Original Article

The influence of cardiac rehabilitation on heart rate variability indices in men with type 2 diabetes and coronary artery disease

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Katarzyna Szmigielska and Anna Jegier

Abstract
The study evaluated the influence of cardiac rehabilitation (CR) on heart rate variability (HRV) in men with coronary artery disease (CAD) with and without diabetes.
Method: The study population included 141 male CAD patients prospectively and consecutively admitted to an outpatient comprehensive CR program. Twenty-seven patients with type-2 diabetes were compared with 114 males without diabetes. The participants performed a 45-min cycle ergometer interval training alternating 4-min workload and a 2-min active restitution three times a week for 8 weeks. The training intensity was adjusted so that the patient's heart rate achieved the training heart rate calculated according to the Karvonen formula. At the baseline and after 8 weeks, all the patients underwent the HRV assessment.
Results: HRV indices in the patients with diabetes were significantly lower as compared to the patients without diabetes in SDNN, TP, LF parameters, both at the baseline and after 8 weeks of CR. After 8 weeks of CR, a significant improvement of TP, SDNN, pNN50% and HF occurred in the patients without diabetes, whereas in the patients with diabetes only HF component improved significantly.
Conclusions: As regards HRV indices, CR seems to be less effective in patients with CAD and type-2 diabetes.

Keywords
Diabetes, HRV, cardiac rehabilitation, CR

Introduction

The activity of the autonomic nervous system which regulates the heart function may be assessed based on measurement of heart rate variability indices (HRV).[1–3] Decreased values of HRV indices are associated with an increased risk of total mortality and cardiac events, especially in patients after myocardial infarction[4,5] and are observed in patients with coronary artery disease (CAD) treated with percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG).[6–9]

Diabetes, as a metabolic disorder connected with chronic hyperglycaemia, is associated with damage and failure of various organs as well as with autonomic nervous system dysfunction observed as decreased HRV indices.[10–12] Decreased HRV in patients with diabetes has been found to be a predictor of cardiovascular morbidity and mortality.[13,14]

Regular physical activity is considered to be one of the factors that increase HRV indices.[15–20] Improvement of HRV indices along with better exercise capacity after cardiac rehabilitation program (CR) were observed in patients with coronary artery disease treated with PCI[21,22] and with CABG.[17,23]

There are few available studies evaluating outcomes of cardiac rehabilitation program in CAD patients with diabetes.[24] We hypothesise that the influence of cardiac rehabilitation program on HRV indices are compromised in CAD and type-2 diabetes due to autonomic dysfunction. The aim of the study was to evaluate and compare the influence of a CR program based on regular aerobic interval training on HRV indices in CAD patients with type-2 diabetes and CAD patients without diabetes.

Department of Sports Medicine, Medical University of Lodz, Lodz, Poland

Corresponding author:
Katarzyna Szmigielska, Department of Sports Medicine, Medical University of Lodz, ul. Pomorska 251, Łódź 92-213, Poland.
Email: katarzyna.szmigielska@umed.lodz.pl

Materials and methods

Participants

The study included 141 men, aged 36–75 years (mean age 56.4 years ± 7.6 years) with coronary artery disease after revascularisation procedures, prospectively and consecutively admitted to an outpatient comprehensive cardiac rehabilitation program for 8 weeks. The mean time following PCI was 21.8 days ± 9.3 days and following CABG—27.5 days ± 8.9 days. The study was conducted in the Outpatient Rehabilitation Centre of the Clinical University Hospital and lasted 15 consecutive months.

The single exclusion criterion in the study was the left ventricular ejection fraction below 35%.

The studied group was divided according to the diagnosis of diabetes. Twenty-seven out of 141 patients with CAD were previously diagnosed with type-2 diabetes and were analysed as group 1 to be compared with 114 patients without diabetes.

At the beginning of and after completion of the rehabilitation program, all participants had fasting blood tests to assess serum glucose concentration, and to exclude a new diagnosis of diabetes.

