Effects of exercise-based cardiac rehabilitation on heart rate variability and turbulence in patients with ST elevation myocardial infarction

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ABSTRACT

Objectives: The objective of this study was to evaluate the effect of the exercise-based cardiac rehabilitation (CR) on the heart rate variability (HRV) and turbulence (HRT) in patients with ST elevation myocardial infarction (STEMI) treated with the primary percutaneous coronary intervention (PCI).

Methods: One hundred one patients with STEMI, who underwent primary PCI were included in our study. Sixty-eight of these patients were randomized to the CR group and the remaining 33 patients to the control group. One month after the primary PCI, cardiac rehabilitation was performed in CR group with a cycle ergometer for 8 weeks (30 sessions). One month after STEMI, rhythm Holter monitorization was carried out in both groups for 48 hours. The rhythm Holter monitorization was repeated in cardiac rehabilitation group (CR group) after the cardiac rehabilitation again for 48 hours. HRV was evaluated according to time and frequency domains; HRT was evaluated with the turbulence onset and turbulence slope parameters obtained from the Holter recordings.

Results: Baseline characteristics and baseline HRV and HRT parameters were comparable between CR group and control group. In CR group, there was no statistically significant difference between the HRV and HRT parameters, which were obtained before and after the cardiac rehabilitation. The subgroup analyses (left ventricular ejection fraction lower or higher than 40%) showed that turbulence onset improved with the cardiac rehabilitation in the group with an ejection fraction lower than 40%.

Conclusions: Our results showed that exercise-based cardiac rehabilitation did not affect HRV and HRT in patients whose left ventricular ejection fraction was mildly affected (> 40%) after the treatment with primary PCI. However, the cardiac rehabilitation provided an improvement of turbulence onset in patients with the low left ventricular ejection fraction.

Keywords: Cardiac rehabilitation, ST elevation myocardial infarction, heart rate variability, heart rate turbulence

The cardiac rehabilitation (CR) can be defined as the whole of the activities, which are necessary for the patients with cardiovascular diseases to restore the premorbid physical, mental and social skills as quickly as possible [1]. Several studies documented the efficacy of the exercise-based CR after diffuse myocardial infarction (MI). The exercise improves concurrently the physical performance, muscle strength; dyspnea and angina symptoms and a comprehensive CR implementation are related to the improvement of

the psychological and social functions, going back to work and biological risk factors.

It is well known that the balance between the sympathetic tonus and vagal tonus is changing in favor of sympathetic tonus after the MI. The CR decreases the risk of sudden death as a result of the increase in the fibrillation threshold depending on the increase in the vagal tonus [2]. The autonomous function disorders of the cardiac system have an important place in the pathophysiology of the malign arrhythmias and sudden cardiac death (SCD) [3]. It was reported that after the ischemia and infarction, the parasympathetic tonus decreases along with the decrease of the ventricular fibrillation (VF) threshold due to the increased catecholamines [4]. Heart rate variability (HRV) and heart rate turbulence (HRT) are tests related to the cardiac autonomous functions. HRV shows the effects of the parasympathetic and sympathetic systems on the heart rate. After a ventricular ectopic beat, the sinus rate first increases and then decreases. HRT is used to investigate this phenomenon. It is a reliable indicator of the baroreceptor sensitivity [5, 6]. HRT is evaluated with these two parameters: Turbulence onset (TO) and the turbulence slope (TS). The European Society of Cardiology stated that HRV is a reliable indicator of the vagal activity and is an independent indicator of the total mortality [7]. Likewise, our objective was to evaluate the effect of the CR on the cardiac autonomous functions with the help of the HRV and HRT parameters in ST elevation myocardial infarction (STEMI) patients.

