehabilitation, initial workload was determined to obtain the target heart rate. The software then modifies the workload to maintain the set heart rate. The patient is instructed to cycle at 55–65 rpm. After 12 training sessions, another CPET was performed to evaluate the effect of training on exercise capacity and determine VO_2AT and HRR to allow determination of the workload during subsequent training sessions. After the second CPET, patients underwent another 12 training sessions followed by a final CPET to evaluate exercise capacity after completion of the training. Patients exercised 3–5 times a week. All training sessions and CPETs were performed in the same air-conditioned room. A single training session consisted of a 60-s warm-up period, followed by a gradual increase in workload during a period of 60 s, the actual training for 30 min, and a 90-s cool-down period. After the session, patients were observed and monitored for another 10 min. Upon completion of exercise rehabilitation, patients were given instructions regarding physical activity during daily life. They were also encouraged to participate in various forms of exercise (walking, jogging, swimming, dancing) to maintain the effects of rehabilitation.

Statistical analysis

The study parameters were reported as mean values and standard deviations or medians and quartiles for continuous variables, and using contingency tables for categorical variables. To compare percentages, the χ^2 test or the exact Fisher test was used. To evaluate whether the change after 12 and 24 training sessions differed significantly from zero, the Wilcoxon rank-sum test for paired samples or one-sample Student *t* test was used.

RESULTS

Patient characteristics are shown in Table 1. More than 60% of patients, mostly men, were obese or overweight. The mean age of the study population was 54.1 ± 7.1 years.

Table 2 shows heart rates and workload values during the first and the second series of 12 training sessions.

Among resting spiroergometric parameters, a significant increase in forced vital capacity (FVC) was observed, from 4.22 ± 0.96 L at baselines to 4.36 ± 0.98 L after 24 training sessions ($p = 0.04$). Significant increases were also noted for peak expiratory flow and the forced expiratory volume in 1 s to FVC ratio (FEV1/FVC) (Table 3).

Table 4 shows selected CPET variables. Of note, parameters of exercise capacity such as exercise duration on a treadmill, workload (VO_2peak), VO_2AT, minute ventilation, and energy expenditure expressed in metabolic equivalents (MET) increased significantly after 24 training sessions. All these parameters except for VO_2peak also increased significantly during the first and the second series of 12 training sessions. The difference in VO_2peak between CPET after 12 and 24 training sessions did not reach statistical significance.

Table 1. Clinical and biochemical characteristics of the study patients

Parameter	N = 52
Age [years]	54.1 ± 7.1
Height [cm]	174.3 ± 8.4
Body weight [kg]	82 ± 18.8
Male gender	46 (88.5%)
BMI [kg/m^2]	27.3 ± 4.4
Overweight + obesity (BMI > 25 kg/m^2)	32 (61.5%)
Overweight (BMI 25–30 kg/m^2)	20 (38.5%)
Obesity (BMI > 30 kg/m^2)	12 (23%)
Duration of hospital stay [days]	6.1 ± 2
Hypertension before admission	23 (44.2%)
Current smoking	22 (42.3%)
Diabetes type 2 before admission	5 (9.6%)
ST elevation myocardial infarction	50 (96.2%)
Non ST elevation myocardial infarction	2 (3.8%)
History of smoking	30 (57.7%)
Haemoglobin [g/dL]	13.9 ± 1.5
White cell count [$10^3/\mu L$]	9.6 ± 2.8
TnI max [ng/mL]	42.4 ± 45.7
CKMB mass max [ng/mL]	136.8 ± 159.1
Ejection fraction [%]	50.6 ± 7.62

BMI — body mass index; TnI max — peak troponin level during hospitalisation; CKMB mass max — peak creatinine kinase MB isoenzyme level during hospitalisation

