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A – preparing concepts
B – formulating methods
C – conducting research
D – processing results
E – interpretation and conclusions
F – editing the final version

Interval training effects in patients with implantable cardioverter defibrillator depending on their exercise tolerance level

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Abstract

Introduction: Patients with implantable cardioverter defibrillator require physical therapy due to their decreased physical fitness. This is why standardized training has been designed for groups of subjects of varying endurance.

Material and methods: Patients with heart failure and implantable cardioverter defibrillator who wished to do interval training program. The program included 55 patients. We divided them into two study groups. The first group had lower exercise tolerance level (3.94 ± 0.72 MET), and the other had higher exercise tolerance level (7.97 ± 1.80 MET). The training group had an 8-week long training program. The patients received treatment at an outpatient clinic three times a week. Patients had cardiac stress tests with modified Bruce protocol before receiving physical therapy and after they have finished the training program. We assessed the metabolic equivalent of task (METS), the duration of exercise, blood pressure, heart rate and BMI.

Results: We observed longer duration of cardiac stress test performance and improvement of exercise tolerance. In patients from the group with lower exercise tolerance, the level of exercise tolerance was 3.94 ± 0.72 MET before therapy and rose to 5.93 ± 1.12 MET ($p < 0.001$) after therapy. In the group of higher exercise tolerance, the level was 7.97 ± 1.80 MET before therapy and rose to 9.32 ± 2.01 MET ($p < 0.001$) after the training cycle.

Conclusions: Participation in 8-week interval training cycle resulted in greater increase of exercise tolerance and exercise time, as well as hemodynamic parameters in patients with lower exercise tolerance.

Keywords: physical therapy, cardioverter defibrillator, interval training

Introduction

Within the current decade, a number of studies have shown that patients with heart failure (HF) in II and III NYHA class may use moderate physical training with a significant improvement in exercise tolerance, quality of life, and decreased hospitalization.

Implantable cardioverter defibrillator (ICD) may increase survivorship of patients with HF failure and with a serious dysfunction of the left ventricle. Exercise is beneficial, and therefore ACC/AHA HF recommend that patients do physical exercise [1]. Patients' limited awareness of the influence of physical activity on the function of the cardiovascular system results in lack of motivation to engage in any kind of physical activity. Unfortunately, it is still commonly believed that patients with reduced ejection fraction and ICD should not overexert and should not exercise.

Beneficial effects of interval training (IT) on mortality rate and incidence in patients with coronary artery disease (CAD) are well documented worldwide [2,3]. Still, there are very few recommendations of defined training sections for patient with pacemaker (PM), cardiac resynchronization (CRT) or implantable cardioverter defibrillator (ICD) [4]. In 2011, 938 PMs, 140 CRTs and 149 ICDs were implanted in every million citizens in Europe [5]. The frequency of implanting CRT and ICD is currently quickly increasing in patients with heart failure and reaches 7 to 17% and 15 to 19%, respectively. This means that cardiac rehabilitation is increasingly often offered to high risk patients.

Patients with ICD have survived cardiac arrest (secondary prevention) or are vulnerable to increased risk of developing malignant arrhythmia (primary prevention). Studies conducted so far have shown that physical effort in ICD patients results in improved coronary perfusion and increase in maximal oxygen consumption (VO_2) [8–12]. Regular physical activity curbs the progression of coronary artery disease [8]. Studies have shown a fall in repeated hospitalization in the group of patients with physical therapy [13]. Our study aims to show that intensive physical training not only does not have to be prohibited, but it actually has positive effects on hemodynamic parameters and functional capacity (MET) and exercise time in high risk cardiac patients.

The aim of the study was to assess the short term effects of interval training on the improvement of endurance in patients with heart failure and implantable cardioverter defibrillator depending on their exercise tolerance.

Research questions

1. Does physical training result in increased endurance and hemodynamic indices in patients with implantable cardioverter defibrillator?
2. Does interval training result in changes to the frequency of contractions of the heart and to blood pressure?
3. Does physical therapy have the same effects on hemodynamic parameters and endurance in patients of lower and higher exercise tolerance?

Material and methods

Assessments were conducted in 2017 at the Pro Corde Cardiac Centre in Wrocław. The project included 55 men with implantable cardioverter defibrillator (ICD) aged 50 to 70 years (mean age 61.5) who signed informed consent form to participate in the study and had no contraindications for physical therapy. The study was conducted according to the ethical standards of the Helsinki Declaration. The research was carried out with the approval of the Bioethics Committee at the Medical University in Wroclaw no. – 224/2019.

