Kardiologia Polska 2015; 73, 2: 118–126; DOI: 10.5603/KP.a2014.0165 ISSN 0022–9032

ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

A novel model of exercise walking training in patients after coronary artery bypass grafting

Jadwiga Wolszakiewicz[1], Ewa Piotrowicz[2], Bogna Foss-Nieradko[3], Barbara Dobraszkiewicz-Wasilewska[1], Ryszard Piotrowicz[1]

[1]Department of Cardiac Rehabilitation and Noninvasive Electrocardiology, National Institute of Cardiology, Warsaw, Poland
[2]Telecardiology Centre, National Institute of Cardiology, Warsaw, Poland
[3]Unit for Screening Studies in Inherited Cardiovascular Diseases, National Institute of Cardiology, Warsaw, Poland

Abstract

Background: Exercise training is an established, guideline-recommended treatment approach in cardiovascular disease. Designing novel methods of exercise training that would be accepted by the patients seems to be a way to increase patient attendance at cardiac rehabilitation (CR). The 6-min walking test (6-MWT) is a simple, safe and objective method to assess exercise capacity. In patients without heart failure, oxygen consumption after 6 min of walking reaches the ventilatory threshold (VT) level. Training up to the VT level is recommended in CR. Theoretical grounds exist for designing a novel model of CR based on diagnostic 6-MWT.

Aim: Pilot implementation and evaluation of the effectiveness of a new form of walking training based on 6-MWT in low-risk patients after coronary artery bypass grafting (CABG).

Methods: The study included 119 men after CABG undergoing phase II CR. Depending on whether patients granted a consent to undergo home-based electrocardiography (ECG) telemonitored CR or not, they were divided into two groups: group A (60 patients) — standard CR combined with the new model (walking 6 times for 6 min with 3-min intervals) for 5 days a week; and group B (59 controls) — standard CR. At baseline and after 3 and 12 months, the patients underwent the following tests: 6-MWT, 24-h Holter ECG monitoring (including evaluation of heart rate variability), and biochemical laboratory tests.

Results: No significant differences in 6-MWT distance were found between the groups at baseline and at 3 and 12 months. At 3 months, 6-MWT distance increased significantly in both groups (group A: 419 ± 73 vs. 515 ± 70 m, $p < 0.02$; group B: 422 ± 86 vs. 519 ± 73 m, $p < 0.02$). At 3 and 12 months, body mass was higher in group B controls ($p < 0.05$). At 3 months, glycaemia and high-sensitivity C-reactive protein (hsCRP) levels were significantly lower in group A patients ($p < 0.05$). At 12 months, triglyceride levels were higher in group B ($p < 0.05$). At 3 months, SDNN was higher in group A. After 12 months, LF was lower in group A. At baseline, the LF/HF ratio was significantly higher in group A ($p < 0.05$) but during further follow-up, favourable changes in the LF/HF ratio were noted only in group A.

Conclusions: The novel model of exercise walking training had a favourable effect on body mass, glycaemia and hsCRP level reduction, and induced favourable changes of the sympathovagal balance.

Key words: cardiac rehabilitation, telerehabilitation, 6-min walking test, walking training

Kardiol Pol 2015; 73, 2: 118–126

INTRODUCTION

Exercise training is an established, guideline-recommended treatment approach in patients after coronary artery bypass grafting (CABG), among others [1, 2]. In this context, concerning data indicate that a low proportion of such patients (below 20%) is referred for phase II comprehensive cardiac rehabilitation (CR) [3, 4]. This is particularly the case with low-risk patients who, due to their experiences related to the surgery, are unwilling to be admitted again for inpatient CR. Outpatient rehabilitation is also not accepted by patients due to

Address for correspondence:
Jadwiga Wolszakiewicz, MD, PhD, Department of Cardiac Rehabilitation and Noninvasive Electrocardiology, National Institute of Cardiology, ul. Alpejska 42, 04–628 Warszawa, Poland, e-mail: jwolszakiewicz@ikard.pl
Received: 14.05.2014 **Accepted:** 07.07.2014 **Available as AoP:** 21.08.2014

following reasons: inconvenient transportation, incompatibility with professional activities, financial burdens, and insufficient knowledge regarding the need for and benefits of rehabilitation [3]. A question thus arises how to increase physical activity of patients after CABG. Development of new, simple-to-use forms of physical training that would be easily acceptable for the patients seems to be an important research direction.

According to the current knowledge on designing physical exercise in patients with cardiovascular disease, an optimal solution would be endurance, interval training of adequate intensity (measurable in an objective way) that might be undertaken in any conditions and time [5]. In addition to fulfilling the above conditions, the training should be effective and safe. Walking is the most common form of everyday physical activity, recommended to increase daily physical activity, but this form of physical training has not been included in rehabilitation guidelines. One difficulty are problems with objective evaluation of this form of exercise. The most popular diagnostic walking test, the 6-min walking test (6-MWT), is a simple, safe, and objective method to evaluate exercise capacity in patients with coronary artery disease (CAD) [6, 7]. Clinical studies indicate that in patients without heart failure, tissue oxygen uptake reaches ventilatory threshold level after 6 min of walking [8]. Training up to the ventilatory threshold level is recommended in CR [5]. Thus, theoretical grounds exist to develop a new form of training based on 6-MWT. We suggest performing 6-MWT repeated 6 times with 3-min intervals between walking sessions. The aim of our study was to introduce this new form of exercise walking training and to evaluate its effectiveness.

