e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(2); 497-507

Original Research Article

A Prospective Assessment of Exercise-Induced ECG Changes in Healthy Children and Evaluate the Effects of Gender and Four Different Formulas of Heart Rate Correction

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Received: 25-11-2022 / Revised: 21-01-2023 / Accepted: 07-02-2023
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Conflict of interest: Nil

Abstract

Aim: To investigate the exercise-induced ECG changes in healthy children and evaluate the effects of gender and four different formulas of heart rate correction of Bazett, Fridericia, Framingham and Hodges on ventricular repolarization parameters pre-and post-exercise.

Methods: A prospective study was Department of Pediatrics, DMCH, Darbhanga, Bihar, India. over a period of one year and children who underwent TET and had the following criteria were included in the study. A total of 100 children from the hospital OPD were study participants.

Conclusion: Diastolic time decreased more than systolic time with exercise and systolic time to diastolic time increased with exercise. Hodges' and Fridericia's formulas resulted in the longest and shortest QT and QoT, JT, and JTP, respectively. Thus, using a single value as the cut-off for long QT syndrome can lead to under or over-diagnosis. Nomograms incorporating data on age, heart rate, and heart rate correction formula are indispensable for accurate long QT diagnosis. Furthermore, gender differences in ventricular repolarization parameters are not generally present in 5 to 14-year-old healthy children. The lack of U wave in this study may implicate the need for more careful investigation in the presence of U wave in the treadmill exercise testing of healthy children.

Keywords: Electrocardiogram, exercise test, J to peak T interval, J point to end of T wave interval, Onset of Q wave to the end of T wave interval, T peak to T end interval.

Introduction

Standardized exercise testing has almost become a routine procedure in the care of children with cardiac disease [1].Impairment of functional capacity is usual in this population and may be the result of the primary cardiac problem, its treatment or hypo activity. The test is often conducted to provide objective information about exercise capacity, to identify abnormal responses to exercise, to make management decisions, to assess the efficacy of medical and surgical interventions, to evaluate exercise-related adverse events, to define individual safety limits, to instill confidence in child and family, and to motivate patients to engage in physical activity, resulting in improved patient outcomes. [2]

Treadmill exercise testing (TET) is a crucial diagnostic tool for evaluating congenital and acquired heart disease in the pediatric population. Nevertheless, although there are numerous studies on exercise testing in various cardiac diseases in children, studies addressing exercise-induced electrocardiographic (ECG) changes in normal children are very old and scant, if any. [3] Furthermore, these studies do not include all ECG parameters of atrial and ventricular depolarization and repolarization. [2-5]

Thus, the aim of this study is to investigate the exercise-induced ECG changes in healthy children and evaluate the effects of gender and four different formulas of heart rate correction of Bazett, Fridericia, Framingham and Hodges on ventricular repolarization parameters pre-and post-exercise.

Material & Methods:

Study design and study population

A prospective study was Department of Pediatrics, DMCH, Darbhanga, Bihar, India. over a period of one year and children who underwent TET and had the following criteria were included in the study. A total of 100 children from the hospital OPD were study participants. Normal baseline electrocardiogram and echocardiogram, normal reports of exercise testing, acceptable quality of ECG tracing, and consent to participate in the study. Those with a history of congenital or acquired heart disease were excluded from the study. The exercise test was performed to evaluate chest pain with exercise, determination of exercise capacity before participation in competitive sports in children with complaints of exercise-related easy fatigability or palpitation.

Ethical considerations: Informed consent was obtained from all participants and their guardians. The study was performed in accordance with the Helsinki Declaration on ethical principles for medical research involving human subjects and was approved by the Institutional Committee for Ethics.

Treadmill exercise testing protocol: Following the American Heart Association guidelines regarding clinical stress testing in children, TET (Avicenna Company, Medical Equipment Stress Test System, Version 6.1.0, CE 2195, and Iran) was performed, using a modified Bruce protocol, which is shown in Table 1. [21]

Table 1: Modified Bruce protocol used for graded treadmill exercise testing in this study

	Speed (km/h)	Speed (mile/h)	Duration	Grade (%)	METs
Before starting	0	0	2	0	1
Stage 1†	2.7	1.7	2	0	2.3
Stage 2	2.7	1.7	2	5	3.4
Stage 3	2.7	1.7	2	10	4.6
Stage 4	4	2.5	2	12	7
Stage 5	5.5	3.4	2	14	10.2
Stage 6†	6.8	4.2	2	16	13.6
Stage 7	8	5	2	18	17.1
Stage 8	8.9	5.5	2	20	20.5
Stage 9	9.7	6	2	22	23.9