The criteria for subject inclusion in the study were: male gender, post-myocardial infarction heart failure, recent cardiac arrest, arrhythmia and early stages of ICD implantation of 4–5 weeks, ejection fraction <35%. All patients were adults. We included both primary and secondary indications for ICD implantation.

The criteria for subject exclusion were: inability to express informed consent, inability to participate in regular training due to severe concomitant diseases (kidney failure, limb paresis, unstable coronary artery disease, recent pulmonary or peripheral embolism) or a planned surgery within 2 months.

We involved pharmacological treatment, inter alia Vivacor, Tritace, Torvacard, Furosemid, Eleveon. We conducted submaximal cardiac stress test with modified Bruce protocol. The test was conducted on a treadmill. The patient was monitored (ECG and subjective wellbeing) by a doctor throughout the test. The measurement and registration of blood pressure and heart rate were taken at a minimum of every 3 minutes. The exercise finished when the criteria for test conclusion were met (i.e. a decrease of systolic blood pressure by more than 10mmHg despite increasing load; increase in blood pressure above 250/115mmHg, reaching the limit of training heart beat of 20 beats/min lower than the program threshold of the device's detector, depression of the ST segment >2mm or change to hearth's electrical axis, elevation of ST segment (>1mm) without abnormal Q wave or QS complexes (apart from V1 or aVR), premature ventricular contractions, supraventricular tachycardia, AV block, bradyarrhythmia, bundle branch block difficult to differentiate from VT, sustained ventricular tachycardia, contractions and pain in lower extremities, increasing pain in the chest, symptoms from the peripheral nervous system (dizziness), tiredness, dyspnea, difficulties in monitoring of ECG or of blood pressure, patient's request to finish the test). The first group consisted of 18 patients with lower exercise tolerance level (3.94 ± 0.68 MET), and the second group consisted of 37 patients with higher exercise tolerance level (7.97 ± 1.75 MET). The patients with higher endurance were significantly younger, less obese and had lower NYHA class (p = 0.625).

Prior to the study, we designed a program of physical therapy and health education according to recommendations of the Cardiac Rehabilitation and Exercise Physiology Section of the Polish Cardiology Association

Tab. 1. Characteristics of the two subgroups in terms of age, BMI, NYHA class and ejection fraction

		BMI			CLASS NYHA					Fraction ejection		
	The average age	Correct	Overweight	Obesity	I	II	III	IV	Unclassified	>50%	36–50%	<35%
Low efficiency n = 18	67.3	2	7	9	2	7	4	0	5	0	0	18
High efficiency n = 37	55.7	9	18	10	12	22	1	0	2	0	0	37

[14]. All the patients who were able to participate in the training program three times a week for two months were assigned to the therapeutic program. All of them completed the program – 24 training sessions in total. We reviewed their clinical data prior to the training, including the transthoracic echocardiography (TTE) and/or the simulator control printout.

The patients did training in an outpatient clinic. Within the time span of 8 weeks, they spent approximately two hours three times a week with a qualified physical therapist. The training started with 34 minute exercise on a cycloergometer. We took patients' blood pressure before the training, during the most intensive exertion, and at the end of the exercise. The exercise started with 2-minute warm-up. Then, 5 intervals followed. The intensity of intervals was 60–80% of aerobic heart rate, calculated in the cardiac stress test conducted with the modified Bruce protocol. Each interval was 4 minutes long, and it was followed by 2 minute of active rest. Cycling was done with submaximal load, adjusted to each patient's individual capacity. The load was calculated in Watt and it was determined on the basis of submaximal values in the cardiac stress test and in the rating of perceived exertion (the Borg scale), as well as patients' subjective well being on a given training day. After the first part of training, there was a 10 minute break, and then the second part followed. Throughout the training, patients were monitored with pulse meter which used Bluetooth to transmit the ECG signal to the therapist' computer.

In the second training room, cardio-fitness training followed. We used equipment such as: treadmill, indoor rower, workbench, cross-trainer and cycloergometer. The patients worked out 5 minutes on every piece of equipment, had a two minute break of breathing and relaxing exercises, and then changed equipment. After this part of training, the patients had their blood pressure taken, and their heart rate was monitored with a pulse meter.