At the study time, all the patients were treated with angiotensin converting enzyme inhibitors or angiotensin receptor blockers, β-blockers, statins and antiplatelet agents. The patients with type-2 diabetes were treated with insulin or noninsulin glucose-lowering agents.

Any changes in pharmacotherapy during the rehabilitation program also resulted in being excluded from the investigation. Only the patients who completed the whole, 8-week comprehensive cardiac rehabilitation program were included in the statistical analysis.

The study protocol was approved by the local ethics committee at Medical University. All the procedures were followed in compliance with the ethical standards of the committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, revised in 2008. The written informed consent was obtained from all the participants.

Cardiac rehabilitation program

The subjects participated in interval training, three times a week for 45 min, on cycle ergometers Ergoselect II 100/200 Ergoline Reha System GmbH, Schiller, Switzerland.

Their blood pressure and electrocardiography values were continuously monitored during training sessions. Workloads were increasing in the first part of the training session, whereas in the second part, they were decreasing, alternating a 4-min workload with 2 min of active restitution. The intensity of training was adjusted so that the patient's heart rate achieved, but not exceeded, the calculated training heart rate and ranged from 11 to 15 points on Borg scale.

The peak intensity of the exercise was determined based on training heart rates (THR) calculated according to the Karvonen formula.[25] The source of the data for calculation of peak THR was the exercise test.

$$\text{THR} = \text{rest HR} + (0,6 \text{ to } 0,8) \bullet \text{HRR}$$

Heart rate reserve (HRR) was calculated as a difference between the highest heart rate achieved during the exercise test and the resting HR.

The comprehensive cardiac rehabilitation program included 24 sessions of exercise training and health education on cardiovascular risk factors, lifestyle modification including the recommendations concerning a healthy diet, physical activity, as well as psychological support in stress management.

Data collection

At the beginning of cardiac rehabilitation and 8 weeks afterwards, all the participants underwent physical examination, Holter ECG monitoring, an exercise test, echocardiography and fasting blood tests. The total cholesterol, high-density lipoprotein cholesterol (HDLc), triglycerides and serum glucose concentration were assessed using the enzymatic calorimetric method with Cormay reagents. Concentration of low-density lipoprotein cholesterol (LDLc) was calculated using the Friedewald formula.[26]

All the participants underwent physical examination including an electrocardiogram at rest in the supine position, as well as heart rate (HR) and blood pressure (BP) measurements. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Body weight rounded to the nearest 50 g and body height rounded to the nearest millimetre were determined with standard anthropometric methods, using a digital, medical scale (Radwag WPT 100/200) and a stadiometer (GMP, Switzerland). Waist circumference, with the accuracy of 10 mm, was measured at the midpoint between the lowest rib and the iliac crest.

A multistage, symptom-limited exercise test was performed on the cycle ergometer Ergoselect II 100/200 with continuous 12-lead electrocardiographic monitoring using Cardiovit CS-200 Ergo Spiro; Schiller, Switzerland.

The exercise test was initiated with the workload of 60 W and it was gradually increased by 30 W every 3 min until exhaustion. After the completion of the exercise phase, the participants were monitored for 6 min or longer, if necessary. The recovery phase involved 2 min of unloaded pedalling followed by 3–5 min of rest.

The criteria applied for discontinuation of the exercise tests included: the occurrence of clinical symptoms like chest pain, breathing difficulties, headache, or dizziness, blood pressure values above 250/115 mmHg, abnormal ECG results or exhaustion. Blood pressure measurements were taken at rest, within the last 30 s of each stage of the exercise test, and every 2 min during the recovery. Heart rate during the exercise test was evaluated using continuous 12-lead ECG. The highest heart rate achieved during the exercise test determined the peak heart rate (HR*peak*). The rate pressure product (RPP) was calculated as HR x systolic BP. The resting RPP was calculated using resting values, while the RPP*peak* was based on the highest values obtained during the exercise test. The highest workload during exercise test expressed in Watt determined the peak workload (W*peak*). If the last stage of the exercise test was interrupted within 2 min, the workload of the previous stage defined the W*peak*. Also, at the last stage of the exercise test, the rating of perceived exertion was assessed according to the 20-point Borg scale.[27]

HRV assessment

Heart rate variability was analysed twice, at the beginning and after the CR program, using 24-h Holter monitoring with Holter Recorder DMS 300-3A, (USA) and Cardio Scan 10.0 software.