Electrocardiographic measurements: All measurements were performed immediately before stage 1 and immediately after stage 6 of the test while the child was in the erect position [Table 1]. Lead II was selected for all measurements. All tracings were recorded and printed at a speed of 100 mm/s. Amplitude was variable between 5 mm (mm)/1 millivolt (mv) and 20 mm/1 mv, adjusted according to the voltages' height. All amplitude calculations were based on millivolts. At the time of measurement, the region of interest of the tracing was magnified using a digital magnifier.

Statistical analysis: Categorical variables were expressed as number and percentage and continuous variables as mean ± standard deviation (SD) or median and interquartile range, depending on the variable's distribution. We used the Shapiro–Wilk test to test the normality of the distribution of the variables. A paired t ‑test was applied to compare the variables with normal distribution and Wilcoxon signed‑ranks test was performed for nonnormal distribution variables. An independent‑samples t‑test was utilized to compare ventricular repolarization parameters in boys and girls. The mean of heart‑rate corrected QT, QoT, JT, and JTP by the four formulas of Bazett, Fridericia, Framingham, and Hodges were compared using repeated‑measures analysis of variance (ANOVA). IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) was used for statistical analysis. $P < 0.05$ was considered statistically significant.

Results:

100 children aged 5–12 years were enrolled in this study. Basic characteristics and basic data of TET of the study population are shown in Table 2.

Table 2: Basic characteristics and data of treadmill exercise testing of the study population (100 healthy children)

Basic Characteristics	Values
Age in years (range, mean±SD) Sex, n (%)	5‑12 (10.4±2.9)
Male	64
Female	36
Weight in kg (range, mean±SD)	18‑105 (38.73±16.9)
Height in cm (range, mean±SD)	110‑175 (142.52±15.81)
Body surface area (m^2), mean±SD	1.31±0.58
BMI (kg/m^2), mean±SD	25.72±5.66
Duration of exercise in min (range, mean±SD)	11.11‑25.37 (18.39±2.30)
Estimated METs (range, mean±SD)	10.20‑23.83 (14.55±3.21)
Heart rate at the beginning of exercise in beats/min (range, mean±SD)	70‑150 (109±18)
Heart rate at the end of exercise in beats/min (range, mean±SD)	145‑215 (181±15)
Percentage of achieved target heart rate (range, mean±SD)	80‑120.54 (102.80±0.09)
Systolic BP before exercise in mmHg (range, mean±SD)	76‑128 (94.8±12.09)
Diastolic BP before exercise in mmHg (range, mean±SD)	49‑90 (65.7±7.77)
Systolic BP at the end of exercise in mmHg (range, mean±SD)	85‑140 (110.63±13.82)
Diastolic BP at the end of exercise in mmHg (range, mean±SD)	50‑95 (73.57±9.13)

SD: Standard deviation, BMI: Body mass index, METs: Metabolic equivalents, BP: Blood pressure

Changes in amplitudes of P, Q, R, S, T, and U waves before and after treadmill exercise testing: All amplitudes were significantly increased after exercise except for amplitudes of Q and R waves, which were not increased significantly

[Table 3]. Of note, there was no U wave detected either in the pre-exercise or post-exercise ECG tracings. Since U waves are more evident in mid-precordial leads, these leads of ECG tracings were also investigated. Nevertheless, no U waves were detected.

Changes in duration of P wave, P wave time to peak QRS, T wave, T wave time to peak and PR, Onset of Q wave to the end of T wave, Q to onset of T wave, J point to end of T wave, J to peak T, T to end T and T to end T/Onset of Q wave to the end of T wave intervals: All durations, except P wave time to peak and Tp‑e/ QT interval, decreased significantly. P wave time to peak decreased at the end of the exercise, but the decrease was not statistically significant [Table 3].

