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Heart Rate–Corrected QT and JT Intervals in Electrocardiograms in Physically Fit Students and Student Athletes

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In literature, data on the prevalence of prolonged and shortened corrected QT (QTc) have shown considerable variability. The aim of the study was to compare QTc and JTc intervals of competitive student athletes and noncompetitive sport participants to QTc cutoff points used in athletes. A group of 485 physically fit candidates for the study of kinesiology (139 female and 346 male candidates) aged 18–20 participated in the study. Basic anthropometry, field fitness test, cardiovascular, electrocardiograms measurements, and blood sampling for lipid profile were conducted. The prolonged QTc according to European Society of Cardiology criteria was found in 2.9% of female and 4.3% of male students. When the “Seattle criteria” were used, the proportion of prolonged QTc was 1.44% in female and 0.29% in male students. The shortened QTc according to the Seattle cutoff points was presented in 0.7% of female and 2.0% of male students. The JTc over 400 ms was found in 0.72% of female and 0.29% of male students. The JTc shorter than 320 ms was presented in 0.7% of female and 1.1% of male students. No significant differences were found between students involved in competitive sport and those involved in recreational sporting activities. Female students had lower body mass index and blood pressure values, better blood lipid profile, and lower uric acid concentrations. In conclusion, the Seattle criteria markedly decreased the proportion of prolonged QTc in student athletes, particularly in male students. It seems that the JTc interval could be a better parameter than the QTc interval for the estimation of specific repolarization time in physically fit university students.

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electrophysiology; long QT syndrome; clinical; noninvasive techniques; electrocardiography

The electrocardiogram of athletes could differ from the values of general population. Five years ago, European Association of Cardiovascular Prevention and Rehabilitation and European Society of Cardiology (ESC) published updated guidelines for the interpretation of electrocardiograms (ECG) in athletes, and in 2013, the Seattle criteria are released to improve specificity and reduce the false-positive rate of ECG screening.^{1–3} Long and short heart rate–corrected QT (QTc) intervals belong to a group of uncommon, training-unrelated and potentially pathologic ECG changes (group 2 changes, according to the ESC classification). QTc interval is a parameter of the electric systole of the ventricle, i.e. the duration of

repolarization state. Prevalence of abnormal QTc interval duration reported by a numerous screening studies varied and ranged from very low 0.03% to over 6%^{3–6} and for a combination of long and short QTc to over 16% in some studies,⁷ due to age, sex, characteristics of the population studied—sport activity status, in particular, ethnicity, measurement technique, and criteria of cutoff points used by authors. The heart rate–corrected JT (JTc) interval has been proposed as a more appropriate measure of ventricular repolarization than the QTc interval in individuals with the increased QRS duration.^{8,9}

The aim of the study was to determine length values of the QTc and JTc intervals, the corrected

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QT and JT interval index, and some biochemical risk factors for atherosclerosis in a sample of healthy university students of both sexes, physically fit and ready to be subjected to high physical loads during their study course of kinesiology. The task was to compare findings of competitive student athletes and noncompetitive sport participants and to ascertain the number and percentage of young athletes and noncompetitive sport participants, who display longer or shorter QT and JT intervals, according to the ESC criteria¹ and the Seattle criteria for the ECG interpretation in athletes.²

METHODS

A group of 485 young healthy individuals, 139 female and 346 male candidates aged 18–20, were examined for the study of kinesiology. According to the sporting activities the subjects were involved in, the sample of female and male students were divided in two groups: a group of athletes and a group of noncompetitive sport participants. The group of athletes (competitive sport participants) consisted of athletes engaged in many different sports and levels of competition: 124 females and 316 males. The group of noncompetitive sport participants consisted of students involved, more or less regularly, just in recreational sporting activities: 15 females and 30 males.