METHODS

Patient Selection

One hundred one consecutive patients, who had applied to the Bursa Yüksek İhtisas Training and Research Hospital and had been admitted with the diagnosis of STEMI in 2014, were included in the study. Their ages ranged between 35 and 85 years and all had undergone primary PCI. In 68 of these patients, CR was performed at least one month after the primary PCI. The remaining 33 patients formed the control group. Patients, who had serious valve disease, had an age over 85 years, respiratory function disorders, decompensated heart failure, uncontrolled hypertension (HT), diabetes mellitus (DM),

orthopedic disability, previous cerebrovascular disease and did not accept the CR program for different reasons, were excluded from the study. Patients, who did not have a sinus rhythm and had a pacemaker rhythm, were also excluded from the study. The findings in the anamnesis and physical examination, risk factors related to atherosclerosis, demographic characteristics, maximum troponin and CK-MB levels at admission, lipid parameters were recorded. Echocardiographic examination was performed and the obtained data were evaluated according to the guideline of the American Echocardiography Society with the standard technique and the 3.5 MHz phase-adjusted transducer GE Vivid 7 pro device (General Electric Company, Connecticut, USA).

Cardiac Rehabilitation Procedure

The patients, who had STEMI and underwent PCI were included in the 8-week CR program after one month from the intervention. CR was performed with a cycle ergometer for 8 weeks, according to the targeted Watt level and heart rate. The average numbers of sessions per week were 4 and each session lasted approximately 30 minutes (5 minutes warm-up, 20 minutes aerobic exercise, which increased the heart rate up to 70-85% and 5 minutes cool down).

Rhythm Holter Analysis

In both groups, at least one month after STEMI, rhythm Holter monitorization (ELA Spiderview Digital Recorder, Ela Medical, Paris 2007) was carried out for 48 hours. The rhythm Holter monitorization was repeated for 48 hours in patients, who completed the rehabilitation. The records of the Holter monitorization were uploaded to a computer and analyzed with the Holter software package (ELA Medical SYNESCOPE MultiChannel- Multiday Version 3.10). Initially, the artifacts at the "template" tab, normal and ventricular beats were determined. Then, the average maximum, minimum and mean heart rates were calculated as the mean of the 48-hour recordings. The HRV values were evaluated with the following parameters: Time domain; PNN50 (The division of the NN50 counts to the total NN count), RMSSD (root-mean-square differences of successive NN intervals), ASDNN (mean of the standard deviation in all 5-minute segments), SDNN (standard deviation of all NN intervals). The frequency domain

Table 1. The demographic characteristics, laboratory parameters, lesion and intervention features

	CR Group (n = 68)	Control Group (n = 33)	*p* value
Age (years)	58.23 ± 9.69	55.48 ± 9.99	0.21
Gender			0.77
Male, n (%)	54 (79.4)	27 (81.8)	
Female, n (%)	14 (20.6)	6 (18.2)	
Diabetes mellitus, n (%)	13 (19.4)	7 (21.9)	0.77
Hypertension, n (%)	24 (35.8)	6 (18.8)	0.08
Hyperlipidemia, n (%)	16 (23.9)	10 (31.3)	0.43
Smoking, n (%)	31 (46.3)	21 (70)	**0.03**
Previous PCI n (%)	7 (10.4)	4 (12.1)	0.80
LVEF (%)	42.13 ± 11.07	42.12 ± 9.13	0.90
End-diastole diameter (mm)	47.00 ± 3.58	47.06 ± 4.47	0.84
End-systole diameter (mm)	32.03 ± 4.46	32.19 ± 4.97	0.67
Systolic blood pressure (mmHg)	115.80 ± 9.79	111.77 ± 13.81	0.10
Diastolic blood pressure (mmHg)	71.02 ± 7.94	69.03 ± 8.4	0.28
Mean heart rate (beat/min)	66.23 ± 8.04	69.69 ± 10.31	0.069
WBC (×10^3)	9.61 ± 2.80	9.5 ± 2.34	0.97
Hemoglobin (g/dl)	13.10 ± 1.52	13.79 ± 1.26	**0.03**
Platelet count (×10^3)	256.70 ± 83.85	230.41 ± 42.69	0.27
Urea (mg/dl)	15.77 ± 4.51	15.51 ± 5.43	0.49
Creatinine (mg/dl)	0.8 ± 0.17	0.79 ± 0.18	0.55
Total Cholesterol (mg/dl)	179.96 ± 47.41	182.48 ± 41.33	0.51
LDL-C (mg/dl)	120.36 ± 44.61	117.84 ± 35.26	0.70
HDL-C (mg/dl)	35.60 ± 10.54	31.38 ± 8.6	0.08
Triglycerides (mg/dl)	114.95 ± 94.11	167.48 ± 163.46	0.056
Sodium (mEq/L)	140.07 ± 2.57	140.64 ± 2.25	0.19
Potassium (mEq/L)	4.43 ± 0.39	4.27 ± 0.45	0.10
Troponin max (ng/mL)	91.99 ± 97.62	89.34 ± 87.76	0.71
CK-MB max (ng/mL)	180.02 ± 163.67	198.35 ± 140.27	0.27
Time to the start of rehabilitation (days)	62.21 ± 29.33	-	
Drugs			
ASA, n (%)	68 (100)	33 (100)	1.0
Klopidogrel, n (%)	42 (61.8)	17 (51.5)	0.32
Ticagrelor, n (%)	26 (38.2)	16 (48.5)	0.32
Beta-blocker, n (%)	66 (98.5)	33 (100)	0.99
ACE-I, n (%)	60 (89.6)	30 (90.9)	0.83
ARB, n (%)	6 (9.1)	2 (6.1)	0.60
Statin, n (%)	68 (100)	32 (97)	0.99
Nitrate, n (%)	7 (10.6)	2 (6.1)	0.45
Diuretics, n (%)	6 (9.1)	2 (6.1)	0.60
Spironolactone, n (%)	27 (40.9)	9 (27.3)	0.18
Myocardial infarction region			0.66
Anterior, n (%)	34 (50)	15 (45.5)	
Inferior, n (%)	34 (50)	18 (54.5)	
Location of the responsible lesion			0.77
LAD, n (%)	35 (53)	15 (45.5)	
CX, n (%)	12 (18.2)	7 (21.2)	
RCA, n (%)	19 (28.8)	11 (33.3)	
Intervention			0.55
Stent, n (%)	66 (97)	33 (100)	
PTCA, n (%)	2 (3)	-	
Duration of pain (min)	205.56 ± 202.61	142.96 ± 133.36	0.11
Door-to-balloon time (min)	23.46 ± 11.60	22.16 ± 10.72	0.60