METHODS

Study material

We studied 119 low-risk men who underwent phase II CR after CABG. Exclusion criteria included heart failure, unstable angina, perioperative myocardial infarction, concomitant valve surgery and/or transmyocardial laser revascularisation, atrial fibrillation, implanted pacemaker, massive postcardiotomy syndrome, anaemia (haemoglobin level < 10.0 g/dL), peripheral arterial disease, conditions limiting patient's ability to walk, and poorly controlled diabetes.

Depending on patient's consent to continue rehabilitation supervised using home electrocardiographic (ECG) telemonitoring, patients were divided into two groups:

- Group A (60 patients) — standard rehabilitation (as in group B) combined with the new training model undertaken for 3 months;
- Group B (59 patients) — standard rehabilitation (breathing exercises, isometric exercises of small muscle groups, general conditioning exercises, monitored interval training using cycloergometer or treadmill). Total daily training duration was 30 to 60 min. Training was undertaken 6 days a week for 3 to 4 weeks.

Pilot implementation of the new form of training

Interval walking training was undertaken for 36 min per day (walking 6 times for 6 min, with 3-min intervals) for 3 months after CABG. In hospital settings, it was undertaken daily, and in home-based settings it was performed 5 times a week. Monitoring was deemed necessary to evaluate safety of the new model, similarly to standard training. ECG telemonitoring was used to supervise training in home-based conditions.

Home-based training monitoring

We used an ECG telemonitoring system that allows simultaneous management of the training session and verbal contact via a mobile phone. The ECG recording device was equipped with 4 leads placed on the patient's chest. Training sessions according to the developed model were programmed in the device. Before initiation of the training cycle, patients transmitted a resting ECG tracing to the monitoring centre and received a permission to start a training session if no abnormalities were seen. The planned cycle of the interval walking training was directed by light and sound signals emitted by the device, providing synchronisation with the planned duration of the training cycle phases. At peak exercise, ECG was automatically recorded by the device.

Study protocol

At baseline and at 3 and 12 months, patients underwent the following tests to evaluate the effectiveness of training.

Six-minute walking test. The test was performed after at least 10 min of rest. The patients were walking at a comfortable pace, making breaks as necessary, on a flat 25-m long course. Heart rate was measured by telemetry at rest (HR-P) and after 6 min of walking (HR-K). The 6-min walking distance was evaluated.

Laboratory tests. These included lipid profile (total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides) evaluated by colorimetric and spectrometric methods, serum fasting glucose level by the hexokinase method, and serum high-sensitivity C-reactive protein (hsCRP) level by latex-enhanced immunoturbidimetric method.

Holter monitoring. The Spacelabs system (Del Mar, Reynolds, Heartford, UK) was used for Holter monitoring. We evaluated minimum, mean, and maximum heart rate, the presence of arrhythmias, and heart rate variability (HRV). HRV analysis included time domain measures (standard deviation of the mean RR interval — SDNN) and frequency domain measures (fast Fourier transformation of five 5-min ECG recordings between 2 and 6 AM). Extremes values were discarded, and the remaining values were averaged. Low frequency (LF) component was defined as oscillations in the range of 0.04–0.15 Hz, and high frequency (HF) component was defined as oscillations in the range of 0.15–0.4 Hz. The LF/HF ratio was calculated.

Statistical analysis

Statistical analysis was performed using the SAS statistical package. For between-group comparisons of variable distributions, the Student *t* test was used for normally distributed continuous variables, and the nonparametric Wilcoxon rank test for non-normally distributed continuous variables. Normal distribution of variables was evaluated using the Shapiro-Wilk test. In addition, parametric linear regression analysis was performed using the respective SAS package programme. The significance level was set at $p < 0.05$.

The study was approved by the Bioethics Committee at the National Institute of Cardiology in Warsaw. All patients gave their written informed consent for participation in the study.

RESULTS

Baseline characteristics of the study groups

The two groups differed by age, as patients in group A were older. Patients in group A started phase II CR at a later time and had a higher number of bypass grafts. No differences were noted between groups in regard to CAD risk factors, postoperative complications, and drug therapy (Table 1).

Evaluation of the effectiveness of the new training model (Table 2)

Body mass. At baseline, the mean body mass [kg] did not differ significantly between the two groups. At 3 and 12 months, body mass was higher in group B.

Six-minute walking test. The 6-MWT distance did not differ significantly between groups at baseline and at 3 and 12 months. The increase in 6-MWT distance at 3 months was significant in both groups (group A: 419 ± 73 vs. 515 ± 70 m, $p < 0.02$; group B: 422 ± 86 vs. 519 ± 73 m, $p < 0.02$). No increase in 6-MWT distance was noted between 3 and 12 months. In linear regression analysis, the only independent predictor of the increase in 6-MWT distance was low 6-MWT distance at baseline (Table 3).

Laboratory tests. Serum lipid levels were comparable in the two groups at baseline and at 3 months. An increase in total cholesterol and triglyceride levels was seen in group B at 12 months. Fasting glucose and hsCRP levels did not differ between the two groups at baseline and at 12 months, while at 3 months, fasting glucose levels were significantly lower in group A compared to group B.