Table 3: Amplitudes and duration of electrocardiographic waves and intervals before and after exercise

Electrocardiographic characteristics (mean ± SD)	Preexercise	Postexercise	*P*
Amplitudes of electrocardiographic waves (mm)			
P wave amplitude	1.84±0.48	2.57±0.76	<0.001
Q amplitude	1.74±3.45	2.08±2.07	0.483
R amplitude	20.06±6.51	20.25±6.97	0.483
S amplitude	2.47±2.55	3.03±2.98	<0.001
T wave amplitude	2.8±1.30	4.06±1.51	0.001
Durations of waves and intervals (s)			
PR interval	0.108±0.018	0.089±0.019	0.001
P wave duration	0.075±0.014	0.06±0.01	0.001
P wave time to peak	0.04±0.05	0.03±0.008	0.293
QRS duration	0.072±0.198	0.06±0.01	0.006
T wave duration	0.11±0.02	0.09±0.05	<0.001
T wave time to peak	0.06±0.01	0.04±0.02	<0.001
QT interval	0.30±0.4	0.23±0.03	<0.001
QoT interval	0.19±0.03	0.14±0.03	<0.001
JT interval	0.23±0.04	0.15±0.04	<0.001
J to peak T interval	0.17±0.36	0.11±0.32	<0.001
Peak T to end T interval (Tp‑e)	0.06±0.01	0.04±0.02	<0.001
Tp‑e/QT interval	0.20±0.06	0.20±0.10	0.732
Tp‑e/QTc (B)	0.15±0.04	0.12±0.06	<0.001
Tp‑e/QTc (Fridericia's formula)	0.17±0.05	0.14±0.07	<0.001
Tp‑e/QTc (Framingham's formula)	0.16±0.04	0.14±0.07	<0.001
Tp‑e/QTc (Hodges's formula)	0.16±0.04	0.10±0.06	<0.001
Absolute shortening of QT interval with exercise		0.231±0.31	
QT shortening as fraction		25.6%±12.4 %	

SD: Standard deviation, QoT: Q to onset of T wave, JT: J point to end of T wave, Tp‑e: T peak‑T end interval, QTc: Corrected B: Bazett's formula, QT: Onset of Q wave to the end of T wave, QRS: QRS complex, PR: PR interval

Exercise‑induced changes in the duration of heart rate‑corrected Onset of Q wave to the end of T wave, Q to onset of T wave, J point to end of T wave, J to peak T intervals by four formulas of Bazett, Fridericia, Framingham, and Hodges: Mean ± SD of values of corrected QT (QTc), QoTc, JTc and JTPc at pre- and post-exercise are shown in Table 4. All intervals significantly decreased with exercise [Table 4].

Table 4: Heart rate corrected onset of Q wave to the end of T wave, Q to onset of T wave, J point to end of T wave and J point to peak T intervals by four formulas of Bazett, Fridericia, Framingham and Hodges before and after treadmill exercise testing

	Preexercise	95% CI	Postexercise	95% CI	*P*
Heart‑rate correction of QT interval					
QT‑c‑Bazett (mean±SD)	0.41±0.04	0.38-0.41	0.33±0.03	0.37-0.39	<0.001
QT‑c‑Fridericia (mean±SD)	0.33±0.04	0.37-0.37	0.32±0.03	0.31-0.32	<0.001
QT‑c‑Framingham (mean±SD)	0.36±0.03	0.36-0.37	0.32±0.02	0.32-0.33	<0.001
QT‑c‑Hodges (mean±SD) Heart‑rate correction of QoT interval	0.39±0.04	0.38-0.40	0.42±0.02	0.41-0.43	<0.001
QoT‑c‑Bazett (mean±SD)	0.26±0.04	0.25-0.26	0.22±0.03	0.21-0.23	0.001
QoT‑c‑Fridericia (mean±SD)	0.21±0.04	0.21-0.23	0.20±0.03	0.18-0.19	<0.001
QoT‑c‑Framingham (mean±SD)	0.25±0.03	0.24-0.26	0.23±0.02	0.23-0.24	<0.001
QoT‑c‑Hodges (mean±SD) Heart‑rate correction of JT interval	0.2±0.04	0.26-0.28	0.33±0.03	0.32-0.34	<0.001
JT‑c‑Bazett (mean±SD)	0.30±0.04	0.29-0.31	0.25±0.05	0.24-0.26	<0.001
JT‑c‑Fridericia (mean±SD)	0.27±0.04	0.27-0.28	0.21±0.04	0.20-0.22	<0.001
JT‑c‑Framingham (mean±SD)	0.28±0.03	0.28-0.30	0.25±0.03	0.24-0.25	<0.001
JT‑c‑Hodges (mean±SD) Heart‑rate correction of J point to peak T interval	0.31±0.04	0.30-0.32	0.34±0.03	0.34-0.35	<0.001
J‑T peak‑c‑Bazett	0.22±0.04	0.21-0.23	0.19±0.05	0.17-0.19	<0.001
J‑T peak‑c‑Fridericia	0.20±0.04	0.21-0.21	0.15±0.04	0.14-0.16	<0.001
J‑T peak‑c‑Framingham	0.23±0.03	0.23-0.24	0.21±0.03	0.20-0.22	<0.001
J‑T peak‑c‑Hodges	0.26±0.04	0.24-0.26	0.32±0.03	0.31-0.33	0.002