Data are shown as mean±standard deviation or number (%). ACEI = angiotensin-converting enzyme inhibitors, ARB = angiotensin receptor blockers, ASA = acetylsalicylic acid, CKMB = creatinine kinase MB isoenzyme, Cx = circumflex artery, HDL-C = high density lipoprotein cholesterol, LAD = left anterior descending artery, LDL-C = low density lipoprotein cholesterol, LVEF = left ventricular ejection fraction, PCI = percutaneous coronary intervention, PTCA = percutaneous transluminal coronary angioplasty, RCA = right coronary artery, WBC = white blood cell

HRV parameters were determined in 5 different band intervals: HF (0.15-0.4 Hz), VLF (0.0-0.04 Hz), LF (0.04-0.15 Hz), total power (0.0-2.0) and LF/HF ratio. For the evaluation of the relative changes in the frequency field, HF power HFnu=100×HF power/totalpower), normalized LF power (LFnu=100×LF power/total power) and low/high frequency power ratio (LF/HF ratio=LF power/HF power) were calculated. The TO and TS values (HRT parameters) were automatically calculated with the help of the Holter software package (HRT View Version 0.60–0,1 Munich, Germany) and ventricular premature beats, which provided the conformity criteria for the HRT measurement. The values less than 0 % were accepted for the TO and the values more than 2.5 msec/RR were accepted for the TS [8]. Turbulence loss was accepted as the increase in TO and decrease in TS.

Statistical Analysis

SPSS software package (IBM SPSS Statistics Version 22) was used for the statistical analysis. The continuous variables were expressed in mean ± standard deviation; categorical variables were expressed in percentages. The normal distribution characteristics of the continuous variables were checked with the Shapiro-Wilk normality test. Independent-samples t-test and Mann-Whitney U test were used for the comparison of the parametric data and Chi-square test and the Fisher's exact test were used for the comparison of the categorical variables. The analysis of the repeated measurements (before and after the rehabilitation) was performed with the Wilcoxon signed-rank test. For all analysis, $p < 0.05$ was considered as statistically significant.