Holter ECG monitoring. Minimum, mean, and maximum heart rate did not differ significantly between the groups

Table 1. Study group characteristics

Variable	Group A (n = 60)	Group B (n = 59)	P
Age [years]	60 ± 7.8	56 ± 7.9	< 0.02
Body mass [kg]	80.0 ± 10.1	80.52 ± 9.5	NS
Body mass index [kg/m^2]	27.3 ± 3.0	27.1 ± 2.8	NS
Hypertension	50 (83%)	47 (80%)	NS
Smoking	12 (20%)	14 (24%)	NS
Diabetes	12 (20%)	11 (20%)	NS
History of hyperlipidaemia	57 (95%)	57 (95%)	NS
Ejection fraction [%]	57.1 ± 7.4	56.4 ± 6.2	NS
Previous myocardial infarction	19 (32%)	17 (28%)	NS
Number of stenosed coronary arteries before CABG	2.6 ± 0.5	2.3 ± 0.7	< 0.05
Number of coronary bypass grafts	2.56 ± 0.7	2.3 ± 1.03	< 0.05
Onset of rehabilitation (days after CABG)	14.5 ± 7	12.3 ± 4.7	< 0.05
Postoperative complications:			
Pericardial effusion	3 (5%)	4 (7%)	NS
Pleural effusion	18 (30%)	14 (23%)	NS
Cardiac arrhythmia	4 (6%)	3 (5%)	NS
Medications:			
Beta-blocker	60 (100%)	57 (97%)	NS
ACE inhibitor	58 (97%)	59 (100%)	NS
Statin	60 (100%)	59 (100%)	NS
Aspirin	58 (97%)	59 (100%)	NS

Group A — standard phase II cardiac rehabilitation and new training model for 3 months after CABG; group B — standard phase II cardiac rehabilitation; ACE — angiotensin-converting enzyme; CABG — coronary artery bypass grafting

Table 2. Comparison of the evaluated variables (group A vs. group B) at various time points

Variable	Time points					
	0M		3M		12M	
	Group A (n = 60)	Group B (n = 59)	Group A (n = 60)	Group B (n = 59)	Group A (n = 60)	Group B (n = 59)
Body mass [kg]	80.1 ± 10.3	80.5 ± 9.5	**79.8 ± 9.6**	**82.6 ± 9.9***	**81.8 ± 9.6**	**84.7 ± 10.3***
6-MWT distance [m]	419 ± 73	422 ± 86	515 ± 70	519 ± 73	512 ± 72	520 ± 76
HR-P (6-MWT)	75 ± 10	75 ± 12	68 ± 9	67 ± 8	71 ± 10	68 ± 10
HR-K (6-MWT)	89 ± 11	92 ± 12	**87 ± 17**	**91 ± 14***	94 ± 14	93 ± 11
TC [mmol/dL]	4.0 ± 0.8	4.1 ± 0.9	4.0 ± 0.9	3.9 ± 0.8	**4.0 ± 0.9**	**4.3 ± 1.0#**
HDL-C [mmol/dL]	0.97 ± 0.2	1.0 ± 0.5	1.2±0.3	1.2 ± 0.25	1.3 ± 0.3	1.3 ± 0.3
LDL-C [mmol/dL]	2.53 ± 0.7	2.64 ± 0.9	2.4 ± 0.7	2.3 ± 0.7	2.5 ± 0.9	2.4 ± 0.7
TG [mmol/dL]	1.6 ± 0.7	1.5 ± 0.6	1.4 ± 0.7	1.3 ± 0.5	**1.3 ± 0.5**	**1.5 ± 0.7***
Glucose [mmol/dL]	5.6 ± 2.2	5.3 ± 0.7	**5.6 ± 1.0**	**6.2 ± 2.1***	6.0 ± 1.4	5.8 ± 0.3
hsCRP [mg/dL]	1.5 ± 1.8	1.5 ± 1.6	**0.27 ± 0.3**	**0.33 ± 0.6***	0.25 ± 0.4	0.21 ± 0.3

*p < 0.05; #p = 0.054 (group A vs. group B); group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation; 0M — baseline; 3M — 3 months; 12M — 12 months; 6-MWT — 6-min walking test; HR-P — heart rate before 6-MWT; HR-K — heart rate at the end of 6-MWT; TC — total cholesterol; LDL-C — low-density lipoprotein cholesterol; HDL-C — high-density lipoprotein cholesterol; TG — triglycerides; hsCRP — high-sensitivity C-reactive protein

Table 3. Univariate linear regression analysis evaluating the relations between baseline walk distance, variables showing baseline differences between the two groups, and the increase in walk distance at 12 months. Dependent variable — increase in 6-MWT distance at 12 months after CABG

Variable	Increase in walk distance at 12M vs. 0M		
	Regression coefficient	Standard error	P
Age [years]	–0.33983	0.99127	0.7326
Number of stenosed coronary arteries before CABG	–8.43906	15.11251	0.5780
Number of coronary bypass grafts	–4.38875	10.77463	0.6848
Onset of rehabilitation (days after CABG)	–0.38688	1.16377	0.7404
6-MWT distance at baseline	–0.50403	0.08055	< 0.0001

Group A — standard phase II cardiac rehabilitation and new training model for 3 months after CABG; group B — standard phase II cardiac rehabilitation; 0M — baseline; 12M — 12 months; 6-MWT — 6-min walking test; CABG — coronary artery bypass grafting

at any of the time points (Table 4). Comparable reductions in heart rate were seen in both groups at 3 months after CABG.

