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RESEARCH

Evaluation of cardiac biomarkers, electrocardiogram changes and echocardiography findings before and after exercise in paediatric athletes

Çocuk sporcularda egzersiz öncesi ve sonrası kardiyak biyobelirteçlerin, elektrokardiyogram değişikliklerinin ve ekokardiyografi bulgularının değerlendirilmesi

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Abstract

Purpose: The aim of this study was to investigate the structural and electrical changes in the heart associated with exercise in young athletes under 18 years of age and to examine the relationship between these changes and biochemical markers.
Materials and Methods: In this study, 32 male paediatric athletes (five rowers, five kayakers and 22 footballers) were prospectively evaluated. Dynamic exercise training for 75 minutes was applied to all athletes. An echocardiographic evaluation was performed on the athletes at rest. An electrocardiogram (ECG) was taken before and after the exercise. Blood samples were taken from all athletes before the exercise, during the first hour of exercise and after the fourth hour of the training session to analyse the serum levels of creatine kinase myocardial band, troponin T(cTnT) and pro-brain natriuretic peptide.
Results: The mean age of all athletes was 15.3±0.9 years. In the echocardiography examination, end-diastolic thickness, left ventricular end-diastolic diameter, posterior wall end-diastolic diameter, left ventricular end-systolic diameter, left ventricular mass measurements (LVM) and left ventricular mass indices (LVMI) were higher among the rowers than in the remaining groups. In the post-exercise ECG, T-wave peaks were observed in 16 individuals, including all rowers, all kayakers, and six footballers. The cTnT values in the first hour and after the fourth were 0.31–0.71 ng/ml in football players, 0.10–0.27 ng/ml in rowers, and 0.04–0.15 ng/ml kayakers. An increase in cTnT levels was detected after the fourth hour of exercise in all groups. There was a correlation between T-wave peaks in the ECG taken after exercise and age, cTnT serum level and increased LVM.

Öz

Amaç: 18 yaş altı çocuk sporcularda egzersizle ilişkili kalbin yapısal ve elektriksel değişikliklerini araştırmak ve bu değişiklikler ile biyokimyasal belirteçler arasındaki ilişkiyi incelemektir.
Gereç ve Yöntem: Bu çalışmada 32 erkek pediatrik sporcu (beş kürekçi, beş kanocu ve 22 futbolcu) prospektif incelendi. Tüm sporculara 75 dakikalık dinamik egzersiz antrenmanı uygulandı. Atletlerde istirahat halinde ekokardiyografik değerlendirme yapıldı. Egzersiz öncesi ve sonrasında elektrokardiyogram (EKG) çekildi. Tüm sporculardan antrenman öncesinde, antrenman sonrası 1.saatinde ve 4. saat kan örnekleri alınarak kreatin kinaz miyokardiyal bant, troponin T(cTnT) ve pro-beyin natriüretik peptid düzeylerine bakıldı.
Bulgular: Tüm sporcuların yaş ortalaması 15,3±0,9 yıldı. Ekokardiyografi incelemesinde diyastol sonu kalınlığı, sol ventrikül diyastol sonu çapı, arka duvar diyastol sonu çapı, sol ventrikül sistol sonu çapı, sol ventrikül kitle ölçümleri (SVK) ve sol ventrikül kitle indeksleri (SVKİ) bu gruptan daha yüksekti. Egzersiz sonrası EKG bulgusu kürekçi ve kanocuların tümünde ve altısı futbolcu olmak üzere 16 kişide T dalgası pikleri görüldü (p<0,001). Egzersiz sonrası 1.saat ve 4.saatten cTnT değerleri futbolcularda 0,31-0,71 ng/ml; kürekçilerde 0,10-0,27 ng/ml ve kanocularda 0,04-0,15 ng/ml ölçüldü. Tüm gruplarda egzersiz sonrası dördüncü saatte cTnT düzeylerinde artış tespit edildi. Egzersiz sonrası çekilen EKG'deki T dalgası piki ile yaş, cTnT serum düzeyi ve SVK artış arasında korelasyon vardı.
Sonuç: Bu çalışmada sporcuların yarısında egzersiz sonrası T dalgasında piki saptandı. Sonuçlarımız genç sporcuların serum cTnT düzeylerinin egzersizle yükselebileceğinir. Sporcularda SVK ve SVKİ daha yüksekliği görülebilir.