RESULTS

The evaluation of the demographic characteristics and the laboratory analysis of the patients showed that the smoking rate was significantly higher in the control group ($p = 0.03$). The hemoglobin value was also significantly higher in the control group ($p = 0.03$). The biochemical parameters were comparable in both groups. There was no difference between the groups regarding the systolic and diastolic blood pressure and mean heart rate. The use of the medication was also comparable between the groups (Table 1).

There was also no difference between the rehabilitation group and the control group in respect of the MI area, treatment strategies and duration of pain (Table 1).

Table 2. 48-hour Holter findings in the rehabilitation and control groups

	CR Group (n = 68)	Control Group (n = 33)	p value
Mean HR (beat/min)	66.23 ± 8.04	69.69 ± 10.31	0.06
Ventricular extrasystole	624.05 ± 1841.97	129.78 ± 252.40	0.35
QT interval (msec)	415.93 ± 32.35	401.93 ± 29.06	**0.03**
VT			0.055
Yes, n (%)	11 (16.2)	1 (3)	
No, n (%)	57 (83.8)	32 (97)	
SVT			0.26
Yes, n (%)	25 (36.8)	16 (48.5)	
No, n (%)	43 (63.2)	17 (51.5)	

Data are shown as mean±standard deviation or number (%). HR = heart rate, SVT = supraventricular tachycardia, VT = ventricular tachycardia

Table 3. **HRV and HRT parameters obtained from the Holter recordings before the rehabilitation**

	CR Group (n = 68)	Control Group (n = 33)	*p* value
HRV frequency domain analysis			
TP (msec^2)	7133.66 ± 12572.95	4037.30 ± 7005.60	0.41
LF (msec^2)	1964.19 ± 4000.70	989.63 ± 2129.09	0.74
LF (nu)	20.99 ± 7.92	21.20 ± 6.46	0.58
HF (msec^2)	1734.29 ± 4235.26	874.27 ± 3252.12	0.92
HF (nu)	12.19 ± 11.66	11.84 ± 9.71	0.55
LF/HF ratio	2.94 ± 2.12	2.67 ± 1.68	0.67
HRV time domain analysis			
SDNN (msec)	103.74 ± 35.08	99.76 ± 33.33	0.77
ASDNN (msec)	71.80 ± 51.89	58.88 ± 39.15	0.45
RMSSD (msec)	70.81 ± 87.68	52.82 ± 67.10	0.72
pNN50 (%)	9.22 ± 10.85	8.62 ± 8.77	0.85
HRT parameters			
TO	-0.0089 ± 0.027	-0.0027 ± 0.031	0.24
TS	9.26 ± 8.13	7.30 ± 9.16	0.17

Data are shown as mean±standard deviation. CR = cardiac rehabilitation, HR = heart rate, HRV = heart rate variability, HRT = heart rate turbulence, TO = turbulence onset, TS = turbulence slope

There was no significant difference between the groups considering the main findings of the 48-hour Holter monitorization. There was no significant difference between the groups regarding the ventricular extrasystole count, the presence of the supraventricular and ventricular tachycardia. The QT-interval was 415 ± 32 msec and 401 ± 29 msec in the rehabilitation and control groups respectively. The QT-interval was significantly longer in the rehabilitation group (*p* = 0.03) (Table 2).

There was no difference between the pre-rehabilitation frequency domain analysis of the basal HRV parameters (TP, LF, LFnu, HF, HFnu, LF /HF) and time domain parameters (SDNN, ASDNN, RMSSD, pNN50). HRT parameters (TO and TS) were comparable in both groups (Table 3). In the rehabilitation group, there was no significant difference between HRV and HRT parameters before and after the rehabilitation (Table 4).

The analysis of the subgroup consisting of the patients with a left ventricule ejection fraction below than 40% showed that there was no significant difference between the HRV parameters before and after the rehabilitation. Regarding the HRT parameters; there was no significant difference before and after the rehabilitation for TS, but TO parameter significantly improve with CR (before the rehabilitation: -0.00014 ± 0.021, after the rehabilitation: – 0.0051 ± 0.029, *p* = 0.04). (Table 5) (Fig. 1).