Artefacts and abnormal heart beats were automatically and manually recognised and removed from the analysis. Frequency and time parameters were assessed according to the standards of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[1]

Among the time analysis indicators, the following parameters were measured: the mean RR interval (mRR), the standard deviation of the normal RR interval (SDNN), square root of the mean square differences of successive RR intervals (rMSSD), and proportion of the total RR intervals with differences of successive RR intervals exceeding 50 ms (pNN50).

Among the parameters of the frequency domain the total power (TP), the low-frequency component (LF: 0.04–0.15 Hz), the high-frequency component (HF: 0.15–0.4 Hz) and the LF/HF ratio were measured.

Echocardiography

All participants underwent echocardiography twice, at the beginning and after 8 weeks of the CR program. The same researcher performed the M mode and two-dimensional echocardiography with Doppler technique using VIVID7, General Electric Healthcare, USA. Data were obtained at rest using a 3.5-MHz linear transducer. The measurements were taken and analysed according to the guidelines of the American Society of Echocardiography.[2] For assessment of left ventricular function, the end diastolic volume (EDV), end systolic volume (ESV), systolic volume (SV) and left ventricular ejection fraction (LVEF) were measured.

Statistical analysis

The measured values were presented as the median with interquartile range and as mean ± standard deviation, if appropriate.

To compare initial and final values in each group, a paired *t* test and a Wilcoxon test were applied for parametric and nonparametric data, respectively.

To analyse the differences between the groups, two-sample Student's *t*-test was used to compare the means of continuous variables with a normal distribution, and *U* Mann–Whitney test was used for continuous variables without a normal distribution. The difference was considered statistically significant when *p* value was lower than 0.05. The statistical analysis was performed with Statistica software, Version 13.1, USA.

Results

The study population consisted of 141 male patients with CAD, who were consecutively enrolled to an outpatient cardiac rehabilitation program. Twenty-seven patients with CAD and type-2 diabetes (19.14%) were analysed as group 1 compared to 114 patients without diabetes. The study participants were not significantly different in terms of age, clinical history, cardiovascular risk factors or frequency of a coexisting disease (Table 1). In our investigation, all the subjects with cardiovascular disease were treated with the same groups of drugs, including β-blockers, which inhibit sympathetic activity thereby affecting HRV indices. To avoid interpretation error, the patients who were not treated with β-blockers were excluded.

Nineteen patients with type-2 diabetes were treated with noninsulin glucose-lowering agents only. Most of them took metformin ($n = 15$). Other four patients were treated with gliclazide, which is sulfonylureas. Eight patients with type-2 diabetes were treated with insulin, whereas six of them also received metformin. (Table 1).

Waist circumference and BMI were statistically significantly higher after 8 weeks of CR in the patients without diabetes while in the group of patients with type-2 diabetes those values remained unchanged (Table 2).

Resting heart rate, resting systolic and diastolic arterial blood pressure were significantly decreased in both groups after 8 weeks of CR as compared to the baseline measurements.

Moreover, workload during the last stage of the exercise test improved in both groups after 8 weeks of the investigation (Table 2).

Echocardiographic parameters were similar in both groups of patients, with type-2 diabetes and without diabetes, at the baseline and did not change after 8 weeks of CR in either of the them. Only left ventricular ejection fraction significantly improved in the group of patients without diabetes ($p = 0.003$) (Table 3).