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Conclusion: In this study, we found T-wave peaks in half of the athletes after exercise. The serum cTnT levels of young athletes may be elevated by exercise and that LVM and LVMI may be higher in athletes. Echocardiography and ECG evaluations should be performed in paediatric athletes.
Keywords:. Pediatric athletes, T-wave peak, troponin T, echocardiography

Çocuk sporcularda ekokardiyografi ve EKG değerlendirmesi yapılmalıdır.
Anahtar kelimeler: Çocuk sporcular, T dalga piki, troponin T, ekokardiyografi

INTRODUCTION

Regular exercise causes changes in the structure and function of the heart[1]. Athletes at rest present with bradycardia, increased left ventricular mass (LVM) and increased stroke volume[2,3]. Physiological changes in young athletes are similar to those observed in adult athletes, but produce fewer symptoms[4]. Despite the beneficial effects of physical activities, they can trigger pre-existing cardiac abnormalities and/or directly cause malignant arrhythmia or hypertrophic cardiomyopathy, leading to athlete death[5].

Evaluation of an athlete's heart remodelling based on electrical changes observed on echocardiography may cause different electrocardiogram (ECG) findings[6,7]. To evaluate these ECG findings, the athlete's history, family history, age, the type of sports in which he/she engages and the presence of pathological findings on echocardiography should also be considered.

Studies have found an increase in markers specific to myocardial damage, such as creatine kinase myocardial band (CK-MB) and cardiac troponin T (cTnT), after exercise in athletes, which are considered to be related to physiological changes triggered by exercise[8,9]. However, excluding myocardial damage associated with intense training is not always possible. The pro-brain natriuretic peptide (pro-BNP) serum level indicates heart failure and may also be elevated after prolonged dynamic exercise[10]. It is important to determine whether echocardiography findings, ECG findings and cardiac biomarkers indicate a pathological or physiological state in the evaluation of the hearts of athletes.

In this study, we aimed to investigate the structural and electrical changes in the heart associated with exercise in young athletes under 18 years of age who had been exercising regularly and intensively for at least two years and to examine the relationship between heart-related biochemical markers and exercise.

In the literature, there are no studies in which ECG, echocardiographic examination, and cardiac biomarkers are evaluated simultaneously in the same athletes. To understand the pathophysiology of an athlete's heart, it is necessary to evaluate these findings together. In our study, we examine the athlete's heart in detail and draw attention to findings that can be considered normal.

MATERIALS AND METHODS

Sample

This study was conducted with male rowers, kayakers and Adana Demirspor football club footballers aged under 18 years who attended the Physical Education and Sports Vocational School of Cukurova University. Five rowers, five kayakers and 22 footballers participated in our study. This study was designed prospectively and followed the tenets of the Declaration of Helsinki. Informed consent was obtained from the participants and their parents. This study was approved by the Clinical Research Ethics Committee of Cukurova University (57-07/10/2016). All athletes performed endurance and resistance exercises for equal durations. The inclusion criteria for the athletes were that they engaged in regular and intense exercise for at least 10 hours a week for at least two years. Exclusion criteria were athletes participating in regular exercise training, chronic disease and known familial arrhythmia. Although 34 athletes were selected initially, 2 rowers were not included in the study because they did not regularly participate in the training.

Procedure

Initially, the scope of the study was explained to all participants. In addition, their families were informed about the study by the coaches. During the first interview, the participants' demographic data, type of sport, sports history and weekly exercise time were recorded. The participants were questioned about the presence of systemic disease, drug use and their history of fatigue or syncope, chest pain or dyspnea during or after exercise. A family history of heart disease under 50 years of age or sudden cardiac death at an early age were specifically questioned.