All the participants underwent a medical evaluation. Heart rate (HR) (beats/minute) and blood pressure measurements were conducted on two occasions in a sitting position after resting period of 10 minutes using a mercury sphygmomanometer (mmHg). The anthropometry, including body height (in cm) and body mass (in kg), was performed according to the standard protocols. Body mass index (BMI) was calculated as body weight/height (in kg/m²). Individual fitness was estimated using 1500-m running field test in male students and by 800-m running test in female students. Running time was recorded in seconds. Blood samples for the analysis of biochemical parameters were drawn from the forearm vein by venepuncture using a vacutainer blood collection tube with a 21-gauge needle. Laboratory measurements of serum total cholesterol (TC) (mmol/L), serum high-density lipoprotein cholesterol (HDL-C) (mmol/L), low-density lipoprotein cholesterol (LDL-C) (mmol/L), serum triglycerides (TG)

(mmol/L) and uric acid were collected according to standardized procedures.

The ECG values were recorded in all the examinees after 10 minutes of rest in a supine position on a three-channel recorder using all 12 leads: I–III, aVR, aVF, V₁–V₆, with a paper speed of 25 mm/s. Reading was done manually by the same cardiologist. The ECG analysis was performed according to the clinical criteria and to the Minnesota code criteria.¹⁰ For the purpose of this study, we analyzed following parameters in an electrocardiogram: RR interval, measured QT interval (QT), corrected QT interval (QTc), QT interval index (QTi), and corrected QT interval index (QTci); JT interval (JT), corrected JT interval (JTc), JT interval index (JTi), and corrected JT interval index (JTci). The RR interval was measured as a distance between two consecutive R waves. The QT interval was measured in each lead from the onset of the QRS complex: the beginning of the QR wave to the terminal inscription of the T wave in the lead with clearly identified T wave termination or from the beginning of the R wave, if the Q wave was absent. The terminal inscription of the T wave was determined as the return to the TP baseline. When the U wave was present, the QT interval was measured to the nadir of the curve between the T and U waves.¹¹

All the QT values were analyzed, and the highest values of three consecutive intervals were used for the analysis. The measured QT intervals were corrected for heart rate by the following equation: $QTc = \text{measured QT interval (s)} / \sqrt{RR \text{ interval (s)}}$.^{12–14} The prevalence of prolonged QTc interval in student athletes and noncompetitive sport participants in this study was determined according to the ESC criteria for the interpretation of ECG in athletes as QTc >460 ms in females and QTc >440 ms in males¹ and also according to the Seattle criteria as QTc interval >480 in females and >470 in males. Marked QT prolongation predictive for the increased risk for sudden cardiac death in long QT syndrome was defined as QTc >500 ms.² The length less than 320 ms was considered as short QTc according to the Seattle criteria.²

The QT interval index (QTi) was calculated by the following formula¹⁵: $QTi = (QT: 656) \times (HR + 100)$. The corrected QT interval index (QTci) was calculated by the same formula: $QTci = (QTc: 656) \times (HR + 100)$. All the JT

intervals were measured also in each of the 12 leads in three consecutive intervals in ms, from the J point to the terminal inscription of the T wave. When the U wave is present, the JT interval was measured to the nadir of the curve between the T and U waves. In most studies, the JT interval has been simply calculated by the formula: $JT = QT - QRS$ and the heart rate-corrected JT interval (JTc) calculated by the following formula: $JTc = QTc - QRS$.⁹ By this calculation, and taking in the consideration upper limits of normal QTc in athletes, the upper limit of normal values for the JTc interval for female athletes is 380 ms, and for male athletes, it is 360 ms, and marked prolongation of JTc for athletes reaches 420 ms. The length less than 240 ms is considered as short JTc.