SDNN did not differ significantly between the two groups at baseline and at 12 months. At 3 months, SDNN was significantly higher in group A compared to group B (Fig. 1, Table 4).

The HRV-LF component did not differ significantly between the two groups at baseline and at 3 months. At 12 months, it was significantly lower in group A (Fig. 2, Table 4).

The HRV-HF component did not differ significantly between the two groups at baseline and at 3 and 12 months (Fig. 3, Table 4).

Although at baseline the LF/HF ratio was significantly higher in group A, no differences in the LF/HF ratio between the two groups were seen at 3 and 12 months (Fig. 4, Table 4).

Adverse events during 12 months of follow-up. The number of patients with complications and the types of complications did not differ significantly between the two groups (Table 5).

DISCUSSION

Unsatisfactory patient participation in CR has prompted a search for new forms of exercise training that would be effective, safe, acceptable for the patients, and feasible in home conditions. We developed a new training model based on 6-MWT which was implemented in 60 patients during phase II CR following CABG. To evaluate its effectiveness, we assessed cardiovascular risk factors that are most readily modifiable following training, including exercise tolerance, body mass, serum glucose, hsCRP, lipid profile, and autonomic balance.

Table 4. Comparison (group A vs. group B) of 24-hour Holter monitoring variables

Variable	Time points					
	0M		3M		12M	
	Group A (n = 60)	Group B (n = 59)	Group A (n = 60)	Group B (n = 59)	Group A (n = 60)	Group B (n = 59)
HR-min	57 ± 8	58 ± 9	52 ± 7	52 ± 6	51 ± 7	51 ± 6
HR-max	101 ± 14	104 ± 13	103 ± 13	106 ± 13	107 ± 17	105 ± 14
HR-avg	71 ± 8	74 ± 10	69 ± 8	69 ± 7	69 ± 9	67 ± 8
SDNN [ms]	99.7 ± 28	98.9 ± 28.9	**132 ± 34**	**122 ± 37***	133 ± 28	127 ± 34
LF [ms²/Hz]	310 ± 931	228 ± 211	242 ± 223	282 ± 211	**298 ± 381**	**526 ± 739***
HF [ms²/Hz]	201 ± 255	159 ± 173	198 ± 267	202 ± 196	271 ± 409	280 ± 294
LF/HF	**4.5 ± 2.4**	**2.23 ± 2.7***	1.7 ± 1.3	1.8 ± 1.1	2.0 ± 2.1	2.3 ± 1.98

*$p < 0.05$ (group A vs. group B); Group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation; 0M — baseline; 3M — 3 months; 12M — 12 months; HR-min — minimum heart rate during 24-h monitoring; HR-max — maximum heart rate during 24-h monitoring; HR-avg — average heart rate during 24-h monitoring; SDNN — standard deviation of the mean RR interval; LF — low frequency component of the heart rate variability spectrum; HF — high frequency component of the heart rate variability spectrum

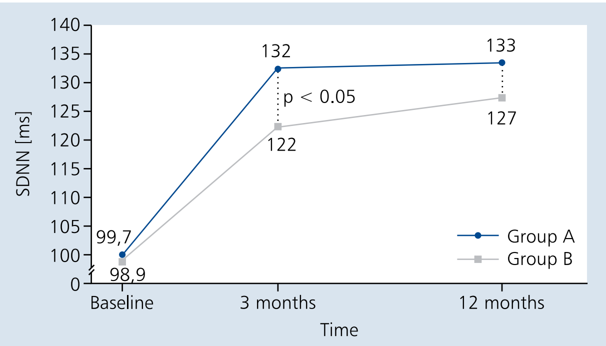

Figure 1. Heart rate variability time domain analysis (SDNN — standard deviation of the mean RR interval). SDNN at 3 months was significantly higher in group A compared to group B; group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation

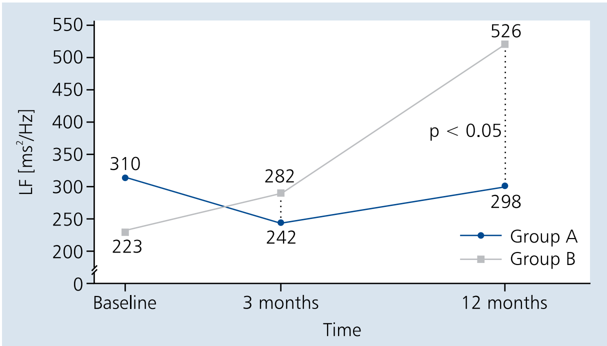

Figure 2. Heart rate variability frequency domain analysis (LF — low frequency component of the heart rate variability spectrum). At baseline, LF was non-significantly higher in group A compared to group B. At 3 months, LF decreased in group A and increased in group B. Further significant increase in LF was seen in group B from 3 till 12 months of follow-up, with only a slight change in group A; group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation

Exercise tolerance

At baseline, 6-MWT distance was comparable in both groups (group A vs. group B: 419 ± 73 vs. 422 ± 86 m, p = NS). In the 2007 study by Fiorina et al. [9], 6-MWT was performed in 1370 patients at 15 days after cardiac surgery and the mean walk distance was 328 ± 34 m. In the study by Opasich et al. [10], 6-MWT was performed in 2555 patients during phase II CR following cardiac surgery, and the mean walk distance was 296 ± 111 m. The walk distance was affected by age, gender, concomitant conditions, and left ventricular ejection fraction [10]. Patients in our study had preserved ejection fraction, and significant concomitant conditions were among the exclusion criteria, likely contributing to good exercise tolerance in our study population. The increase in walk distance at 3 months after CABG was comparable in both groups. In the study by Fiorina et al. [9], an increase in walk distance was affected not only by exercise training but also by low walk distance at baseline, which was confirmed by our observations. At 3 months, 6-MWT distance was similar to predicted age-specific values. This probably explains why the increase in walk distance was similar in both groups regardless of the training "dose" (standard rehabilitation vs. standard rehabilitation combined with pilot walking training).