Blood samples were taken from the participants at rest to analyse the serum levels of CK-MB, cTnT and pro-BNP. Dynamic exercise training lasting 75 minutes was applied to all athletes. Prior to the exercise, ECGs were taken at rest and after 75 minutes of dynamic exercise. The rowers and kayakers were evaluated after 12 km and 7.8 km of hard rowing exercise, respectively and footballers were evaluated after running training. Echocardiographic evaluation was performed at rest before the athletes started to exercise. Blood samples were taken from all athletes before and after the first and fourth hours of exercise during the same session.

An anamnesis of the athletes was taken. Before exercise, fatigue and chest pain were reported by two footballers, chest pain and shortness of breath were reported by one rower and grayout was reported by two rowers after exercise. None of the athletes had a known history of systemic disease. However, there was coronary artery disease at an early age in a kayaker's father and early sudden cardiac death in a rower's aunt.

Physical examination

All participants' systemic physical examinations, body weight, height and weight percentile values, body mass index (BMI), blood pressure, pulse and murmurs were recorded.

Electrocardiography

A 12-lead ECG was taken from all participants to make an overall assessment. ECG recordings (filter range 0.05–150 Hz, AC filter 60 Hz, 25 mm/s, 10 mm/mV) were manually analysed by a cardiologist with more than 20 years of echocardiography experience. During the measurements, care was taken to place the leads at the same points before and after the exercise.

In addition, the ECG recordings and evaluations were repeated immediately after 75 minutes of dynamic exercise. The T-wave peak criterion was accepted, as the T wave was longer than 2/3 of the QRS complex in the participants. The ST-segment elevation criterion was accepted as the elevation being ≥0.2 mV (2 mm) at the J point in leads V2-V3. A heart rate <60 beats/min was defined as bradycardia.

CK-MB, cTnT and pro-BNP levels

Blood samples were taken from the peripheral vein by an injector, placed into a vacuum gel tube and centrifuged. Plasma samples were separated, kept in a refrigerator at -80 degrees, and assayed within four weeks using the electrochemiluminescence immunoassay method and pro-BNP, CK-MB and cTnT kits (Roche Diagnostics; Mannheim, Germany). The Elecsys System 1010/2010 device was used for the analyses.

Echocardiography

Echocardiography was performed on all participants in the supine position using the Philips Epiq 7 ultrasonography device. Examinations were undertaken in parasternal long axis, apical four-chamber, short axis, subcostal and suprasternal sections. The anatomical structure was examined using two-dimensional echocardiography. Colour Doppler and pulse Doppler examinations were also performed.

Left ventricular systolic and diastolic diameters and systolic functions were measured from the parasternal long axis position with M-mode echocardiography using the Teichholz method[11]. The diameters of the aorta and left atrium were measured in the parasternal long axis section using M-mode echocardiography, and the ratio of the left atrium diameter to the aortic diameter was calculated. The athletes underwent a standard echocardiographic assessment in which the LVM was calculated using Devereux's formula[12]. LVM = 1.04 × [(interventricular septum thickness + left ventricular end-diastolic diameter + posterior wall thickness) − left ventricular end-diastolic diameter −14 g][13]. The LVM index (LVMI) (g/m^2) was obtained by taking the ratio of the LVM to the body surface area.

The examination was performed by experienced paediatric cardiologists (SE, >15 years of experience in echocardiography experience or certification in echocardiography) using a high-end device with cardiac probe using the Philips Epiq 7 (Philips, the Netherlands) ultrasonography device.

Statistical analysis

The SPSS v. 23.0 (Version 23.0, SPSS Inc., Chicago, IL, USA) package programme was used for the statistical analyses of the data. Continuous variables were tested for the normality of the data distribution using an analytical method (Kolmogorov–Smirnov test) and visual methods (histograms and probability plots). Continuous variables were summarised as mean ± standard deviation or, where appropriate, median and minimum–maximum values. Categorical variables were expressed as numbers (n) and percentages (%), as appropriate. An independent-sample t-test or the Mann–Whitney U test was conducted to analyse continuous variables. Categorical variables were compared using the chi-square test.