DISCUSSION

Our study showed a significant increase in exercise capacity among patients undergoing outpatient cardiac rehabilitation, as reported in other clinical studies [11–13]. Resting spirometry parameters including FEV1 and FEV1/FVC also improved. Our study indicates a strong relationship between physical activity and improvement of exercise capacity. Thus, an interesting issue is the effect of improved exercise capacity on patient outcomes. A positive association between improved exercise capacity and reduction of overall and CV mortality was found in a group of coronary artery disease patients undergoing cardiac rehabilitation [14–17]. The key to success seems, however, to maintain exercise capacity at a high level. Comprehensive rehabilitation with continuous patient support and advice to maintain exercise capacity are key factors promoting mortality reduction among patients with coronary artery disease undergoing outpatient or in-hospital exercise training. An interesting analysis was performed by Lee et al. [18] who compared the effect of body weight reduction and exercise capacity on overall and CV mortality. This study included 14,345 men in whom baseline exercise capacity in MET and body mass index (BMI) were evaluated. Changes in BMI and exercise capacity during 6.3 years of follow-up were categorised as a decrease, increase, or no change. During 11.4 years of follow-up, 914 noncardiac deaths and 300 CV deaths were noted. Hazard ratios (with 95% confidence intervals [CI]) for total and CV mortality in comparison to patients with a decrease in exercise capacity were 0.70 (0.59–0.83) and 0.73 (0.54–0.98), respectively, among patients with no change of exercise capacity, and 0.61 (0.51–0.73) and 0.58 (0.42–0.80), respectively, among patients with an increase in exercise capacity. This means that overall mortality was reduced by 39% among patients in whom an increase in exercise capacity was noted. An increase in exercise capacity by 1 MET was associated with a reduction in total and CV mortality by 15–19%. BMI changes did not correlate significantly with total mortality, while CV mortality among men with an increase in body weight was 39% higher compared to men with a decrease in body weight. When adjusted for maximum change in exercise capacity, this associa-

Table 2. Heart rate and workload during cycle ergometer training in the first (12 training sessions) and the second series (additional 12 training sessions)

Parameter	First 12 training sessions (n = 52)	Second 12 training sessions (n = 52)	P
Heart rate during training [1/min]	94.8 ± 11.71	95.3 ± 13.4	> 0.1
Load [W]	57.7 ± 16.88	71.6 ± 22.87	< 0.001

Table 3. Spirometry parameters at baseline and after 12 and 24 training session in the overall study group

Parameter	Baseline (n = 52)	After 12 training sessions (n = 52)	After 24 training sessions (n = 52)	P for baseline vs. 12 sessions	P for 12 vs. 24 sessions	P for baseline vs. 24 sessions
FVC [L]	4.22 ± 0.96	4.33 ± 0.95	4.36 ± 0.98	0.1	> 0.1	0.04
FEV1 [L]	3.41 ± 0.88	3.45 ± 0.86	3.44 ± 0.88	> 0.1	> 0.1	> 0.1
FEV1/FVC	80.67 ± 9.28	79.75 ± 9.27	78.69 ± 9.32	> 0.1	> 0.1	0.03
PEF [L/min]	7.99 ± 2.13	8.32 ± 1.89	8.42 ± 1.81	0.05	> 0.1	0.02

FVC — forced vital capacity; FEV1 — forced expiratory volume in 1 s; FEV1/FVC — FEV1 to FVC ratio; PEF — peak expiratory flow

Table 4. Spiroergometry parameters at baseline and after 12 and 24 training session in the overall study group

Parameter	Baseline (n = 52)	After 12 training sessions (n = 52)	After 24 training sessions (n = 52)	P for baseline vs. 12 sessions	P for 12 vs. 24 sessions	P for baseline vs. 24 sessions
Duration [s]	519 ± 103	613 ± 119	653 ± 121	< 0.001	< 0.001	< 0.001
Load [W]	231.19 ± 66.52	291.25 ± 79.48	327.75 ± 93.72	< 0.001	< 0.001	< 0.001
HR peak [1/min]	122.92 ± 16.07	134.27 ± 17.30	138.38 ± 21.48	< 0.001	> 0.1	< 0.001
VO_2peak [mL/kg/min]	32.3 ± 7.05	36.6 ± 10.03	39.3 ± 12.27	0.003	0.065	< 0.001
VO_2AT [mL/kg/min]	18.3 ± 4.44	22.3 ± 5.63	24.7 ± 7.56	< 0.001	0.003	< 0.001
VE [L/min]	60.52 ± 18.09	75.25 ± 22.86	81.92 ± 25.18	< 0.001	0.002	< 0.001
METs	9.39 ± 1.73	10.75 ± 2.08	11.79 ± 2.24	< 0.001	< 0.001	< 0.001