At 3 months after CABG, heart rate at the end of 6-MWT was significantly lower in group A. Thus, patients walked

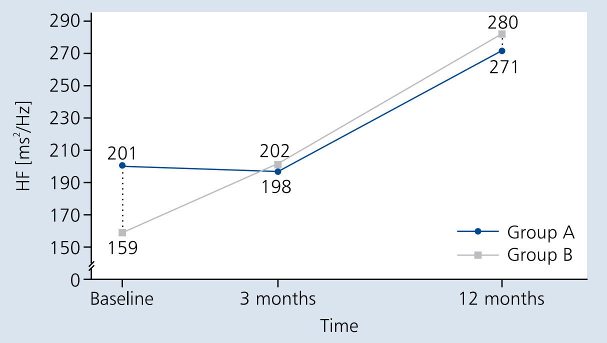

Figure 3. Heart rate variability frequency domain analysis (HF — high frequency component of the heart rate variability spectrum); group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation

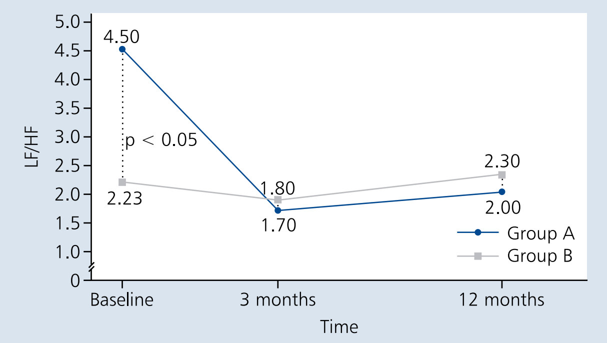

Figure 4. Heart rate variability frequency domain analysis (LF/HF — low frequency component of the heart rate variability spectrum/high frequency component of the heart rate variability spectrum). At baseline, LF/HF was significantly higher in group A compared to group B. At 3 months, LF/HF decreased significantly in group A and only modestly in group B. Further modest increase in LF/HF was seen in both groups from 3 till 12 months of follow-up; group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation

Table 5. Complications during follow-up.

Variable	Group A (n = 60)	Group B (n = 59)	P
Angina[1]	9	4	0.06
Heart failure[2]	0	1	NS
Arrhythmia[3]	4	3	NS
Hospitalisation	1	1	NS

Group A — standard phase II cardiac rehabilitation and new training model for 3 months after coronary artery bypass grafting; group B — standard phase II cardiac rehabilitation; [1]Angina de novo or increase in the Canadian Cardiovascular Society class; [2]Development of heart failure symptoms requiring diuretic therapy and hospitalisation; [3]Atrial fibrillation documented by electrocardiography or Holter monitoring, hospitalisation due to atrial fibrillation in 1 patient

a comparable distance with a lower increase in heart rate during exercise (which results in lower energy expenditure). This indicates better improvement in exercise tolerance and may be associated with favourable changes of the autonomic balance.

Body mass

In our study, lack of additional training led to a significant increase in body mass. Patients in both groups received the same dietary recommendations, consistent with the current guidelines. Moderate exercise training without reduction of caloric intake results in only modest reduction of body mass (by 2–3 kg at 3–6 months) [5]. In a study by Lavie et al. [11], 3-month exercise training in patients with CAD did not result in reduction of body mass but decreased body fat content. Increase in body mass due to increased amount of fat and metabolic consequences of overweight are established cardiovascular risk factors. By reducing the increase in body mass, our new model of walking training may have a favourable effect on cardiovascular risk.

Serum glucose

A significant increase in serum glucose level was seen in the control group at 3 months, which might have been related to significant increase in body mass and lower physical activity. No changes in serum glucose level were seen in the intervention group. Exercise improves insulin sensitivity and reduces hepatic glucose production. A favourable effect of physical training on glucose metabolism is more pronounced in obese patients, patients with diabetes or metabolic syndrome, and patients with a low level of physical activity [11, 12]. These factors were not more prevalent in the intervention group.

C-reactive protein

We noted a significant reduction in hsCRP level at 3 months after CABG, with significantly lower hsCRP levels in group A compared to group B at 3 months. An increase in hsCRP level is seen after CABG, with return to normal values within 4–6 weeks after the surgery. In patients with atherosclerosis, hsCRP levels are higher and correlate with other risk factors for CAD including a low level of physical activity [13]. An increased hsCRP level is a risk factor for cardiovascular events and mortality. Systematic exercise training is an independent factor leading to reduction in hsCRP level [14]. Significantly lower hsCRP levels seen in patients in the intervention group confirm a favourable effect of the new training model on the reduction of systemic inflammatory response.