In comparing serum parameters between groups before and after exercise, analysis of variance was used for normally distributed parameters, and the Kruskal–Wallis test was used for nonnormally distributed parameters. Bilateral tests with an overall significance level (alpha) of 0.05 were used in all analyses. Friedman test was used to evaluate CK-MB, troponin T, and pro-BNP levels before and after exercise according to sport types. The relationship between T wave peaks and age, troponin T and cardiac parameters, and T wave peaks in the post-exercise ECG Mann-Whitney U test was applied. Bilateral tests with an overall significance level (alpha) of 0.05 were used in all analyses. A post-hoc power analysis was calculated using G* Power 3.1 (Erdfelder, Faul ve Buchner, Version 3.1 Germany) of the study to determine the proportion. The analysis indicated that the study had a power of 82% at an alpha level of 5%.

RESULTS

A total of 32 male athletes, including five rowers (15.6%), five kayakers (15.6%), and 22 footballers (68.8%), were included in the study. None of the athletes had any pathological findings in the cardiovascular system examination. Malnutrition was detected in one football player. All athletes' preexercise blood pressure measurements were within normal limits according to age and height. The rowers' mean height, weight, BMI and body area were higher when compared to the remaining athlete groups. The demographic data and physical examination findings of the athletes are shown in Table 1.

Table 1. Physical examination data of athletes according to sport types

	Football player		Kayaker		Rower	
Physical examination	Mean ±SD	Min-Max	Mean ±SD	Min-Max	Mean± SD	Min-Max
Body weight (kg)	56.8 ± 6.6	40-68	70.3 ± 12.2	59-88	81.4 ± 4.2	77-88
Height (cm)	171.1 ± 7.8	150-186	175.5 ± 10.1	162-188	189 ± 3.1	184-191
BMI (kg/m^2)	19.4 ± 2.2	15.7-25.3	22.2 ± 1.7	20.2-24.9	22.8 ± 1.3	21.5-24.2
Body area (m^2)	1.6 ± 0.1	1.28-1.76	1.8 ± 0.2	1.6-2	1.9 ± 0.1	1.84-2.02
Systolic blood pressure (mmHg)	103.8 ± 7.4	90-120	117.0 ± 6.7	110-125	114.0 ± 6.5	105-120
Diastolic blood pressure (mmHg)	64.1 ± 7.7	50-80	70.0 ± 0.0	70-70	66.0 ± 8.9	60-80
Demographic data						
Age (years)	14.8 ± 0.2	14.3-15	16.5 ± 1.1	15.4-17.9	16.5 ± 0.6	15.4-16.9
Weekly training duration (hour)	10.0 ± 0	10-10	15.4 ± 3.1	14-21	16.4 ± 0.9	16-18
Sports history (year)	5.1 ± 1.4	1.5-6	2.6 ± 0.9	1.5-4	3 ± 1.4	1-5

SD: standard deviation, **BMI:** body mass index, **Min:** minimum, **Max:** maximum

The ECGs of the athlete showed normal sinus rhythm except for one rower with wandering atrial pacemaker rhythm. One football player had sinus bradycardia (58 beats/min) before the exercise. The mean heart rate was 76.3 ± 10.8 beats/min before exercise and 98.3 ± 15.7 beats/min after exercise. An increase in heart rate was observed in 28 athletes after exercise. An incomplete right bundle branch block was observed before and after exercise in one football player. The PR interval was 0.16 seconds before exercise and 0.28 seconds after exercise in one rower. This athlete developed a first-degree atrioventricular block according to the ECG taken after exercise. The PR intervals of the remaining athletes were within normal limits. T-wave peaks were observed in three rowers and one kayaker in the preexercise ECG examination. After exercise, T-wave peaks were seen in all rowers, all kayakers and six footballers.ST-segment elevation was observed in two rowers before exercise and in all rowers (n = 5) and all kayakers (n = 5) after exercise. Table 2 shows the distribution of heart rate measurements and sports types of the athletes, and Table 3 presents the distribution of general ECG findings and pre- and post-exercise ECG findings according to sports type.