In the group of patients without diabetes, a significant increase in TP ($p = 0.035$), SDNN ($p = 0.03$), pNN50% ($p = 0.032$) and HF ($p = 0.039$) was observed following CR as compared to the baseline. In the group of patients with type-2 diabetes, among the parameters of frequency domain, only the HF component improved significantly after 8 weeks of CR ($p = 0.03$) (Table 4).

Table 1. Baseline anthropometric parameters, risk factors and clinical history of men with CAD with type-2 DM and without DM before CR.

Man (n = 141)	CAD with type-2 DM (n = 27)	CAD without DM (n = 114)	p
Age (years)	57.2 ± 6.5 57.5 (46–71)	55.8 ± 9 56 (36–75)	0.43
BMI (kg/m^2)	29.1 (23.9–32.3)	27.7 (20.5–37.5)	0.18
Waist circumference (cm)	105 (87–117)	101 (83–126)	0.32
Clinical history			
PCI (fraction)	15 (0.56)	67 (0.59)	0.56
CABG (fraction)	12 (0.44)	47 (0.41)	0.22
Duration of CAD (years)	2.5 (0.5–12)	3 (0.5–16)	0.17
Duration of DM (years)	5 (0.5–10)	–	
Time since PCI or CABG (days)	20 (10–46)	25 (8–45)	0.08
Myocardial infarction (fraction)	18 (0.66)	64 (0.56)	0.12
Arterial hypertension (fraction)	16 (0.59)	70 (0.61)	0.34
Smokers/exsmokers (fraction)	0/21 (0.8)	0/99 (0.86)	0.64
Total cholesterol (mg/dl)	159 (110–236)	159.3 (100–293)	0.55
HDLc (mg/dl)	45 (30–62)	42 (20–72)	0.15
LDLc (mg/dl)	87.5 (42.7–171)	89.3 (41.9–230.4)	0.5
Triglycerides (mg/dl)	100 (50–313)	108.9 (55–366)	0.43
Glucose (mmol/l)	6 (3.77–17.4)	5.27 (3.16–6.81)	0.02
Pharmacotherapy (fraction)			
β-blockers	27	114	Ns
ACE inhibitors or ARB	27	114	Ns
Statin	27	114	Ns
Antiplatelet agents	27	114	Ns
Metformin	21 (0.77)	0	
Gliclazide	4 (0.15)	0	
Insulin	8 (0.29)	0	

CAD: coronary artery disease; DM: diabetes mellitus; CR: cardiac rehabilitation; BMI: body mass index; PCI: percutaneous coronary intervention; CABG: coronary artery bypass grafting; HDLc: high-density lipoprotein cholesterol; LDLc: low-density lipoprotein cholesterol; ACE inhibitors: angiotensin converting enzyme inhibitors; ARB: angiotensin receptor blockers; ns: $p > 0.05$.
Values are presented as median and (interquartile range) ore mean ± standard deviation.

There were no statistically significant changes in the serum lipid concentrations and in the glucose serum concentrations after 8 weeks of cardiac rehabilitation in both examined groups, so it was not presented in this manuscript. Moreover, all patients were treated with statins in individually selected doses for various periods of time. It would be difficult to assess what influenced the lipid serum concentrations, regular training or pharmacotherapy.

Discussion

Estimation of heart rate variability indices is used to assess the activity of the autonomic nervous system which is responsible for the regulation of the heart function.[1–3] The SDNN as a parameter of time domain and the total power of frequency domain illustrate the total activity of the autonomic nervous system. The HF component in frequency domain and the rMSSD and pNN50% in time domain are considered to be the indicators of parasympathetic activity, while the activity of the sympathetic nervous system is best represented by the LF/HF ratio.[1,28]