C: Corrected, QoT: Q to onset of T wave, JT: J point to end of T wave, JTP: J point to peak T, CI: confidence interval, SD: standard deviation, QT: Onset of Q wave to the end of T wave

Pairwise comparison of effects of four different formulas of heart rate correction of Bazett, Fridericia, Framingham and Hodges on the values

of onset of Q wave to the end of T wave, Q to onset of T wave, J point to end of T wave, and J to peak T: Except between preexercise QoTc and postexercise JTc, by Bazett and Framingham formulas, pairwise comparison by multiple measurements of ANOVA revealed significant differences among mean values obtained by different formulas of heart rate correction for these parameters of ventricular repolarization [Table 5].

Table 5: Pairwise comparison of values of Onset of Q wave to the end of T wave, onset of Q to onset of T, J point to end of T wave, and J point to peak T intervals at preexercise and postexercise by four different formulas of heart rate correction including Bazett, Fridericia, Framingham and Hodges

Formula	*P* value (significance[b])
QTc: Preexercise Bazett	
Fridericia	<0.001
Framingham	<0.001
Hodges QTc: Postexercise Bazett	<0.001
Fridericia	<0.001
Framingham	<0.001
Hodges QoTc: Preexercise Bazett	<0.001
Fridericia	<0.001
Framingham	0.529
Hodges QoTc: Postexercise Bazett	<0.001
Fridericia	<0.001
Framingham	0.002
Hodges JT: Preexercise Bazett	<0.001
Fridericia	<0.001
Framingham	<0.001
Hodges JT: Postexercise Bazett	0.013
Fridericia	<0.001
Framingham	<0.001
Hodges JTP interval: Preexercise Bazett	<0.001
Fridericia	<0.001
Framingham	<0.001
Hodges JTP interval: Postexercise Bazett	<0.001
Fridericia	<0.001
Framingham	<0.001
Hodges	<0.001

Gender differences in ventricular repolarization parameters (onset of Q wave to the end of T wave, Q to onset of T wave, J point to end of T wave, J to peak T, T to end T interval, T to end T/Onset of Q wave to the end of T wave ratio, corrected onset of Q wave to the end of T wave, QoTc, JTc, J to peak Tc

and Tp‑e/Corrected Onset of Q wave to the end of T wave): Except for the preexercise QT and JT intervals and postexercise JTP corrected by Hodges formula, there was no statistically significant difference between girls and boys for the parameters mentioned above for ventricular repolarization, either in preexercise or postexercise [Table 6]. At preexercise, uncorrected QT was slightly higher in boys (0.30 ± 0.05 in boys versus 0.28 ± 0.02 in girls, P = 0. 001).

Table 6: Gender differences in ventricular repolarization parameters and their heart rate corrected values at pre‑ and post‑exercise in 100 healthy children