Table 2. ECG findings of the athletes before and after exercise

ECG Finding		Before Exercise		After Exercise	
		n	%	n	%
Rhythm	Sinus rhythm	31	96.9	31	96.9
	Other	1	3.1	1	3.1
PR interval	Normal	32	100.0	31	96.9
	Other	0	0	1	3.1
QTc	Normal	32	100.0	32	100.0
	Other	0	0	0	0.0
ST	Normal	30	93.8	22	68.8
	ST-segment elevation	2	6.3	10	31.3
T wave	Normal	28	87.5	16	50.0
	T-wave peak	4	12.5	16	50.0
Additional finding	Absent	30	93.8	29	90.6
	Other	1*,1**	6.3	1*,1**,1***	9.4

*wandering atrial pacemaker rhythm, **incomplete right branch block, ***sinus bradycardia

Table 3. T-wave and ST-segment findings in ECG evaluation before and after exercise according to sport types

			Football player		Rower		Kayaker		p
			n	%	n	%	n	%	
Pre-exercise	T wave	Normal	22	100.0	2	40.0	4	60.0	0.002
		T-wave peak	0	0.0	3	60.0	1	20.0	
	ST segment	Normal	22	100.0	3	60.0	5	100.0	0.016
		Elevation	0	0.0	2	40.0	0	0.0	
Post-exercise	T wave	Normal	16	72.3	0	0.0	0	0.0	<0.001
		T-wave peak	6	27.3	5	100.0	5	100.0	
	STsegment	Normal	22	100.0	0	0.0	0	0.0	<0.001
		Elevation	0	0.0	5	100.0	5	100.0	

When the echocardiography findings were evaluated according to sport types, the mean values of interventricular septum diastolic diameter, left ventricular diastolic diameter, posterior wall diastolic diameter, left ventricular systolic diameter, LVM and LVMI values were higher in rowers than in the remaining athlete groups. However, only the difference in LVMI was statistically significant (p = 0.01). In five athletes—four rowers and one kayaker-LVM was measured to be over 200 g. Among footballers, mild aortic insufficiency, mild mitral valve prolapse and mild mitral insufficiency (MI) were found in one athlete from each sport. In addition, in the rower group, one athlete had a bicuspid aortic valve and mild aortic insufficiency, one had MI, and one had mild MI, mild tricuspid insufficiency, and concentric ventricular hypertrophy. One of the kayakers developed concentric ventricular hypertrophy, and the other presented with eccentric ventricular hypertrophy. The echocardiography findings of the athletes are shown in Table 4.

Table 4. Echocardiography findings of the athletes according to sport types

	Football player		Kayaker		Rower	
	Mean± SD	**Min-Max**	**Mean ± SD**	**Min-Maks**	**Mean ± SD**	**Min-Max**
IVSDd (mm)	9.3 ± 1.0	7.3-11.8	10.0 ± 0.7	9.3-11	11.1 ± 0.8	10-12
LVDd (mm)	47.5 ± 3.2	40-52	50 ± 4.2	46-57	52.6 ± 1.1	51-54
PWDd (mm)	8.8 ± 0.8	7-10	10 ± 1.2	9-12	10.7 ± 0.8	10-12
LVDs (mm)	29.3 ± 2.6	23.6-33.6	31.1 ± 3.6	26-36	33.7 ± 2.3	30-35.6
EF (%)	68.1 ± 4.9	61-76	66.6 ± 6.5	62-78	64.8 ± 4.7	61-73
KF (%)	37.6 ± 3 .9	33-45	37.2 ± 5.7	33-47	35.6 ± 3.7	33-42
IVSD (mm)	12.7 ± 1.4	10-14.8	14.1 ± 1.3	12.2-16	16.2 ± 1.7	13.8-17.8
PWDs(mm)	13.9 ± 1.6	11-16	15.9 ± 1.2	14-17.5	15.6 ± 1.0	14.2-16.5
LVM (g)	140.8 ± 24.9	86-182	180 ± 22.9	158-209	219.6 ± 16.2	194-235
LVMI (g/m²)	85.0 ± 11.3	63-101	97.8 ± 14.3	81-116	106.8 ± 6.7	95-111