HR peak — maximum heart rate during a treadmill test; VO_2peak — peak oxygen uptake during a treadmill test; VO_2AT — oxygen uptake at the anaerobic threshold; VE — minute ventilation; MET — metabolic equivalent

tion was attenuated and lost statistical significance. A decrease in exercise capacity was associated with increased total and CV mortality. These findings indirectly indicate a major role of increased exercise capacity in the effects cardiac rehabilitation, while body weight reduction is of lesser importance.

In our study, the mean increase in exercise capacity in the overall study population was 2.4 MET. This increase was significant both during the first and the second series of 12 training sessions. In light of the analysis by Lee et al. [18], an increase in exercise capacity among patients undergoing cardiac rehabilitation along with advice to maintain appropriate physical activity during daily life (weekly energy expenditure above 1500 kcal) may be expected to have a beneficial effect on patients outcomes. An increase in VO_2peak by 21.4% and in VO_2AT by 34.4% should translate to a large reduction of total and CV mortality. Of note, a significant increase in VO_2peak was obtained mostly during the first 12 training sessions, while subsequent 12 training sessions did not result in an additional significant increase in VO_2peak. Exercise duration, workload, and VO_2AT improved significantly both during the first and the second series of 12 training sessions, but these increases were considerably smaller during the second cycle of training. This observation of a smaller increase in exercise capacity during the second series of 12 training sessions brings up a question whether outpatient cardiac rehabilitation needs to be continued for 24 to 36 cycles or 2–4 months. A shortened duration of outpatient cardiac rehabilitation, which would be subsequently continued as home-based rehabilitation, would significantly increase availability of the former, as more patients might undergo outpatient cardiac rehabilitation during the same time. According to Korzeniowska-Kubacka et al. [19], home-based rehabilitation as a part of a hybrid approach that also comprised outpatient rehabilitation was similarly effective in regard to an increase in exercise capacity and improvement of sympathetic-parasympathetic nervous system activity balance as was rehabilitation performed solely on an outpatient basis.

An interesting metanalysis of the relationship between the effects and duration of cardiac rehabilitation was reported by Lawler et al. [20]. These authors analysed 34 randomised studies evaluating the effect of cardiac rehabilitation among post-MI patients on the risk of recurrent MI, cardiac mortality, and total mortality. The results of this metaanalysis confirmed high efficacy of cardiac rehabilitation in reducing these endpoints. The odds ratio (OR) for total mortality in comparison to patients who did not undergo cardiac rehabilitation was 0.74 (95% CI 0.58–0.95). For CV mortality, risk reduction was even greater (OR 0.61, 95% CI 0.40–0.91). Even short-term cardiac rehabilitation lasting 0.5–3 months was associated with a large reduction of total mortality (OR 0.71, 95% CI 0.51–1.01) and cardiac mortality (OR 0.59, 95% CI 0.34–1.03) [20]. Obviously, cardiac rehabilitation lasting longer than 3 months also led to largely improved outcomes, with reduced total mortality (OR 0.77, 95% CI 0.54–1.09) and cardiac mortality (OR 0.66, 95% CI 0.44–0.98). The authors concluded that cardiac rehabilitation reduces the risk of recurrent MI, CV death, and all-cause mortality when used for secondary prevention in patients after MI. Even short-term rehabilitation programs (0.5–3 months) were associated with a significant reduction in mortality.

No improvement in VO_2peak and much reduced increase in VO_2AT during the second series of training sessions in our study also bring up a question whether extended duration of outpatient cardiac rehabilitation is reasonable. Assuming a mean of 3 training sessions a week, the whole cycle of 12 training sessions would last only 4 weeks. This would largely increase the number of patients undergoing cardiac rehabilitation, which is of major importance especially in light of data indicating that cardiac rehabilitation is currently used in only about 25% patients after MI [21, 22]. On the other hand, longer duration of cardiac rehabilitation has a beneficial effect on other coronary risk factors including smoking, overweight, and patient compliance [23], and also reduces the rate of depression [24, 25]. To determine optimal duration of outpatient or in-hospital cardiac rehabilitation, appropriately designed randomised studies are needed, but these would unfortunately require many years of follow-up and large costs.