In our study, HRV indices in the patients with type-2 diabetes were statistically significantly lower as compared to the subjects without diabetes both at the baseline, in SDNN, TP, LF and HF parameters and after 8 weeks of CR, in SDNN, TP and LF parameters. Impaired glucose tolerance leads to dysfunction of the autonomic nervous system and a decrease in HRV.[10–14] It might be due to cardiac autonomic neuropathy and nerve destruction as a serious complication of diabetes which influences cardiovascular mortality in these patients.[12,29–31] Regular physical activity is considered to be one of the factors improving HRV indices in healthy individuals.[18–20]

The most important finding of our investigation is an improvement of HRV indices after 8 weeks of CR in the CAD patients without diabetes, whereas, in CAD patients with type-2 diabetes only the HF component of frequency domain improved.

There was also a significant improvement of exercise capacity after CR in both examined groups. Previously published studies have shown that CR programs based on regular physical activity improve exercise capacity and ability to

Table 2. Anthropometric and hemodynamic parameters and selected indices of exercise tolerance in the examined CAD males with type-2 DM and without DM at baseline and after 8 weeks of CR program.

Men (n = 141)	CAD with type-2 DM (n = 27)			CAD without DM (n = 114)		
	Baseline	After 8 weeks of CR	p	Baseline	After 8 weeks of CR	p
BMI (kg/m^2)	29.1 (23.9–32.3)	29.06 (24.3–33.7)	0.76	27.7 (20.5–37.5)	28.2 (21.1–38.5)	<0.001
Waist circumference (cm)	105 (87–117)	105 (88–117)	0.5	101 (83–126)	102 (85–128)	<0.001
HR at rest (beats × min^{-1})	70 (56–88)	67 (50–92)	0.031	71.5 (50–105)	66 (48–97)	<0.001
SBP at rest (mmHg)	120 (110–140)	120 (100–146)	0.016	125 (90–160)	117.5 (90–190)	<0.01
DBP at rest (mmHg)	80 (69–90)	80 (60–90)	0.03	80 (56–105)	70 (60–90)	<0.01
Resting RPP × 10^{-2} (beats × min^{-1} × mmHg)	84.5 (67.2–114.8)	74.4 (56–119.6)	<0.014	88.1* (52.2–145.6)	76.3 (53–133)	<0.001
Peak workload (W)	90 (60–120)	120 (60–150)	<0.001	90 (60–150)	120 (60–150)	<0.001
Peak workload (W/kg)	1.03 (0.63–1.5)	1.3 (0.74–1.8)	<0.001	1.1* (0.53–1.9)	1.4 (0.67–2.24)	<0.001
RPP*peak* × 10^{-2} (beats × min^{-1} × mmHg)	178.5 (95.4–248)	182.6 (98.3–261.7)	0.25	175.7 (97.7–234.2)	177.5 (96.9–242.4)	0.34
RPE (points)	14 (13–17)	15 (13–17)	0.12	15 (13–18)	16 (14–17)	0.27

CAD: coronary artery disease; DM: diabetes mellitus; CR: cardiac rehabilitation; BMI: body mass index; HR: heart rate at rest (beats/min); SBP: systolic arterial blood pressure at rest (mmHg); DBP: diastolic arterial blood pressure at rest (mmHg); RPP: rate pressure product (HR × SBP); Peak workload: workload during the last stage of exercise test; RPP*peak*: rate pressure product (HR*peak* × SBP*peak*: the highest values achieved during the last stage of exercise test); RPE: rating of perceived exertion on 20-point Borg scale during the last stage of exercise test.
Values are presented as median and (interquartile range).
*$p < 0.05$ DM group versus without DM group at baseline.

Table 3. Echocardiographic parameters of CAD males with type-2 DM and without DM at baseline and after 8 weeks of CR program.