The JT interval index (JT_i) was calculated by the following formula: $JT_i = (JT: 518) \times (HR + 100)$. The corrected JT interval index (JT_{ci}) was calculated by the formula: $JT_{ci} = (JTc: 518) \times (HR + 100)$.^{8,15}

The statistical analyses were made by the descriptive statistical methods. Since the subsample groups were different in size, the Welch unequal variances *t*-test (Welch-Satterthwaite *t*-test)¹⁶ was applied to assess the mean differences in analyzed quantitative ECG, cardiovascular and biochemical variables according to sex and engagement in sporting activities.

RESULTS

Table 1 shows BMI, running field test times, and cardiovascular indicators in female and male athletes and noncompetitive sport participants. The BMI and systolic and diastolic blood pressure in the whole group of participants as well in the subgroup of competitive athletes were significantly lower in female than in male students. The differences in BMI and blood pressure between groups of athletes and noncompetitive sport participants were not significant.

Students engaged in competitive sport had on average a better running time in the conducted field test; however, the difference did not reach statistical significance. The mean HR was significantly higher in female than in male students. However, gender difference in HR was not significant in the group of competitive athletes. In female students, the mean HR was significantly lower in the athletes than in noncompetitive sport participants, while the mean HR in male students was similar in both groups.

The ECG findings in female and male athletes and noncompetitive sport participants are presented in Table 2. In comparison to measured HR, gender differences and the differences between groups according to sport activities in mean values of the RR interval in ECG showed the opposite tendencies. However, the differences

Table 1. Body Mass Index, Running Field Test Times, and Cardiovascular Parameters in Female (F) and Male (M) Athletes and Noncompetitive Sport Participants

		All Subjects	Athletes	Noncompetitive Sport Participants	P Value ^b
Body mass index (kg/m ²)	F	21.31 ± 1.57 ^a	21.40 ± 1.55	20.19 ± 1.47	0.1022
	M	23.26 ± 1.73	23.32 ± 1.75	22.55 ± 1.50	0.0855
P value ^c		0.00001	0.00001	0.0087	
Running test (sec)	F (800 m)	191.97 ± 22.15	190.78 ± 21.18	202.93 ± 28.30	0.1558
	M (1500 m)	327.40 ± 30.79	326.17 ± 28.94	340.73 ± 44.59	0.0895
Heart rate (beats/min)	F	64.57 ± 12.70	63.76 ± 12.47	71.27 ± 13.09	0.0499
	M	61.89 ± 10.25	61.75 ± 10.40	62.53 ± 8.60	0.6427
P value		0.0278	0.1135	0.0294	
Systolic pressure (mm Hg)	F	115.65 ± 8.02	115.90 ± 8.01	118.62 ± 7.51	0.2938
	M	118.57 ± 7.68	113.42 ± 8.08	118.10 ± 9.49	0.7770
P value		0.0003	0.0014	0.1040	
Diastolic pressure (mmHg)	F	73.36 ± 7.25	73.27 ± 7.30	74.07 ± 6.99	0.6946
	M	75.42 ± 5.75	75.45 ± 5.83	75.17 ± 4.72	0.7663
P value		0.0034	0.0037	0.6003	

^aArithmetic mean ± standard deviation; ^bthe probability value in significance testing according to the involvement in sports of females and males separately; ^cthe probability value in significance testing according to gender (Welch's unequal variances *t*-test).

Table 2. ECG Parameters in Female (F) and Male (M) Athletes and Noncompetitive Sport Participants