Limitations of the study

One major limitation of our study was the lack of a control group. Another limitation was the small number of patients studied.

CONCLUSIONS

Regular physical activity improves exercise capacity after MI as measured by CPET. A statistically significant improvement in exercise capacity was seen already after initial 12 training sessions, while another 12 training sessions were associated with smaller benefits.

Conflict of interest: *none declared*

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Wpływ czasu trwania treningu fizycznego na ergometrze rowerowym na poprawę wydolności fizycznej pacjentów po zawale serca

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Streszczenie

Wstęp: Rehabilitacja kardiologiczna pacjentów po zawale serca (MI) jest elementem prewencji wtórnej o ugruntowanej pozycji w istniejących zaleceniach klinicznych. Względny spadek śmiertelności związany z regularną aktywnością fizyczną szacuje się na 15–30%.

Cel: Ocena wpływu treningu fizycznego na parametry wydolności ustalanej na podstawie ergospirometrii wśród pacjentów po MI oraz ocena relacji między liczbą treningów a zmianą wydolności fizycznej.

Metody: Do prospektywnego badania włączono 52 osoby po MI leczone angioplastyką naczynia odpowiedzialnego za incydent niedokrwienny. W chwili rozpoczynania treningów pacjenci nie mieli jawnych cech niewydolności serca oraz objawów choroby wieńcowej. Od 4 do 6 tygodni po MI chorzy przechodzili elektrokardiograficzny test wysiłkowy. Pacjenci, u których wynik próby wysiłkowej był ujemny, byli poddani badaniu ergospirometrycznemu. Po ustaleniu wyjściowej wydolności fizycznej chorzy odbywali 12 treningów na cykloergometrze rowerowym przy obciążeniu ustalanym na podstawie progu beztlenowego lub rezerwy częstości rytmu. Po 12 treningach wykonywano drugie badanie ergospirometryczne. Następnie chorzy odbywali kolejne 12 treningów, po czym w sercowo-płucnym teście wysiłkowym ustalano ich ostateczną wydolność fizyczną.

Wyniki: U wszystkich osób zaobserwowano znaczący wzrost parametrów wydolności fizycznej: wzrost wydatku energetycznego w trakcie wysiłkowej próby ergospirometrycznej z 9,39 do 11,79 METs, czyli o 25,6%, wzrost szczytowego pochłaniania tlenu (VO_2peak) z 32,32 do 39,25 ml/kg/min, czyli o 21,5% ($p < 0,001$) oraz pochłaniania tlenu na progu beztlenowym z 18,34 do 24,65 ml/kg/min, czyli o 34,4% ($p < 0,001$). Czas wysiłku podczas ergospirometrii wydłużył się z 519 do 653 s, czyli o 25,8% ($p < 0,001$). Podobnie zwiększyło się maksymalne obciążenie podczas próby wysiłkowej z 231,19 do 327,75 W ($p < 0,001$). Wentylacja minutowa wzrosła z wyjściowych 60,52 do 81,92 l/min, czyli o 35,3% ($p < 0,001$). Pierwsze 12 treningów spowodowało istotny statystycznie wzrost szczytowego pochłaniania tlenu z 32,32 do 36,75 ml/kg/min ($p = 0,003$), podczas gdy kolejnych 12 treningów — nieistotny statystycznie wzrost z 36,75 do 39,25 ml/kg/min ($p = 0,065$).

Wnioski: Regularna aktywność fizyczna powoduje poprawę wydolności fizycznej zmierzonej za pomocą badania ergospirometrycznego po MI. Już 12 treningów pod nadzorem rehabilitanta istotnie statystycznie poprawia wydolność fizyczną, podczas gdy kolejne 12 treningów wiąże się z mniejszymi korzyściami.

Słowa kluczowe: rehabilitacja, wydolność fizyczna, zawał serca, ergospirometria, sercowo-płucny test wysiłkowy

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