	Male	**Female**	***P***	**Male**	**Female**	***P***
Heart rate	105±17	118±18	0.005	183±17	185±17	0.582
QT (s)	0.32±0.03	0.29±0.03	0.001	0.22±0.02	0.21±0.02	0.621
QTc‑Bazett	0.42±0.04	0.40±0.05	0.528	0.38±0.03	0.37±0.02	0.527
QTc‑Fridericia	0.34±0.03	0.36±0.04	0.628	0.32±0.03	0.31±0.02	0.628
QTc‑Framingham	0.35±0.03	0.36±0.03	0.528	0.32±0.02	0.32±0.02	0.268
QTc‑Hodges	0.35±0.03	0.39±0.06	0.427	0.42±0.02	0.42±0.01	0.253
QoT	0.19±0.03	0.18±0.03	0.810	0.13±0.02	0.13±0.019	0.528
QoTc‑Bazett	0.23±0.04	0.25±0.04	0.428	0.22±0.04	0.23±0.02	0.321
QoTc‑Fridericia	0.24±0.04	0.22±0.04	0.881	0.19±0.03	0.19±0.02	0.729
QoTc‑Framingham	0.25±0.03	0.25±0.03	0.328	0.23±0.02	0.23±0.01	0.428
QoTc‑Hodges	0.26±0.03	0.29±0.06	0.029	0.33±0.03	0.33±0.03	0.918
JT	0.24±0.03	0.22±0.04	0.028	0.15±0.04	0.15±0.03	0.528
JTc‑Bazett	0.31±0.04	0.29±0.04	0.720	0.26±0.06	0.26±0.04	0.882
JTc‑Fridericia	0.28±0.04	0.26±0.04	0.077	0.22±0.05	0.21±0.04	0.629
JTc‑Framingham	0.30±0.03	0.28±0.03	0.428	0.25±0.04	0.25±0.02	0.629
JTc‑Hodges	0.32±0.04	0.31±0.02	0.628	0.36±0.03 (0.034)	0.36±0.03 (0.026)	0.321
JTP	0.18±0.04	0.16±0.04	0.528	0.11±0.03 (0.108±0.034)	0.11±0.03 (0.105±0.028)	0.421
JTPc‑Bazett	0.22±0.04	0.22±0.04	0.682	0.18±0.06	0.18±0.05	0.326
JTPc‑Fridericia	0.20±0.04	0.19±0.04	0.772	0.16±0.05	0.15±0.04	0.528
JTPc‑Framingham	0.23±0.03	0.23±0.03	0.702	0.21±0.03	0.21±0.03	0.719
JTPc‑Hodges	0.26±0.05	0.26±0.03	0.292	0.32±0.03	0.32±0.03	0.428
Tp‑e	0.07±0.01	0.05±0.01	0.07	0.04±0.01	0.04±0.04	0.466
Tp‑e/QT	0.22±0.06	0.19±0.04	0.183	0.19±0.04	0.21±0.16	0.629
Tp‑e/QTc‑Bazett	0.18±0.05	0.14±0.03	0.281	0.11±0.03	0.12±0.10	0.881
Tp‑e/QTc‑Fridericia	0.19±0.06	0.15±0.03	0.045	0.13±0.03	0.15±0.12	0.327
Tp‑e/QTc‑Framingham	0.19±0.05	0.15±0.03	0.518	0.13±0.03	0.14±0.12	0.482
Tp‑e/QTc‑Hodges	0.17±0.05	0.14±0.03	0.066	0.10±0.02	0.11±0.10	0.552

c: Corrected, J‑T_{peak}: J point to peak T interval, B: Bazett, JTP: J point to peak T interval, Tp‑e: T peak‑T end interval, QoT: Onset of Q to onset of T, JT: J point to end of T wave, QTc: Corrected QT, QT: Onset of Q wave to the end of T wave, JTc: Corrected JT interval, JTPc: Corrected J point to peak T interval

Changes in electrocardiographic ‑derived estimated duration of systole, diastole, and systolic‑to‑diastolic time ratio before and after treadmill exercise testing: ECG‑derived estimated duration of systole and diastole decreased significantly with exercise and the systolic‑to‑diastolic time ratio increased significantly [Table 7].

Table 7: Comparison of electrocardiographic‑derived estimation of duration of systole and diastole and systolic‑to‑diastolic time ratio at preexercise and postexercise in 100 healthy children

	Preexercise	Postexercise	*P*
Duration of systole (milliseconds)	231.63±36.53	1502.5±35.59	<0.001
Duration of diastole (milliseconds)	333.6±82.12	182.5±32.6	<0.001
Systolic to diastolic time ratio	0.77±0.19	0.86±0.31	<0.001
Percentage of decrease in ECG‑derived estimation of duration of systole with exercise (mean±SD)			33.65±15.79
Percentage of decrease in ECG‑derived estimation of duration of diastole with exercise (mean±SD)			43.44±13.49
Heart rate (beats/min)	107±18	182±16	<0.001