Lipid levels

All patients received statin treatment. Total cholesterol, HDL cholesterol, and triglyceride levels were within the ranges recommended in the guidelines. Only LDL cholesterol levels were higher than the recommended values at all time points [1]. Significant changes were noted only for triglyceride level in the intervention group at 12 months. Studies evaluating the effect of training on lipid levels have been heterogeneous, with different patient characteristics, duration of follow-up, training intensity, diets, and drug therapies. High lipid levels at baseline (which were not seen in our study population) are a factor which shows the strongest effect on lipid level reduction with training [1]. In our study, walking training had an unclear effect on lipid parameters. Lower triglyceride levels at 12 months might have been related to lower body mass in group A which, however, was a remote effect of walking training

Evaluation of the autonomic system

Although at baseline LF and HF values did not differ significantly between the groups, baseline LF/HF ratio was significantly higher in group A. This adverse phenomenon was likely an effect of more advanced coronary artery disease. However, this situation improved during follow-up. Although LF, HF, and the LF/HF ratio at 3 months did not differ between the two groups, analysis of temporal trends indicated a favourable effect of training (with dramatic intersection of curves in Fig. 2–4), with a significant decrease in LF and an increase in HF in group A, resulting in a favourable change of the LF/HF ratio. At 12 months, this trend in group A continued, although the only significant effect was noted for LF which was significantly lower compared to group B. SDNN did not differ at baseline and increased significantly in Group A at 3 months. At 12 months, SDNN did not differ significantly between the two groups, with a trend for slightly higher, i.e. more favourable values in group A.

Discordant data regarding the effect of training on HRV which are available in the literature [15] result from differences in patient age and duration and intensity of the training. Literature data indicate that HRV may be affected by physical activity lasting for at least 12 weeks, which occurred only in group A in our study. Our findings indicate that the proposed walking training favourably modifies autonomic balance (reduction in the LF/HF ratio), mostly by reducing unfavourable sympathetic activity. Also in the study by Takeyama et al. [16] who evaluated the effect of exercise training on the autonomic nervous system in patients after CABG, normalisation of the sympathetic system function preceded that of the parasympathetic system. Similar findings were noted in a study that compared the effect of 3-month intensive or moderate training on exercise tolerance and HRV in patients undergoing home-based CR after CABG or myocardial infarction [17]. The improvement in exercise tolerance was higher in the intensive training group, and SDNN was improved only by intensive training, with favourable modification of the autonomic activity and improvement in exercise tolerance persisting at 1 year after cessation of the training [17, 18].

Increased sympathetic activity is a risk factor for arrhythmia, cardiovascular events, and sudden death. CR based on the new model of walking training reduces the risk of these adverse outcomes by decreasing sympathetic activity. Our findings indicate that improvement in exercise tolerance occurs and persists after as few as 4 weeks of training, while long-term exercise training is necessary for its pleotropic effects to develop [19].

Limitations of the study

Patients were not randomised into study groups. Our finding cannot be extrapolated to women. Favourable differences between study groups were often not significant, perhaps due to physical activity in the control group which was unaccounted for (but recommended). One-year follow-up period was too short to evaluate the effect of training on hard endpoints such as sudden cardiac deaths, cardiovascular mortality, and total mortality. The study was a single-centre one but its findings warrant designing appropriate multicentre studies on this issue.

CONCLUSIONS

1. Our new model of interval training based on 6-MWT is feasible both in hospital and home-based settings.
2. The proposed model of interval walking training has a favourable effect on body mass reduction, carbohydrate metabolism, reduction of systemic inflammatory response, and autonomic balance.
3. Characteristics of the new training model (safe, effective, and feasible to implement and evaluate objectively in any settings) suggest that its implementation may contribute to increased physical activity of post-CABG patients.
4. Our findings warrant designing appropriate large-scale studies to evaluate effectiveness of the proposed form of training and feasibility of its implementation in cardiac rehabilitation.

Conflict of interest: *none declared*

References

1. Perk J, De Backer G, Gohlke H et al. European guidelines on cardiovascular disease prevention in clinical practice (version 2012): the fifth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). Int J Behav Med, 2012; 19: 403–488.
2. Taylor RS, Brown A, Ebrahim S et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med, 2004; 116: 682–692.
3. Suaya JA, Shepard DS, Normand SL et al. Use of cardiac rehabilitation by Medicare beneficiaries after myocardial infarction or coronary bypass surgery. Circulation, 2007; 116: 1653–1662.
4. Jankowski P, Niewada M, Bochenek A et al. Optimal model of comprehensive rehabilitation and secondary prevention. Kardiol Pol, 2013; 71: 995–1003.