The exercise intensity was 60% to 85% of the maximum heart rate, calculated individually for each patient. We used the Karvonen formula for these calculations [$HR_{max} - HR_{rest}) \times 0.8) + HR_{rest}$ (for 80%)]. The Borg scale training intensity was 15–17. The ICD patients were instructed not the exceed the upper threshold of heart beat frequency. The threshold was determined at the level of ICD detection minus 30 beats/min. The participants used heart beat monitors to determine intensity in each session, and were constantly monitored with ECG. The training was done in groups of 5 to 6 participants. Each patient underwent echocardiography stress test prior to the training program and another one after 8 weeks of training. Throughout the program, the patients were under constant supervision of a physiotherapist, they had consultations with cardiologist and they could make appointments with a psychologist and a dietician. All 55 participants completed the program of cardiac rehabilitation.

We conducted the statistical analysis in the Statistica program. We used the Shapiro-Wilk test to verify the normal distribution of variables. To verify the significance of difference in the dependent and independent variables, we used the Student's t-test for normal distribution. For independent variables, we used the Mann-Whitney U-test, to compare the results of the study population with the clinical control group. For dependent variables, we used the Wilcoxon test (to compare results in each group prior to and after the therapeutic program). We used the chi-squared test to establish the significance of differences in the NYHA class. We set statistical significance at $p < 0.05$.

To compare the groups, we used descriptive statistics; tables, graphs; expressed in percentages, the mean, the median and the standard deviation.

Results

The results of the final cardiac stress test in both groups showed that in 6% of patients exercise tolerance did not change, and the exercise time shortened. In 94% of patients the echocardiography stress test showed longer exercise time in comparison with the initial stress test, and an improvement in exercise tolerance. Prior to the training the MET endurance level was 6.49 ± 2.47, and after the cycle of 24 training sessions this level rose to 8.08 ± 2.39 ($p < 0.001$).

In patients with lower exercise tolerance the level of endurance prior to the physical therapy was 3.94 ± 0.72 MET, and after the program it rose to 5.93 ± 1.12 MET ($p < 0.001$). In the group with higher exercise tolerance the initial endurance was 7.97 ± 1.80 MET, and rose to 9.32 ± 2.01 MET ($p < 0$ .001) after the program. In the higher exercise tolerance group the increase in endurance was 1.35 ± 0.21, while in the lower tolerance group it was 1.99 ± 0.4. In the lower tolerance group the increase in endurance was higher than in the other group by 0.64 METS ($p = 0.8065$).

The mean duration time of cardiac stress test prior to the training program was 10:14 ± 0.14 min, and after the program it was 12.23 ± 0.1 min ($p < 0.0500$).

The duration of cardiac test in the lower exercise tolerance group prior to the physical therapy was 6:41 ± 0.08 min, and after the training cycle it was 10:01 ± 0.05 min ($p < 0.0500$). In the higher exercise tolerance group, the duration was 12:17 ± 0.07 min prior to, and 13:45 ± 0.08 min after the training program ($p < 0.0500$). The increase in duration in the lower exercise tolerance group was higher by 1:58 ($p < 0.0500$) than in the higher tolerance group.

After the training cycle, 100% patients had normal blood pressure reactions. Before the physical therapy, mean systolic blood pressure in all the patients was approximately 155 mmHg, and it fell significantly to 142 mmHg after the training cycle ($p = 0.6472$). At the peak exertion the mean pressure was 166 mmHg. In the group with lower exercise tolerance the pressure fell by 9%, and in the group with higher tolerance it fell by 7%. The situations in which there was no change in blood pressure values between the beginning and the end of exercise, and blood pressure above 180 mmHg, were considered to be abnormal blood pressure reactions.

The mean pulse at rest prior to the therapy was 72.60 beats per minute. After the therapy we noted a statistically significant fall to the mean of 69.77 beats per minute. In the lower exercise tolerance group, the pulse fell by 5%, and in the higher exercise tolerance group the pulse fell by 3%.

During the intervention period there were no adverse events related to cardiovascular system or to symptomatic arrhythmia. There were no severe complications, such as cardiac arrest, death or myocardial infarction. There were no improper communication from ICD at any time