		All Subjects	Athletes	Noncompetitive Sport Participants	P Value ^b
RR interval (ms)	F	961.05 ± 180 ^a	970.29 ± 176.13	884.67 ± 168.48	0.0809
	M	994.38 ± 160	996.89 ± 164.20	979.73 ± 128.11	0.4993
P value ^c		0.0550	0.1480	0.0671	
QRS (ms)	F	81.21 ± 17.24	81.21 ± 17.70	81.20 ± 13.31	0.9980
	M	87.93 ± 18.00	88.35 ± 18.21	84.80 ± 16.01	0.2591
P value		0.0002	0.0002	0.4305	
QT (ms)	F	388.75 ± 36.31	390.27 ± 37.29	376.13 ± 24.28	0.0587
	M	388.46 ± 33.87	389.29 ± 04.39	383.20 ± 28.94	0.2858
P value		0.9367	0.8002	0.3950	
QTc (ms)	F	399.61 ± 33.13	399.07 ± 32.66	404.10 ± 37.68	0.6273
	M	391.89 ± 29.93	392.33 ± 30.47	388.46 ± 24.35	0.4222
P value		0.0177	0.0486	0.1593	
QTi (ms)	F	59.84 ± 5.65	60.08 ± 5.81	57.84 ± 3.77	0.0553
	M	59.82 ± 5.28	59.95 ± 5.36	58.99 ± 4.50	0.2787
P value		0.9810	0.8389	0.3760	
QTci (ms)	F	61.50 ± 5.05	61.42 ± 4.98	62.13 ± 5.72	0.6477
	M	60.30 ± 4.57	60.40 ± 4.65	57.96 ± 3.72	0.4125
P value		0.0187	0.0504	0.1648	
JT (ms)	F	307.54 ± 35.14	309.06 ± 35.81	294.93 ± 26.72	0.0778
	M	300.54 ± 33.45	300.94 ± 34.87	298.40 ± 30.70	0.6701
P value		0.0449	0.0309	0.6992	
JTc (ms)	F	316.97 ± 31.59	315.82 ± 30.74	317.16 ± 39.15	0.8996
	M	303.07 ± 29.37	303.19 ± 30.00	302.14 ± 23.92	0.8226
P value		0.00001	0.0001	0.1881	
JTi (ms)	F	60.30 ± 6.95	60.60 ± 7.09	57.76 ± 5.25	0.0732
	M	58.97 ± 6.61	59.05 ± 5.36	58.51 ± 6.07	0.6489
P value		0.0542	0.0373	0.6764	
JTci (ms)	F	61.94 ± 6.16	61.92 ± 6.00	62.12 ± 7.60	0.9207
	M	59.43 ± 5.74	59.46 ± 5.86	59.24 ± 4.69	0.8159
P value		0.00001	0.0001	0.1941	

^aArithmetic mean ± standard deviation; ^bthe probability value in significance testing according to the involvement in sports of females and males separately; ^cthe probability value in significance testing according to gender (Welch's unequal variances *t*-test).

did not reach statistical significance. The QRS duration was significantly longer in males in the whole group of participants and in a subgroup of athletes. The differences between groups according to sport activities were not significant.

The mean values of the QT interval and QT index were similar in both sexes. Significant differences between groups regarding sport activity status of participants were not found.

In contrast, the JT interval and JT index were significantly wider in the whole group of females than in males and gender differences were significant in the subgroup of competitive athletes. The differences in JT and JTi between competitive

and noncompetitive sport participants were not significant.

The heart rate-corrected values of QT interval and QT interval index (QTc and QTci) and heart rate-corrected JT interval and JT interval index (JTc and JTci) were significantly wider in females than in males in the whole group of physically fit students, as well in the subgroup of competitive athletes. Gender differences were not significant in noncompetitive athletes. Significant differences between groups regarding sport activity status of participants were not found.

The frequencies of prolonged and shortened QTc in student athletes are presented in Figure 1.

Figure 1. The frequency of long and short QTc interval in young athletes.

The QTc prolonged over 440 ms in males and over 460 ms in females (the ESC criteria) was presented in 2.9% of females and 4.3% of males. The QTc longer than 480 ms in females and longer than 470 in males (the Seattle criteria) was presented in 1.4% of females (in two female non-competitive sport participants: having QTc interval of 482 and 517 ms) and in 0.29% of males (in one male athlete in whom QTc interval reached 496 ms). The short QTc (<320 ms according to Seattle criteria) was presented in 0.7% of females and 2.0% of males (Fig. 1).