SD: standard deviation, **Min:** minimum, **Max:** maximum, **IVSDd:**interventricular septum diastolic diameter, **LVDd:** left ventricular diastolic diameter, **PWDd:** posterior wall diastolic diameter, **LVDs:** left ventricular systolic diameter, **EF:** ejection fraction, **FS:** fraction shortening, **IVSDs:**interventricular septum systolic diameter, **PWDs:** posterior wall systolic diameter, **LVM:** left ventricular mass, **LVMI:** left ventricular mass index

A significant increase in cTnT levels was observed in all athletes after exercise (Table 5). It was noted that basal troponin levels before exercise and cTnT levels after exercise significantly increased in rowers compared to the remaining athlete groups (p=0.003). Table 5 presents the CK-MB, cTnT and pro-BNP levels measured before the first hour and after the fourth hour of exercise and their distribution by sport type.

Table 5. Distribution of the athletes' CK-MB, troponin T, and pro-BNP levels before and after exercise according to sport types

		Football player		Kayaker		Rower	
		Median	**Min-Max**	**Median**	**Min-Max**	**Median**	**Min-Max**
CK-MB, U/L	Hour 0	2.3	0.8-8	3.1	2.7-5.2	3.4	2.1-5.1
	Hour 1	2.2	1.2-4.6	2.3	1.5-5.9	4.9	2-9.5
	Hour 4	2.1	0.8-6.5	3.3	2.2-6.9	4.4	2.2-8.4
p-value		0.562		0.174		0.069	
Pro-BNP, pg/ml	Hour 0	20	5-55	10.0	5-43	32.0	5-79
	Hour 1	22	5-67	11.0	5-46	45.5	5-93
	Hour 4	21	5-68	8.0	5-36	29.5	5-90
p-value		<0.001		0.148		0.022	
Troponin T, ng/ml	Hour 0	0.31	0.03-8.4	0.04	0.03-0.09	0.10	0.05-0.34
	Hour 1	0.56	0.03-12.8	0.04	0.03-0.09	0.12	0.06-0.46
	Hour 4	0.71	0.03-65.5	0.15	0.06-0.6	0.27	0.06-0.95
p-value		<0.001		.0.032		0.003	

SD: standard deviation, **Min:** minimum, **Max:** maximum, Comparisons made between hours 0 and 4 using the Friedman test

Athletes with T-wave peaks on the ECG taken after exercise were observed to be older (p=0.001) with a mean age of 15.9±1.1 years. All athletes aged 16 and over were found to have T-wave peaks on the ECG taken after exercise, while the rate of athletes with T-wave peaks after exercise was 36% for the under-16 group.

The increase in cTnT at the fourth hour was statistically significant according to the presence of T-wave peaks on the ECG taken after exercise (p=0.001). Among the patients with T-wave peaks at the fourth hour of exercise, the cTnT value was ≤0.10ng/ml in 14 and >0.10ng/ml in two. The comparisons of the echocardiography findings of the patients with and without T-wave peaks after exercise are shown in Table 6.

Table 6. Relationship between T-wave peaks and age, troponin T, and cardiac parameters