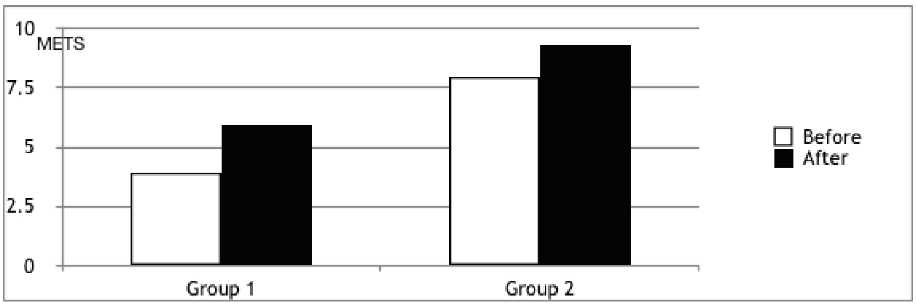

Fig. 1. Change in MET parameter in both groups

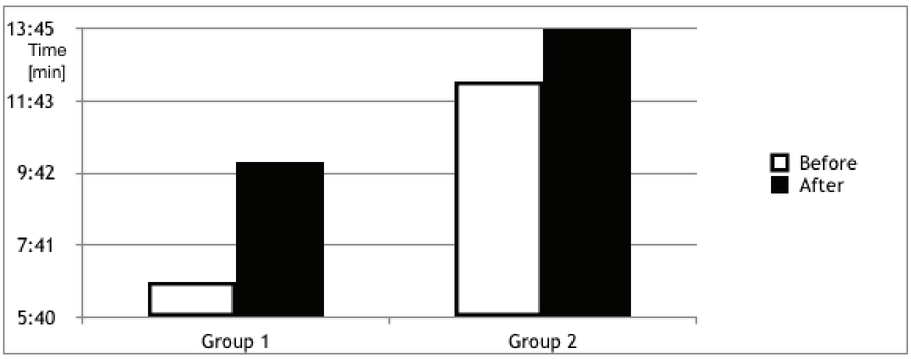

Fig. 2. Duration time of the echocardiographic exercise test in both groups prior to and after the training cycle

during cardiac stress tests or during training. None of the patients had complications which would have required urgent medical assistance during tests or training.

Discussion

Physical therapy of patients with high risk of cardio-vascular complications aged 50 to 70 years with implantable cardioverter-defibrillator is an essential part of treatment. Studies conducted in 1980s confirmed that therapy based on physical exercise has positive effects in patients with coronary artery disease. Adequately chosen exercise and physical training result in decrease in oxygen consumption, slowdown of heartbeat at rest and in exertion, increase in ejection volume, improved blood supply to the heart and development of portal venous system, as well as increase of HDL cholesterol fraction and improved exercise tolerance. Studies conducted in 1990s by Wojtkowska et al confirmed our results on endurance after an interval training cycle in cardiac patients [15]. Furyk et al also noted an improvement in vital signs of patients who had physical therapy both according to A model (in patients with uncomplicated myocardial infarction) and according to B model (in patients with complication in the acute phase of the illness) [16]. After conducting the study we can conclude that appropriately designed physical activity has positive effects on heart function regardless of initial results of cardiac stress test. Patients with lower initial exercise tolerance have greater improvement, as they started physical activity, which they had not engaged in before. Possibly, this group might also be more determined to improve their health. In a study by Kielnar et al, endurance improved after 24 training sessions, with training done three times a week, regardless of gender [17]. In a Copenhagen study, Berg et al randomly divided 196 subjects into two groups. The first group had complex cardiologic rehabilitation, and the other group had standard medical care. In 6-month and 12-month follow ups the authors found a significant improvement in general heath and in endurance in the group which had rehabilitation; a result which our study confirms, too [18]. Our literature review has shown that out of 834 patients with ICD, 7 had interventions during physical therapy; while the ICD patients who had sedentary life style experienced many more ICD discharges [19]. We have shown that physical training does not result in ICD interventions. Despite clear recommendations and studies which prove that training is safe for patients with ICD, there are still few referrals to early outpatient rehabilitation. This may result from fear of discharges, or from doctors' and patients' lack of knowledge [20]. Interest in interval training in patients with implantable cardioverter is increasing, as there is growing reliable evidence on its effects on improvement of cardiovascular system and of metabolic system, both in healthy populations, and in populations with chronic illnesses [21–23].

An additional advantage of the interval system is that it is time efficient. Initial data suggests that many respondent report satisfaction with short and intense physical effort [24–26].

Results of the recent COPE-ICD study are consistent with earlier studies, with considerable improvement in 3, 6, and 12-month follow-ups, with more evident positive effects in men [27].

We analyzed published randomized studies which assessed effects of interval training in patients with heart failure. There is evidence on better effects of interval training in coronary artery disease on endothelium of brachial artery, and on decreased risk of cardiovascular diseases, oxidative stress and insulin sensitivity [28].

Interval training was effective in general cardio-respiratory fitness [29–31].

Conclusions

1. Participation in 8-week long interval training resulted in improved hemodynamic parameters and increased exercise time in patients with implantable cardioverter defibrillator in post-myocardial infarction heart failure.
2. Participation in 8-week interval training cycle had greater effects on endurance improvement in patients with lower exercise tolerance.

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Conflicts of interest
The authors declare no conflict of interest.

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