DISCUSSION

In our study, we found that the 8-week CR program, which STEMI patients underwent at least

Table 4. HRV and HRT parameters in the rehabilitation group before and after the rehabilitation

	Before Rehabilitation (n = 68)	After Rehabilitation (n = 68)	*p* value
HR (bpm)	66.3 ± 8.09	66.9 ± 7.50	0.52
HRV frequency domain analysis			
TP (msec^2)	7133.6 ± 1257.8	5183.0 ± 1220.8	0.88
LF (msec^2)	1964.1 ± 400.0	1376.4 ± 411.7	0.84
LF (nu)	20.9 ± 21.7	21.7 ± 8.0	0.28
HF (msec^2)	1734.2 ± 423.5	1139.0 ± 511.4	0.82
HF (nu)	12.1 ± 11.6	11.0 ± 9.4	0.87
LF/HF ratio	2.9 ± 2.1	3.2 ± 2.4	0.51
HRV time domain analysis			
SDNN (msec)	103.7 ± 35.0	102.7 ± 28.1	0.69
ASDNN (msec)	71.8 ± 51.8	63.5 ± 28.9	0.95
RMSSD (msec)	70.8 ± 8.7	52.9 ± 5.6	0.63
pNN50 (%)	9.2 ± 8.1	8.0 ± 7.2	0.96
HRT parameters			
TO (%)	-0.0089 ± 0.002	-0.0077 ± 0.002	0.72
TS (msec/RR)	9.6 ± 8.3	7.3 ± 6.4	0.26

Data are shown as mean±standard deviation. CR = cardiac rehabilitation, HR = heart rate, HRV = heart rate variability, HRT = heart rate turbulence, TO = turbulence onset, TS = turbulence slope

one month after PCI, had no significant effect on the HRV and HRT parameters. The subgroup analysis showed that CR did not provide any significant change in HRV and HRT parameters in patients, who had a normal or mildly affected LVEF (LVEF > 40%). On the other hand, we determined a significantly positive effect in TO for patients with an LVEF lower than 40%. Our study is the first study in the literature, which is focused on the HRT parameters before and after CR in post-STEMI patients.

Most of the meta-analyses, which focused on the effects of CR on the cardiac mortality in acute MI patients, were conducted before the introduction of the modern revascularization techniques like the thrombolytic treatment and primary PCI. Hereby, it might come to mind whether the effects of CR on the mortality were still in place after the introduction of the modern revascularization techniques. Although, it was shown in a few studies that mortality was decreased, the lack of randomized and controlled studies focused on this topic should be taken into consideration. Goel *et al*. [9] has evaluated a retrospective study (published 2011) focused on a large patient population (n = 2395), who underwent PCI between 1994 and 2008. In conclusion, it was determined that CR decreased significantly all-cause and cardiac mortalities after PCI [9]. In a meta-analysis, which was conducted with the support of the Cochrane Collaboration and published in 2001 and revised in 2005, 51 studies comprising 8440 patients

Table 5. HRV and HRT findings in patients with LVEF < 40 % before and after the rehabilitation

	Before Rehabilitation (n = 24)	After Rehabilitation (n = 24)	*p* value
HRV frequency domain analysis			
HR (bpm)	67.62 ± 9.05	68.42 ± 7.58	0.83
TP (msec^2)	8628.11 ± 15424.91	7926.88 ± 18159.08	0.71
LF (msec^2)	2436.55 ± 4759.98	2314.64 ± 6051.47	0.87
LF (nu)	22.57 ± 8.38	23.52 ± 8.62	0.67
HF (msec^2)	2337.55 ± 5007.81	2478.55 ± 7741.08	0.82
HF (nu)	15.30 ± 12.24	15.76 ± 11.95	0.50
LF/HF ratio	2.39 ± 1.54	2.31 ± 1.54	0.91
HRV time domain analysis			
SDNN (msec)	104.78 ± 35.33	98.42 ± 32.18	0.12
ASDNN (msec)	82.95 ± 60.70	72.10 ± 42.74	0.97
RMSSD (msec)	48.64 ± 42.29	58.00 ± 39.40	0.11
pNN50 (%)	9.84 ± 13.08	8.53 ± 6.63	0.95
HRT parameters			
TO (%)	-0.00014 ± 0.021	-0.0051 ± 0.029	0.04
TS (msec/RR)	6.12 ± 5.18	5.08 ± 5.08	0.50

Data are shown as mean±standard deviation. CR = cardiac rehabilitation, HR = heart rate, HRV = heart rate variability, HRT = heart rate turbulence, TO = turbulence onset, TS = turbulence slope

were systematically investigated [2]. In patients, who underwent cardiac rehabilitation, all-cause and cardiac mortalities decreased 27 % and 31 % respectively. There was also a 19 % decrease in combined events (non-fatal MI, CABS, PTCA) [2].