Discussion

Numerous exercise protocols have been used in children. Most laboratories use continuous graded protocols requiring a maximal effort, even if important data can be obtained during submaximal exercise [6]. The choice of protocol depends on the age and body size of the child to be tested, the measurements planned and the equipment available. Hemodynamic and gas exchange responses are better, and determination of the ventilatory threshold is easier in protocols with shorter stage durations, the so-called ramp protocols, whereas a steady state for more physiological functions (heart rate and oxygen uptake) requires exercise stages of ≥ 3 minutes. In general, the total exercise duration should be kept to 6—12 minutes in children, to avoid premature muscle fatigue and lack of attention and motivation. For treadmill exercise testing, most laboratories use the Bruce treadmill protocol [7-8], in which increase in work rate is accomplished by increasing speed and grade every3 minutes. Disadvantages of the Bruce protocol are large inter stage increments in work that can make estimation of maximal values less accurate, and intermediate stages than can be either run or walked, resulting in different oxygen costs. Alternatives, with a slower increase in workload, are more appropriate for unfit patients; an example is the Balk protocol, in which the speed of the belt is held constant and the increase in work rate is accomplished only by increasing the slope. Different protocols are also used for cycle ergometry [9]. When an electronically braked cycle ergometer is available, a continuous ramp protocol is usually preferred. Increments in workload can be increased by 5 to 20 W/min, depending on height, weight or body surface area [10], or can be standardized by 0.25 W/kg/min [11]. Additional procedars are used to answer specific questions, such as the Wingate test protocol to determine anaerobic power, step-like increases of workload to assess oxygen uptake kinetics, or a 4—10-minute intense exercise bout to induce bronchoconstriction.

The main reason for exercise testing in congenital heart disease is to assess physical capacity, to obtain objective information about the functional status of the heart; this can be used to determine whether complaints have a cardiac cause, to provide recommendations for physical activity [12], to give indications for treatment (heart failure therapy, surgery, transcatheter intervention) and to evaluate the success of interventions [13].

Heart rate dynamics during exercise are often abnormal in operated congenital heart disease. A lower peak heart rate is usually defined as chronoscopic incompetence when < 80% of the predicted value is reached during exercise testing. This is influenced by the surgery itself and is usually not observed after transcatheter therapy [14]. Cardiac denervation with lack of sympathetic reinnervation and damage to the sinus node or its blood supply, leading to sinus node dysfunction, may play a role; it is more frequent after palliation of univentricular heart or atrial switch [15] and, logically, after cardiac transplantation. As the increase in cardiac output is only obtained by an increase in heart rate beyond moderate intensity exercise, chronoscopic impairment may reduce exercise capacity.

Many factors contribute to the decision to transplant patients with congenital heart disease. Rigorous assessment enables the most appropriate candidates to be selected for cardiac transplantation. To stratify the level of risk for out-come of transplantation and to classify the patients as either urgent or standard depending on their prevailing clinical condition, various investigations are undertaken, including metabolic exercise testing. Peak VO2, autonomic response to exercise and ventilatory equivalents contribute to the overall evaluation of the condition of the potential trans-plant recipient; however, their value is limited, as numerous exercise protocols are used [16].

Ogedengbe et al. studied ECG changes in 40 healthy medical students before and after bicycle ergometer exercise testing. [17] They reported an increase in PR, QRS, and QT duration after exercise and they suggested the necessity of further research in this field. Watanabe et al. showed a correlation between R wave amplitude and spatial QRS vector loop during exercise in 43 individuals undergoing supine bicycle testing, with posterior shift resulting in decreased R wave amplitude and anterior shift causing an increase or no change. [18] This finding implies that body position during exercise may affect R amplitude changes and should probably heart failure and implanted cardioverter‑defibrillator and identification of high‑risk patients with congenital and acquired long QT syndrome. [12, 19, 20] In adults, heart rate ‑corrected Tp‑e has been described as a predictor for sudden cardiac arrest (SCA). [21,22] A heart rate‑corrected Tp‑e interval beyond 90 msonds has been reported to be associated with a threefold increase in SCA's risk. [13] In a study on 523 healthy adults aged 31.9 ± 8.9 years, Hnatkova et al. reported significantly higher QTc, JTc, and JTPc and lower Tp‑e intervals in female Individuals. [14]

Conclusion

Diastolic time decreased more than systolic time with exercise and systolic time to diastolic time increased with exercise. Hodges' and Fridericia's formulas resulted in the longest and shortest QT and QoT, JT, and JTP, respectively. Thus, using a single value as the cut-off for long QT syndrome can lead to under or over-diagnosis. Nomograms incorporating data on age, heart rate, and heart rate correction formula are indispensable for accurate long QT diagnosis. Furthermore, gender differences in ventricular repolarization parameters are not generally present in 5 to 14-year-old healthy children. The lack of U wave in this study may implicate the need for more careful investigation in the presence of U wave in the treadmill exercise testing of healthy children.

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