	T-wave peak on post-exercise ECG				p
	Absent		Present		
	n	Mean ±SD	n	Mean ± SD	
Age, years	16	14.7±0.3	16	15.9±1.1	0.001
	n	Median (Min-Max)	N	Median (Min-Max)	
IVSDs	16	12.6 (10-14.6)	16	14.8 (11.3-17.8)	0.005
PWDd	16	10 (8-12)	16	8.6 (7-9.7)	0.002
LVDd	16	50 (43-57)	16	48 (40-50)	0.011
IVSDd	16	10 (8.2-12)	16	9 (7.3-11.8)	0.024
IVSDs/IVSDd	16	1.35 (1.0-1.7)	16	1.4 (1.0-1.7)	0.323
PWDs/PWDd	16	1.63 (1.1-2.0)	16	1.5 (1.1-1.9)	0.094
LVM	16	142 (86-182)	16	176 (123-235)	0.001
LVMI	16	99 (75-116)	16	88 (101-63)	0.009
Troponin T, hour 4	16	0.06 (0.03-0.65)	16	0.2 (0.06-0.95)	0.001
Troponin T, hour 0	16	0.07 (0.03-0.34)	16	0.03 (0.03-0.07)	0.011

ECG: electrocardiogram, SD: standard deviation, Min: minimum, Max: maximum, IVSDs: interventricular septum systolic diameter, PWDd: posterior wall diastolic diameter, LVDd: left ventricular diastolic diameter, IVSDd:interventricular septum diastolic diameter, PWDs: posterior wall systolic diameter, LVM: left ventricular mass, LVMI: left ventricular mass index, p: Mann-Whitney U test

DISCUSSION

This study aimed to evaluate changes in ECG recordings with exercise, determine whether there was an increase in the biochemical markers of the heart and investigate the structural changes in the heart after exercise in young athletes. The sample consisted of 32 young male athletes 22 footballers, five rowers and five kayakers. Football was included in the high-intensity dynamic exercise group. Rowing and kayaking are dynamic exercise types with an increased static component and were placed in the high-intensity category. Therefore, our study evaluated athletes with static and dynamic components from different sports types.

For many years, it has been debated whether ECG changes seen in athletes are physiological or pathological. According to the ECGs taken after exercise, the current study found that T-wave peaks developed in 16 individuals-five rowers, five kayakers and six footballers. T-wave peaks were observed on the ECGs taken after exercise in all athletes aged 16 and over and in 36% of the athletes under 16. In addition, ST-segment elevation was present in all rowers and kayakers (10 individuals in total), according to the ECGs taken after exercise. When we reviewed the literature, we found that most studies evaluating athletes' hearts reported findings of T-wave inversion after exercise[14–16]. Barbosa et al.[17] investigated the physiopathology of post-exercise T-wave peaks in athletes. They stated that early repolarisation could be seen as a result of the voltage difference and electrophysiological changes between the endocardium and epicardium, which might cause T-wave peaks. The authors also suggested that T-wave peaks might occur due to increased vagal tone and decreased sympathetic activity in athletes and sedentary individuals. They also hypothesized that T-wave peaks would increase as the number of cells repolarised between the endocardium and epicardium increased[17]. When the literature is examined, the results concerning the presence of T-wave peaks in young athletes aged over 16 are similar to our study[15,19].

In light of the literature, in the current study, we accepted ST-segment elevation after exercise as a normal variation in all rowers and kayakers. None of these athletes had a pathological increase in heart wall thickness. ECG changes and heart remodelling are common in paediatric and adult athletes. It has been suggested that this may be related to the physiological development process in children[14].

Another parameter evaluated in our study was echocardiographic findings. According to the results, all our athletes' end-diastolic septum wall thickness was ≤12 mm. The highest average septum wall thickness was observed in rowers and the lowest in footballers. All the athletes in our study had normal left ventricular functions. The left ventricular diastolic diameter and LVM values of the rowers and kayakers were higher than those of the footballers. This may be because rowing and kayaking are sports with highly static and dynamic components. Concentric hypertrophy is more common in athletes who engage in static sports, whereas eccentric cardiac hypertrophy can be seen in those who perform dynamic sports. Wall thickening with left ventricular dilatation can be seen in sports that include both static and endurance training, such as rowing, kayaking and cycling[19].