5. Fletcher GF, Balady GJ, Amsterdam EA et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation, 2001; 104: 1694–1740.
6. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med, 2002; 166: 111–117.
7. Enright PL. The six-minute walk test. Respir Care, 2003; 48: 783–785.
8. Gayda M, Temfemo A, Choquet D, Ahmaidi S. Cardiorespiratory requirements and reproducibility of the six-minute walk test in elderly patients with coronary artery disease. Arch Phys Med Rehabil, 2004; 85: 1538–1543.
9. Fiorina C, Vizzardi E, Lorusso R et al. The 6-min walking test early after cardiac surgery. Reference values and the effects of rehabilitation programme. Eur J Cardiothorac Surg, 2007; 32: 724–729.
10. Opasich C, De Feo S, Pinna GD et al. Distance walked in the 6-minute test soon after cardiac surgery: toward an efficient use in the individual patient. Chest, 2004; 126: 1796–1801.
11. Lavie CJ, Milani RV. Effects of cardiac rehabilitation and exercise training in obese patients with coronary artery disease. Chest, 1996; 109: 52–56.
12. Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS, Jr. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. N Engl J Med, 1991; 325: 147–152.
13. Huffman KM, Samsa GP, Slentz CA et al. Response of high-sensitivity C-reactive protein to exercise training in an at-risk population. Am Heart J, 2006; 152: 793–800.
14. Milani RV, Lavie CJ, Mehra MR. Reduction in C-reactive protein through cardiac rehabilitation and exercise training. J Am Coll Cardiol, 2004; 43: 1056–1061.
15. Sandercock GR, Bromley PD, Brodie DA. Effects of exercise on heart rate variability: inferences from meta-analysis. Med Sci Sports Exerc, 2005; 37: 433–439.
16. Takeyama J, Itoh H, Kato M et al. Effects of physical training on the recovery of the autonomic nervous activity during exercise after coronary artery bypass grafting: effects of physical training after CABG. Jpn Circ J, 2000; 64: 809–813.
17. Tygesen H, Wettervik C, Wennerblom B. Intensive home-based exercise training in cardiac rehabilitation increases exercise capacity and heart rate variability. Int J Cardiol, 2001; 79: 175–182.
18. Sato S, Makita S, Majima M. Additional physical activity during cardiac rehabilitation leads to an improved heart rate recovery in male patients after coronary artery bypass grafting. Circ J, 2005; 69: 69–71.
19. Moholdt TT, Amundsen BH, Rustad LA et al. Aerobic interval training versus continuous moderate exercise after coronary artery bypass surgery: a randomized study of cardiovascular effects and quality of life. Am Heart J, 2009; 158: 1031–1037.

Nowy model treningu marszowego u pacjentów po operacji pomostowania tętnic wieńcowych

Jadwiga Wolszakiewicz[1], Ewa Piotrowicz[2], Bogna Foss-Nieradko[3], Barbara Dobraszkiewicz-Wasilewska[1], Ryszard Piotrowicz[1]

[1]Klinika Rehabilitacji Kardiologicznej i Elektrokardiologii Nieinwazyjnej, Instytut Kardiologii, Warszawa
[2]Centrum Telekardiologii, Instytut Kardiologii, Warszawa
[3]Ośrodek Badań Przesiewowych Dziedzicznych Chorób Układu Krążenia, Instytut Kardiologii, Warszawa

Streszczenie

Wstęp: Trening fizyczny jest uznaną w standardach metodą terapii chorób układu sercowo-naczyniowego. Niepokojące są dane wskazujące na niski udział pacjentów po operacji pomostowania tętnic wieńcowych (CABG) w II etapie rehabilitacji kardiologicznej. Powstaje pytanie, jak zwiększyć aktywność fizyczną osób z grupy niskiego ryzyka po CABG? Istotnym kierunkiem poszukiwań jest opracowanie nowych akceptowanych przez pacjentów form treningu. Marsz jest najczęściej wykonywaną czynnością dnia codziennego, a nie jest uznaną w standardach rehabilitacji formą treningu. Jedną z przyczyn są trudności w obiektywizacji tego wysiłku. Diagnostyczny 6-minutowy test marszowy (6-MWT) jest prostą, bezpieczną i obiektywną metodą oceny wydolności fizycznej. U pacjentów bez cech niewydolności serca tkankowe pochłanianie tlenu po 6 minutach marszu osiąga poziom progu beztlenowego (VT). Trening do poziomu VT jest zalecany w rehabilitacji kardiologicznej. Istnieją więc przesłanki teoretyczne do opracowania nowego modelu rehabilitacji kardiologicznej na podstawie 6-MWT.

Cel: Celem pracy były pilotażowe wdrożenie i ocena efektywności nowej formy treningu marszowego opartego na właściwościach 6-MWT u pacjentów z grupy niskiego ryzyka po CABG.

Metody: Do badania włączono 119 mężczyzn w II etapie rehabilitacji kardiologicznej po CABG. W zależności od wyrażonej zgody na kontynuację rehabilitacji domowej monitorowanej tele-EKG pacjentów podzielono na dwie grupy: grupa A (GrA; 60 pacjentów) — standardowa rehabilitacja (jak grupa B) rozszerzona o nowy model treningu stosowany przez 36 minut dziennie (marsz 6 razy po 6 minut, przerywany 3-minutowym odpoczynkiem), przez 5 dni w tygodniu do 3 miesięcy po

CABG; grupa B (GrB; 59 pacjentów) — rehabilitowana wg obowiązujących standardów. Na wstępie, po 3 i po 12 miesiącach pacjenci byli poddani badaniom obejmującym ocenę kliniczną, 6-MWT, 24-godzinne EKG metodą Holtera z określeniem zmienności rytmu zatokowego (HRV), badania laboratoryjne (lipidogram, glukoza na czczo, hsCRP).