As regards cutoffs for athletes, the frequencies of prolonged and shortened JTc in female and male athletes are presented in Figure 2. The JTc longer than 380 ms was observed in 2.6% of

Figure 2. The frequency of long and short JTc interval in young athletes.

female students, and JTc longer than 360 ms was observed in 3.6% of male students. The JTc >400 ms was found in 0.72% of female students (in one female noncompetitive sport participant in whom JTc interval reached 428 ms, alongside with the prolonged QTc interval of 517 ms), and JTc >390 ms was found in 0.29% of male students. The longest value of JTc in one male athlete reached 394 ms with QTc interval of 463 ms. The JTc shorter than 240 ms was presented in 0.7% of female and 1.1% of male students (Fig. 2).

Biochemical blood findings in female and male athletes and noncompetitive sport participants are presented in Table 3. The mean values of total serum cholesterol and HDL cholesterol values in the whole group of participants and in a subgroup of competitive athletes were significantly higher in females than in males. The mean values of total serum cholesterol and HDL cholesterol within the female and male groups did not differ significantly according to sport activities. In contrast, the mean values of LDL cholesterol were similar in females and males as well in groups according to sport activities. The mean values of triglycerides were significantly lower in the whole group of females than in males. The same was observed in the subgroup of competitive athletes. The difference between groups according to sport activities was not significant. The mean values of serum uric acid concentration were significantly lower in females than in males in all groups of students. However, the differences between subgroups according to sport activities were not significant.

DISCUSSION

The QT interval (the time between the onset of Q wave to the end of T wave) corrected for a heart rate (QTc) is a standard measure used to assess the duration of the ventricular repolarization.^{9,11,14,15,17} The QT represents the ventricular cell transmembrane action potential, the electric systole of the ventricles, i.e. the time from the beginning of ventricular depolarization to its completion (a delay between depolarization time and the end of repolarization). The congenital long QTc and short QTc are potentially lethal diseases determined genetically,^{2,18–20} because of mutation of specific ion channels in myocardium, but this finding could be presented in a population with

Table 3. Biochemical Blood Parameters in Female and Male Athletes and Noncompetitive Sport Participants

Biochemical Parameters		All Subjects	Athletes	Noncompetitive Sport Participants	P Value ^b
Total cholesterol (mmol/L)	F	4.14 ± 0.68 ^a	4.11 ± 0.64	4.34 ± 0.87	0.3382
	M	3.97 ± 0.72	3.95 ± 0.72	4.07 ± 0.74	0.3996
P value ^c		0.0140	0.0234	0.3134	
HDL cholesterol (mmol/L)	F	1.54 ± 0.34	1.54 ± 0.35	1.53 ± 0.27	0.8310
	M	1.34 ± 0.28	1.33 ± 0.28	1.37 ± 0.31	0.4913
P value		0.00001	0.0000	0.1082	
LDL cholesterol (mmol/L)	F	2.21 ± 0.59	2.20 ± 0.56	2.31 ± 0.79	0.6179
	M	2.23 ± 0.63	2.22 ± 0.63	2.28 ± 0.62	0.6413
P value		0.8017	0.7746	0.8821	
Triglycerides (mmol/L)	F	0.83 ± 0.39	0.82 ± 0.39	0.91 ± 0.82	0.4621
	M	0.95 ± 0.59	0.96 ± 0.61	0.89 ± 0.38	0.4241
P value		0.0129	0.0088	0.9005	
Uric acid (μmol/L)	F	231.67 ± 57.86	234.52 ± 57.22	207.64 ± 59.84	0.1301
	M	307.60 ± 61.44	308.50 ± 60.53	290.41 ± 62.55	0.1450
P value		0.00001	0.0000	0.0003	

^aArithmetic mean ± standard deviation; ^bthe probability value in significance testing according to the involvement in sports of females and males separately; ^cthe probability value in significance testing according to gender (Welch's unequal variances *t*-test).

no family mutations also. The basic question is to determine when we could consider QTc as long and short and is it of the same range in a population and in a healthy population of both sexes performing physical exercise, and especially in athletes.^{18–22} In 2010, ESC developed the recommendation for the interpretation of ECG findings in athletes,¹ and recently, with the aim to reduce false-positive rates, the Seattle criteria were released.²

The aim of our study was to analyze indicators of electric systole of the ventricle in resting ECG of student athletes and students of both sexes involved in noncompetitive sport activities and to determine the prevalence of prolonged and shortened QTc according to cutoffs recommended for athletes.