Men (n = 141)	CAD with type-2 DM (n = 27)			CAD without DM (n = 114)		
	Baseline	After 8 weeks of CR	p	Baseline	After 8 weeks of CR	p
EDV (ml)	134 (98–210)	127.5 (92–199)	0.22	131 (64–202)	126.5 (76–231)	0.64
ESV (ml)	51 (25–128)	50.5 (27–110)	0.18	49.5 (6–113)	49 (7–141)	0.16
LVEF (%)	59 (36–77)	61 (37–71)	0.25	58 (37–80)	60 (40–81)	0.003
SV (ml)	85 (46–101)	82.5 (52–113)	0.83	78 (41–136)	78 (24–123)	0.29

CAD: coronary artery disease; DM: diabetes mellitus; CR: cardiac rehabilitation; EDV: end diastolic volume; ESV: end systolic volume; LVEF: left ventricular ejection fraction; SV: systolic volume.
Values are presented as median and (interquartile range).
*$p < 0.05$ DM group versus without DM group at baseline.

perform physical exercise in patients with CAD,[21–23,32] and also in CAD patients with type-2 diabetes.[24]

The analysis of HRV indices have shown that after 8 weeks of CR SDNN and pNN50% in time domain and TP and HF component in frequency domain were significantly higher than before CR in the CAD patients without diabetes. LF/HF ratio at the baseline was similar in both groups and did not change after 8 weeks of CR. This proves an increase in the global activity of the autonomic nervous system and in parasympathetic activity without changes in sympathetic activity.[1,28] Moreover, in the patients with CAD and type-2 diabetes only HF component in frequency domain was improved after 8 weeks of CR. The improvement of HRV indices was more pronounced in the group of CAD patients without diabetes as compared to the CAD patients with type-2 diabetes.

At the same time, HR at rest, resting systolic and diastolic arterial BP decreased significantly in both groups after 8 weeks of CR. In contrast, BMI and waist circumference in the group of patients with type-2 diabetes did not change significantly, while in patients without diabetes those parameters increased. The increase was not meaningful, but was statistically significant. The reason for this difference occurring between the two groups may be dietary education received by patients with type-2 diabetes. Moreover, according to recommendations, to effectively reduce bodyweight, physical activity should last more than 150 min a week.[33] Also, the time of observation is an important factor. It might be the reason why the 8-week program of 45-min training three times a week was ineffective in bodyweight reduction.

Table 4. HRV indices of CAD males with type-2 DM and without DM at baseline and after 8 weeks of CR program. .

Men (n = 141)	CAD with type-2 DM (n = 27)			CAD without DM (n = 114)		
	Baseline	After 8 weeks of CR	p	Baseline	After 8 weeks of CR	p
mRR (ms)	816.6 (681.8–1058.6)	864.5 (616.2–1097.4)	0.17	863.6 (680.3–1211.7)	879 (713.4–1139.6)	0.46
SDNN (ms)	99 (44–175)	91 (54–161)	0.33	117* (39–207)	120** (35–249)	0.03
rMSSD (ms)	23 (8–44)	24 (8–49)	0.56	23 (8–810.6)	24 (11–120)	0.22
pNN50 (%)	3 (0–15)	3 (0–35)	0.55	3 (0–46)	4 (0–62)	0.032
TP (ms^2)	1775.1 (168–5252)	1870.5 (337.9–7144.7)	0.2	2329.85* (480.1–8733.7)	2426.5** (516.7–9448.6)	0.035
LF (ms^2)	285 (0.1–1152.6)	350.5 (38.7–1134.9)	0.16	439.1* (33.1–1828.6)	467.3** (75.6–2489.5)	0.2
HF (ms^2)	89.3 (6.9–471.2)	108.4 (10–563.2)	0.04	93.4* (0-914.7)	108.5 (13.3–1100)	0.039
LF/HF	2.9 (0.1–13.9)	2.9 (0.95–11.6)	0.38	3.7 (0.62–13.64)	3.9 (0.5–13.1)	0.61

HRV: heart rate variability; CAD: coronary artery disease; DM: diabetes mellitus; CR: cardiac rehabilitation; mRR: the mean RR interval; SDNN: the standard deviation of the normal RR interval; rMSSD: square root of the mean square differences of successive RR intervals; pNN50: proportion of the total RR intervals with differences of successive RR intervals exceeding 50 ms; LF: low frequency component (0.04–0.15 Hz); HF: high frequency component (0.15–0.4 Hz).
Values are presented as median and (interquartile range).
*$p < 0.05$ DM group versus without DM group at baseline.
**$p < 0.05$ DM group versus without DM group after 8 weeks of CR.