Wyniki: Na wstępie, po 3 i po 12 miesiącach dystans marszu w 6-MWT nie różnił się istotnie między grupami. Do 3. miesiąca w obu grupach stwierdzono istotny przyrost dystansu marszu w 6-MWT [m] (GrA: 419 ± 73 *vs.* 515 ± 70; p < 0,02; GrB: 422 ± 86 *vs.* 519 ± 73; p < 0,02). Od 3. do 12. miesiąca nie zaobserwowano zmian w dystansie marszu w obu grupach. W analizie regresji liniowej jednoczynnikowej wykazano, że niezależnym czynnikiem wpływającym na przyrost dystansu marszu był niski wyjściowy dystans marszu. Wyjściowo masa ciała [kg] pacjentów w obu grupach nie różniła się istotnie (GrA *vs.* GrB: 80,1 ± 10,3 *vs.* 80,5 ± 9,5; p = NS). Po 3 miesiącach (GrA *vs.* GrB: 79,8 ± 9,6 *vs.* 82,6 ± 9,9; p < 0,05) i po 12 miesiącach (GrA *vs.* GrB: 81,8 ± 9,6 *vs.* 84,7 ± 10,3; p < 0.05) pacjenci z GrB charakteryzowali się większą masą ciała. Stężenia lipidów, glukozy i hsCRP były porównywalne w obu grupach na wstępie. Po 3 miesiącach w GrA wartości glikemii [mmol/dl] (GrA *vs.* GrB: 5,6 ± 1,0 *vs.* 6,2 ± 5,1; p < 0.05) i hsCRP [mg/ml] (GrA *vs.* GrB: 0,27 ± 0,3 *vs.* 0,33 ± 0,6; p < 0.05) były istotnie niższe. Po 12 miesiącach glikemia i hsCRP nie różniły się między grupami, a w GrB zaobserwowano wzrost stężenia triglicerydów [mmol/dl] (GrA *vs.* GrB: 1,3 ± 0,5 *vs.* 1,5 ± 0,7; p < 0.05). Minimalna, średnia i maksymalna częstotliwość rytmu serca nie różniła się między grupami w kolejnych etapach obserwacji. Składowa czasowa HRV-SDNN [ms] nie różniła się między grupami na wstępie (GrA *vs.* GrB: 99,7 ± 28,3 *vs.* 98,9 ± 28,9; p = NS). W GrA po 3 miesiącach SDNN było wyższe (GrA *vs.* GrB: 132 ± 34 *vs.* 122 ± 37; p < 0,05). Po 12 miesiącach (GrA *vs.* GrB: 133 ± 28 *vs.* 127 ± 34; p = NS) nie było różnic w zakresie SDNN między grupami. Składowa częstotliwościowa HRV-LF [ms^2/Hz] nie różniła się pomiędzy grupami na wstępie (GrA *vs.* GrB: 310 ± 931 *vs.* 228 ± 211; p = NS) i po 3 miesiącach (GrA *vs.* GrB: 242 ± 223 *vs.* 282 ± 211; p = NS). Po 12 miesiącach LF było istotnie niższe w GrA (GrA *vs.* GrB: 298 ± 381 *vs.* 526 ± 739; p < 0,05). Składowa częstotliwościowa HRV-HF [ms^2/Hz] nie różniła się między grupami na wstępie (GrA *vs.* GrB: 201 ± 255 *vs.* 159 ± 173; p = NS), po 3 miesiącach (GrA *vs.* GrB: 198 ± 267 *vs.* 202 ± 196; p = NS) i po 12 miesiącach (GrA *vs.* GrB: 271 ± 409 *vs.* 280 ± 294; p = NS). Stosunek LF/HF był na wstępie istotnie wyższy w GrA (GrA *vs.* GrB: 4,5 ± 2,4 *vs.* 2,23 ± 2,7; p < 0,05). W trakcie obserwacji stwierdzono korzystną dynamikę zmian LF/HF jedynie w GrA po 3 miesiącach (GrA *vs.* GrB: 1,7 ± 1,3 *vs.* 1,8 ± 1,1; p = NS) i po 12 miesiącach (GrA *vs.* GrB: 2,0 ± 2,1 *vs.* 2,3 ± 1,98; p = NS). Liczba pacjentów, u których wystąpiły powikłania, nie różniła się między grupami.

Wnioski: 1. Proponowany model interwałowego treningu marszowego wpływa korzystnie na redukcję masy ciała, gospodarkę węglowodanową, zmniejszenie ogólnoustrojowej reakcji zapalnej i równowagę współczulno-przywspółczulną. 2. Cechy charakteryzujące nowy model treningu (bezpieczny, skuteczny, możliwy do obiektywnej oceny i realizacji w dowolnym miejscu) stanowią przesłankę do twierdzenia, że jego wdrożenie przyczyni się do zwiększenia aktywności fizycznej pacjentów po CABG. 3. Powyższe wyniki uzasadniają zaplanowanie badań obejmujących duży materiał w celu oceny efektywności i możliwości upowszechnienia proponowanej formy treningu w rehabilitacji kardiologicznej.

Słowa kluczowe: rehabilitacja kardiologiczna, telerehabilitacja, trening marszowy, 6-minutowy test marszowy

Kardiol Pol 2015; 73, 2: 118–126

Adres do korespondencji:
dr n. med. Jadwiga Wolszakiewicz, Klinika Rehabilitacji Kardiologicznej i Elektrokardiologii Nieinwazyjnej, Instytut Kardiologii, ul. Alpejska 42, 04–628 Warszawa, e-mail: jwolszakiewicz@ikard.pl

Praca wpłynęła: 14.05.2014 r. **Zaakceptowana do druku:** 07.07.2014 r. **Data publikacji AoP:** 21.08.2014 r.