The differences in cardiovascular and ECG findings between competitive and noncompetitive sport participants were not significant (except for HR in female students). This is mainly due to the small and insignificant differences in physical fitness between participants from these two groups. The group of competitive sport participants consisted of athletes engaged in many different sports and levels of competition. The QTc interval and JTc interval, as well as other indicators of left ventricular electrical activity, the QTci and JTci were longer in female than in male students in the whole sample and in the group of athletes.

Gender differences in QTc interval duration in resting ECG are known and well documented in athletes,^{23–28} and gender-specific references and cutoffs are used in the ECG evaluation in athletes and in general population.

The prolonged QTc according to ESC criteria (>460 ms in females and >440 ms in males) was found in 2.9% of female and 4.3% of male participants of this study. When the Seattle criteria were used, the proportion of prolonged QTc (>480 ms) decreased to 1.44% in female students. Prolonged QTc was observed in two female noncompetitive sport participants, whereas one of these students had the QTc prolonged over 500 ms (517 ms), indicating an increased risk for long QT syndrome and its consequences.^{2,18,22} In males, prolonged QTc >470 ms (496 ms) was found in only one male athlete (0.29%). The short QTc according to the Seattle criteria cutoff points was presented in 0.7% of female students and 2.0% of male students. In literature, data on prevalence of prolonged and shortened QTc have shown considerable variability. In a large unselected population of young amateur athletes predominately students, Pelliccia et al.⁴ reported a low prevalence of abnormal ECG changes. The prolonged QTc interval (>440 ms in males and >460 ms in females) was rarely found (0.03%). According to the same criteria, Basaravagajiah et al.⁵ reported the prevalence of 0.4% in elite

athletes. None of the athletes with QTc <500 ms had any other feature to indicate long QT syndrome. Evaluating ECG changes according to the ESC recommendations in a large cohort of screened military aircrew, Boos et al.²⁹ found long QTc in 0.69% of ECGs. In highly trained athletes, Macarie et al.⁶ reported the prolonged QTc (480–560 ms) in 7 of 157 young endurance athletes (4.45%). In a large sample of elite football players, Bohm et al.³⁰ revealed 33.7% uncommon ECG patterns according to the classification of ESC and short QT interval was the most frequent change. By changing the QTc cutoff point to 340 ms, the rate of uncommon ECG pattern reduced to 22.2%. Recently, Chandra et al.⁷ comparing the prevalence of potentially abnormal ECG changes in young nonathletes and athletes found group 1 (training related) and group 2 (potentially pathological, training unrelated) patterns more prevalent in athletes. ECG patterns suggestive to ion-channelopathy or electrical heart disease were found in 13.5% of nonathletes and 16.4% of athletes. The proportion of young individuals with long QTc was 6.5% in nonathletes and 3.3% of athletes, while 6.9% of nonathletes and even 13.0% of athletes exhibit short QTc (<380 ms). In a group of elite Australian athletes, Brosnan et al.³ reported long QTc (>440 ms in men and >460 ms in women) in 2.3% and short QTc (<360 ms) in 4.3% accounting for 40% of all group 2 abnormalities. Using the Seattle criteria, this recently published study showed significant reduction in the false-positive ECG findings classified as abnormal according to ESC recommendation.