Eight weeks of physical activity might not have been sufficiently long to induce changes in autonomic nervous system activity, especially in patients with dysfunction of autonomic nervous system due to diabetes observed as decreased HRV indices.[10–12]

The results of the available studies on duration of physical training effecting the HRV indices are not consistent. A significant effect of regular physical activity on HRV indices was demonstrated in the patients with CAD who attended the CR program for 8 weeks.[15,16] On the other hand, some studies did not report any changes of HRV indices after 8 weeks of physical training.[34–36] Another investigation has not shown any significant changes in HRV indices after 5 months of training. The authors claim that to improve the function of the autonomic nervous system, physical training should last at least 1 year.[37] Not only the length of training might have an impact on HRV indices. The volume of training might also be an important factor influencing the outcomes of physical activity. According to recommendations, the frequency of aerobic training, should be at least 3 days a week, but preferably (6-7) 6 or 7 days a week (33).

The outcomes of CR can also be affected by the time after intervention. In our investigation, the participants began CR program within 6 weeks after a cardiovascular intervention. Low left ventricular ejection fraction can also be associated with a decrease in parasympathetic activity and autonomic dysfunction.[38] After 8 weeks of CR, the left ventricular ejection fraction was improved only in the CAD patients without diabetes. Other echocardiographic parameters did not change in either of the groups. This may be due to the fact that 8 weeks is not long enough to indicate functional or morphological changes in the heart muscle.

In addition, many other factors can cause autonomic dysfunction. Decreased HRV indices were observed in patients with more than one vessel affected by severe atherosclerosis or with comorbidities.[6,7,39] In our investigation, the examined subjects did not differ significantly in terms of age, clinical history and frequency of coexisting disease except for diabetes.

Programs of cardiac rehabilitation vary depending on a country. Some cardiac rehabilitation programs have been shown to be ineffective in improving physical capacity, hemodynamic parameters or morbidity and mortality outcomes. It seems that in order to obtain an improvement in HRV, patients with type-2 diabetes should undergo cardiac rehabilitation based on physical training for a longer period of time, and exercise should be used in a larger volume. Eight weeks of the 45-min training program, for three times a week improved exercise capacity, heart rate and blood pressure at rest, however, it was not enough to improve HRV indices in the CAD patients with type-2 diabetes. A larger volume of training might be more effective in achieving better outcomes of cardiac rehabilitation. The time spend on training should be at least 150 min per week, optimally about 300 min per week (33).

Strengths and limitations of the study

The novel aspect of the present study is the comparison of the impact regular aerobic training has on HRV indices in CAD patients, those with and without type-2 diabetes.

A lack of a matched control group, that is, CAD patients after revascularisation without CR, is a limitation of our study. Unfortunately, it is impossible to include the control group because it would be unethical to refuse CR to any patient with indications, and those who refuse to participate in the rehabilitation program are reluctant to attend check-up visits. We realise that our study is purely observational.

Conclusions

An outpatient CR program based on regular aerobic interval training improves physical ability to exercise, autonomic regulation of heart action in CAD male individuals treated with CABG and PCI. With respect to HRV indices, CR seems to be less effective in patients with CAD and type-2 diabetes. Eight weeks of regular physical activity in patients with type-2 diabetes and CAD is insufficient to improve HRV indices, although it improves physical capacity.

Declaration of conflicting interests

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ORCID iD

Katarzyna Szmigielska https://orcid.org/0000-0003-4211-7066

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