Pelliccia et al.[20] performed an echocardiographic evaluation of 1,309 well-trained Italian athletes engaged in different sports. They reported the left ventricular diastolic diameter ranges to be 38–66 mm (mean, 48 mm) in female athletes and 43–70 mm (mean, 55 mm) in men. Furthermore, the left ventricular diastolic diameter was ≥54 mm in 45% of the athletes and >60 mm in 14%, and the ejection fraction (EF) was normal in all athletes. The authors also noted that the increase in the left ventricular diastolic diameter was more pronounced (>60 mm) among athletes with a high body mass and those who engaged in endurance-type exercises (cycling, cross-country skiing and kayaking)[21]. The effect of prolonged and intense exercise on heart health has attracted the attention of many researchers. It is still a matter of debate whether high serum levels of cardiac biomarkers in athletes are a potential risk factor for exercise-induced heart damage and/or dysfunction[22,23].

Increased cardiac biomarkers seen in athletes may indicate myocardial damage or deterioration in cardiac functions as well as physiological changes after long-term endurance exercise[15]. It is considered that the risk of heart damage increases after Ironman triathlons and marathon races require high endurance[16]. Researchers have investigated conditions affecting the increase in cTnT after endurance exercise; however, the mechanisms of exercise-induced cardiac cTnT release are not yet known. It has been suggested that cTnT transiently increases due to a reversible increase in the membrane permeability of myocytes and an increase in cardiac muscle calcium channel sensitivity[9,22,23].

The current study evaluated cardiac biomarker levels before and during the first and fourth hours of exercise. It was determined that all athletes in our study had a significant increase in cTnT values after exercise ($p = 0.001$). The rowers' fourth-hour cTnT values significantly increased compared to the remaining athlete groups ($p = 0.003$). However, no statistically significant relationship was found between the elevation of cTnT and the variables of age, BMI, posterior wall diastolic diameter, interventricular septum diastolic diameter, interventricular septum systolic diameter, left ventricular diastolic diameter, interventricular septum systolic/diastolic diameter ratio, posterior wall systolic/diastolic diameter ratio, EF, fractional shortening, LVM or LVMI. There was a statistically significant correlation between T-wave peaks on the ECG taken after exercise and the cTnT level at the fourth hour after exercise ($p = 0.001$). We believe that this can be explained by the time required to reach the peak blood levels of the biomarkers. Contrary to its release in acute myocardial infarction, cTnT peaks two to five hours after exercise and returns to its basal level after 24 hours[24,25].

In this study, we found no correlation between high cTnT and LVMI. In a study examining male professional footballers, echocardiography was performed. Blood samples were taken approximately 24 h after training, and serum cTnT, CK-MB and pro-BNP levels were compared according to LVMI. It was reported that the cardiac cTnT, CK-MB and CK serum levels of footballers increased, but there was no relationship between LVMI and any of the cardiac markers. In addition, the serum pro-BNP levels of all athletes were found to be normal[26]. Our study determined that all athletes had normal pre- and postexercise pro-BNP values. The relationship between cTnT and pro-BNP values after long-term exercise remains controversial. In a study evaluating adult athletes, Ohba et al.[27] detected a significant correlation between increased cTnT and pro-BNP following exercise.

Our study has certain limitations. First, our sample consisted of a relatively small group of athletes. Second, our study could not evaluate Vmax; therefore, the relationship between the increase in cTnT or T-wave peaks and exercise intensity and athlete performance could not be investigated. To determine whether the post-exercise cTnT elevation in athletes is physiological or due to ischemia, 24-hour serum levels should be examined. Observation of a decrease in the serum cTnT level would indicate that this is a physiological sign of an athlete's heart. However, since the athletes were doing their next training at the 24th hour, a blood sample taken at that time would still be very close to exercise in terms of timeframe.

In our study, T-wave peaks were observed more frequently on the ECGs taken after exercise in the group of athletes whose static component was dominant. As the age of the athletes increased, the incidence of T-wave peaks also increased. In the echocardiographic examination of the athletes, the structural changes that occurred before and after exercise were within normal limits. The serum cTnT level, particularly among the cardiac biomarkers investigated, seemed to increase with exercise. Care should be taken when evaluating whether changes that may occur in the ECGs of athletes are physiological or pathological.

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