The cardiac autonomous functions are impaired in MI patients and this impairment is correlated with the mortality and morbidity. Kleiger *et al*. [10] investigated HRV parameters with 24-hour Holter monitorization after 11 ± 3 days from the acute event in 808 patients. They determined a 2.4-fold increase in the all-cause mortality during the 31-month follow-up in the group with SDNN > 50 msec compared to the SDNN < 50 msec [10].

In a randomized and controlled study conducted

by Oliveira *et al*. [11] and published in 2014, the effects of 8-week exercise-based CR on the cardiac autonomous functions were investigated in the MI patients. The HRV parameters were measured after this exercise program and no difference was detected between the exercise and control group regarding the HRV parameters. Only the VO2 peak level was significantly increased in the exercise group [11]. As the LVEF level was > 50% in this study, we assumed that the PCI implementation was efficient. This study was conducted a short time ago when the revascularization techniques and pharmacological agents were widely used and its results are consistent with our study.

The data related to the MI patients, who
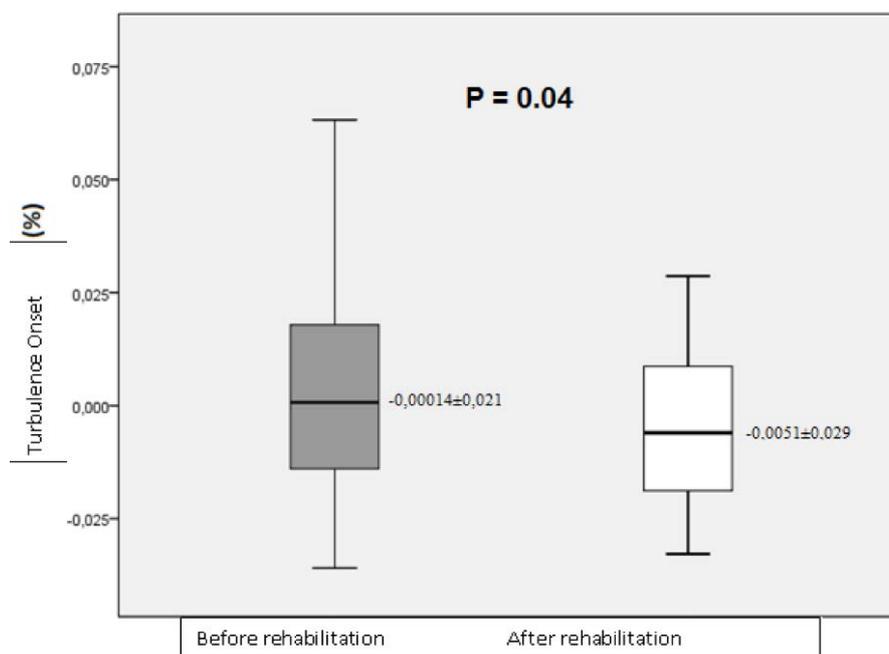
Fig. 1. Turbulence onset value in patients with LVEF < 40% before and after the rehabilitation.

underwent CR, were based on the studies conducted 30 years ago. At that time, efficient revascularization techniques were not introduced yet and the use of several anti-platelet and anti-ischemic agents and the statin derivatives was not prevalent. Therefore, the cardiac damage was more severe and the survival rate was relatively lower. This fact brought along the questioning of the benefits of CR, which was effective at that time. In other words, the faster the treatment and the better the revascularization, the milder is the cardiac damage and consequently the benefit of CR is not much different from its benefit in the healthy population. In our study, our findings – no significant difference between the pre- and post-rehabilitation HRV and HRT values in the control group – confirm these results.