However, because the QT interval encompasses ventricular depolarization, its value is limited when the increased QRS duration contributes to the QT prolongation. Thus, clinicians usually do not assess the QT interval in patients with the bundle-branch block or nonspecific ventricular conduction delay with QRS ≥120 ms. In those cases, the JTc has been determined as a more valid parameter of ventricular repolarization process.⁹

Several investigators have reported that the JTc interval better represents the specific repolarization time than it does the QT interval. In one cross-sectional study in Cuba dealing with 20 healthy women athletes mean aged 22.45 ± 5.30 in comparison with a group of nonathletes of the same ages and sex,³¹ no significant differences in dispersion of QTc (424:405 ms) and JTc (329:307 ms) in lead II were observed. However,

in V₅, lead intervals were significantly greater in athletes (74:43 ms).

The upper limit of QTc in athletes is 500 ms and of JTc is 420 ms. QTc interval duration ≥500 ms²² and JTc interval duration ≥420 denote a risk for the malignant ventricular arrhythmia. In individuals with a prolonged QTc but ≤ 500 ms and positive personal or familial history especially in a first-degree relatives, complete cardiological evaluation is necessary, including stress test, provocative stress test, epinephrine QT stress test, and genetic tests, before a decision about athletic physical effort. If a history is negative, it is necessary to evaluate repeated ECG (and to exclude hypokalemia and drugs responsible for prolongation of QTc), and if a QTc become under normal limits, an athlete could continue with a training. In our analyzed sample, JTc >400 ms was found in 0.72% of females and JTc>390 ms in 0.29% of males. A prolonged JTc over 420 ms (428 ms) with the prolonged QTc interval of more than 500 ms (517 s) was seen in one female non-competitive sport participant, but in only one recorded ECG, and further evaluation is necessary for increased risk of long QT syndrome. In spite of the fact that QTc is not a good enough parameter of ventricular repolarization in athletes with values of 500 ms or above, the drop out from competitive sports is prudent to recommended.²² The JTc shorter than 240 ms was presented in 0.7% of females and 1.1% of males.

Expectedly, in our study, a significantly better cardiovascular risk profile was found in young female in comparison to male students: lower BMI, systolic and diastolic blood pressure, a higher HDL cholesterol, lower triglyceride, and uric acid serum concentration. In this study, a consistent rule in serum risk factors concentrations in relation to sport activities was not found.

The strength of the study includes a large cohort of screened physically fit 18- to 20-year-old university students, kinesiology study candidates involved in competitive sport or at least in regular recreative sport activity, applying two widely used recommendations, ESC and Seattle criteria, for the interpretation of ECG findings in athletes and analysis of several different indicators left ventricular electrical activity.

The study has certain limitations. The study was cross-sectionally designed. Prospective longitudinally designed study would be required to ascertain potential consequences of the ECG

changes. Nonathletic group included recreatively active students who did not participate in competitive sport. However, their regular exercise could in some cases match those of students involved in competitive sport.

CONCLUSIONS

In the sample of 485 students, aged 18–20 years, ready to commence their university study of kinesiology, the prolonged QTc according to ESC criteria was found in 2.9% of females and 4.3% of males. When the Seattle criteria were used, the proportion of prolonged QTc decreased to 1.44% in female students (prolonged QTc was observed in two female noncompetitive sport participants, whereas one of these students had the QTc prolonged over 500 ms) and to 0.29% in male students (QTc $\geq$ 470 ms was found in only one male athlete). Further decrease in proportion of prolonged interval in females was seen when JTc interval was considered: JTc over 400 ms was found in 0.72% of females and JTc over 390 ms in 0.29% of males. A prolonged JTc over 420 ms alongside with the prolonged QTc interval of more than 500 ms was seen in one female noncompetitive sport participant, indicating an increased risk of long QT syndrome. It seems that the JTc interval could be a better parameter than the QTc interval for the estimation of specific repolarization time in physically fit university students. Further investigations using prospective longitudinally designed study are needed.

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