In our study, all patients were diagnosed with STEMI and underwent PCI. Other patients with acute coronary syndrome (ACS) were excluded from the study. Therefore, we can suggest that the study group was balanced and homogeneous. Studies related to the exercise program contained certain differences. In our study, we implemented an 8-week exercise program, which consisted of approx. 30-minute 4 sessions per week. The targeted heart rate was 70-85 % of the resting heart rate. We did not detect any difference between the rehabilitation and control group regarding

the HRV parameters. There was also no difference between the HRV parameters before and after the rehabilitation. These findings might be related to the revascularization at the early stage, minimally valve damage and drug treatment. Probably, the short door-to-balloon time and high rate of the compliance to the drug treatment prevented the deterioration of the cardiac autonomous functions and improved the impaired functions at the early stage. It is well known that post-MI acute sudden death rate is particularly high in the first month. In our study, the rehabilitation was started at least one month after the acute MI (mean time: 62 ± 29 days). Prior to the rehabilitation program, Holter monitorization was carried out for the evaluation of the baseline HRV and HRT parameters. Regarding the control group, 48-hour rhythm Holter monitorization was performed at least one month after the acute MI (mean: 86 ± 57 days). In our study, as it was mostly within the normal limits in both groups and there was no significant difference between the groups regarding the HRV and HRT parameters, we believe that these may be related to the study design, in which the measurements were not done in the first month, which is period with the highest level of the risks of ACD and the cardiac autonomous dysfunction.

The relatively limited cardiac damage may decrease the efficacy of the exercise-based CR and

consequently, no difference in HRV and HRT parameters was detected after CR. The baseline values of the HRV parameters were higher in our study compared to other studies and were mostly within normal limits. These findings might be explained by the early and effective revascularization and the following preservation of the cardiac autonomous functions and with the normal HRV and HRT parameters comparable to the normal population. In addition, like the abovementioned study, the compliance to the treatment, use of the beta-blockers and ACE-inhibitors [12, 13], which particularly improve the cardiac autonomous functions, during the study and high tolerance of the drugs, might be related to this finding.

One of the subgroup analyses in the study ATRAMI (Autonomic Tone and Reflexes After Myocardial Infarction) showed that the patency of the artery responsible for the MI, was the major determinant in the post-MI baroreceptor response in the patient population, who underwent coronary angiography [14]. The post-MI baroreceptor activity and cardiac autonomous functions declined acutely. Nevertheless, it was demonstrated that the HRT parameters, which were one of the indicators of the cardiac autonomous functions, improved after the reperfusion [15]. This may be explained by the limited impact on the autonomous functions and faster improvement of them along with the corresponding HRT parameters as a result of the revascularization at the early stage with modern techniques. According to the findings of our study, CR was carried out on patients, who had mildly affected HRV and HRT parameters with levels similar to the normal population. This may be the reason that the post-rehabilitation levels of these parameters did not change compared to the pre-rehabilitation levels.

HRT is usually abnormal in patients with heart failure. It was determined that TS below 2.5 m/sec was related to the risk of the cardiac complications in patients with heart failure (EF < 35 %) [16]. In our study, in the subgroup analyses, we detected a significant difference between the TO values before and after the rehabilitation in patients with an LVEF below 40%.

Therefore, it may be suggested that the patients, who had delayed revascularization and treatment and consequently increased cardiac damage followed by decreased SVEF, had a distinct clinical condition. It may be also suggested that CR is more effective in decreasing the mortality in patients with an LVEF lower than 40%. However, further studies are needed for the confirmation.

Limitations

One of the limitations of our study is the lack of the 48-hour rhythm Holter monitorization in both rehabilitation and control groups within the same time. This may have caused some heterogeneity in HRV and HRT values. The HRV and HRT parameters were obtained from the rhythm Holter recordings during the routine daily activities. The evaluation of the Holter recordings during the exercise may present different results.

CONCLUSION

We did not determine any significant difference between the HRV and HRT parameters before and after the rehabilitation, in patients with STEMI who was treated with primary PCI. However, there was a significant and positive difference in TO parameter in patients with a left ventricular ejection fraction less than 40%.

Conflict of interest
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