Cardiology in the Young

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SHED LIGHT study (Structural HEart Disease in pupiLs by echocardIoGrapHic Test) is a population-based investigation to detect the burden of structural heart diseases among children in the urban areas of Tehran, Iran, by the implementation of echocardiographic examinations.

Prevalence of electrocardiographic abnormalities among Iranian children and adolescents and associations with blood pressure and obesity: findings from the SHED LIGHT study

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Abstract

Background: There are few studies for detecting rhythm abnormalities among healthy children and adolescents. The aim of the study was to investigate the prevalence of abnormal electrocardiographic findings in the young Iranian population and its association with blood pressure and obesity. *Methods:* A total of 15084 children and adolescents were examined in a randomly selected population of Tehran city, Iran, between October 2017 and December 2018. Anthropometric values and blood pressure measurements were also assessed. A standard 12-lead electrocardiogram was recorded by a unique recorder, and those were examined by electrophysiologists. *Results:* All students mean age was 12.3 ± 3.1 years (6–18 years), and 52% were boys. A total of 2900 students (192.2/1000 persons; 95% confidence interval 186–198.6) had electrocardiographic abnormalities. The rate of electrocardiographic abnormalities was higher in boys than girls ($p < 0.001$). Electrocardiographic abnormalities were significantly higher in thin than obese students ($p < 0.001$), and there was a trend towards hypertensive individuals to have more electrocardiographic abnormalities compared to normotensive individuals ($p = 0.063$). Based on the multivariable analysis, individuals with electrocardiographic abnormalities were less likely to be girls (odds ratio 0.745, 95% confidence interval 0.682–0.814) and had a lower body mass index (odds ratio 0.961, 95% confidence interval 0.944–0.979). *Conclusions:* In this large-scale study, there was a high prevalence of electrocardiographic abnormalities among young population. In addition, electrocardiographic findings were significantly influenced by increasing age, sex, obesity, and blood pressure levels. This community-based study revealed the implications of electrocardiographic screening to improve the care delivery by early detection.

The 12-lead standard electrocardiogram is a non-invasive and easily accessible tool to detect cardiac dysrhythmias.[1] The knowledge of the morphological changes and abnormal findings in the electrocardiogram is of great importance for healthy normal population. Some abnormalities during childhood and adulthood are life-threatening;[2] therefore, screening will help us find the burden of arrhythmias and identify individuals who can benefit more from the implementation of early therapeutic interventions and advanced diagnostic modalities. Few studies have assessed the morphological abnormalities of electrocardiograms among healthy children, which have provided normal ranges for some parameters.[3–7] The majority of large-scale studies among children have been conducted among targeted population, particularly athletes and/or before the initiation of sports activities.[8–13] In addition, some retrospective studies have evaluated the morphological changes of electrocardiogram among healthy individuals.[14]

The electrocardiographic screening of young population participating in sports activities and elite athletes has demonstrated that such a screening programme can reduce the incidence of sudden cardiac death in patients with hypertrophic cardiomyopathy.[15] Therefore, the American Heart Association/American College of Cardiology has recommended electrocardiographic screening not only for young population (12–25 years of age) participating in competitive athletics but also for healthy young population in any community.[1] Although several reports have explored the normal ranges of electrocardiographic intervals and durations among healthy children,[3–5] there are few large-scale studies for detecting abnormal electrocardiographic findings among healthy children and infants.[10,16,17] Herein, in a large-scale population-based study, we sought to determine the prevalence of abnormal electrocardiographic findings and electrocardiographic intervals among healthy children and adolescents who were recruited in the SHED LIGHT study in Tehran urban area, Iran, and also to find the associations between electrocardiographic findings and anthropometric parameters and blood pressure measurements.

Methods

Study protocol and population selection

The SHED LIGHT study is a cross-sectional community-based investigation, in which we tried to find the prevalence of structural heart diseases among randomly selected school-aged population in Tehran urban area using echocardiographic examination concomitant with electrocardiographic examination.[18] In summary, a multi-stage cluster-random sampling was used to choose schools from the Tehran urban area. All students were examined using a handheld Vscan device (GE Healthcare, Milwaukee, WI, USA) by echocardiographer, and the results were concurrently supervised and interpreted by cardiologists. All the major findings were re-evaluated in hospital clinics. A total of 15 130 children were examined in 7 districts of Tehran, between October 2017 and December 2018. Of individuals enrolled in the SHED LIGHT study, electrocardiographic evaluations in 15 084 participants were available to be included in this study. Of electrocardiograms taken from participants, we excluded two subjects from analysis of electrocardiographic parameters due to having implanted permanent pacemaker. All electrocardiograms were interpreted and reported due to lack of prior diagnosis of arrhythmic diseases. The measured features of electrocardiogram and rhythm abnormalities were used in this report. The protocol of study was approved by the Ethics Committee of the National Committee for Ethics in Biomedical Research. The informed consent was also obtained from all parents.

Anthropometric and blood pressure measurements

Blood pressure was assessed by experienced nurses using an automated device (Connex ProBP 3400, Welch Allyn, USA). The identification and classification of hypertension were determined based on the latest recommendations by the American Academy of Pediatrics published in 2017.[19] Among population aged 1 to less than 13 years old, the stage 1 hypertension was defined as blood pressure $\geq$ 95th percentile to $<$ 95th percentile plus 12 mmHg, or 130/80 to 139/89 mm Hg (whichever is lower). The stage 2 hypertension was also defined as $\geq$ 95th percentile plus 12 mm Hg, or $\geq$ 140/90 mm Hg (whichever is lower). For population aged $\geq$ 13 years old, the stages 1 and 2 hypertension were interpreted similarly to the ACC/AHA guidelines for high blood pressure in adults.[20] Height and weight were measured while shoes were taken off. Waist circumference was measured between iliac crest and the lowest rib. Body mass index was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). The classification of body mass index was performed based on the United States of America Centers for Disease Control and Prevention.[21] The central obesity is defined by waist circumference $\geq 90^{th}$ percentile for age and sex.[22]

Electrocardiographic examinations

A standard 12-lead electrocardiogram was recorded by a unique recorder (CP 150 model, Welch Allyn, USA) at a paper speed of 25 mm/s and a scale of 10 mm/mV standardisation. All electrocardiographic traces were provided by 5 technicians with at least 5 years of experience who take about 50 electrocardiograms per working day. Electrocardiograms were performed in students at rest and in a supine position. Electrocardiograms were re-taken if those were not interpretable and had significant noise. The detailed interpretation of electrocardiographic traces was performed based on the international guidelines.[23–28]

All electrocardiographic intervals were measured manually by 4 experienced nurses who completed an educational course for measuring electrocardiographic features by a unique protocol. Visual measurements were performed using a scale rounding to a quarter of small box. Inter and intra-reader variabilities were calculated for 4 readers, using repeated measurements on 30 traces. The readers measured PR, RR, and QT intervals, as well as QRS complex duration. All these measurements were performed in three consecutive beats and the average of three beats was used in this report. For patients with sinus arrhythmia, these values are measured in two separate leads with averaging three consecutive beats. The QT interval was calculated using the threshold method so that the end of the T-wave intersecting with the isoelectric line was considered as the duration of QT interval. The QT interval was measured in lead II, and it was corrected for heart rate (QTc) based on the Bazett's formula.[29] We excluded U-wave during the calculation of the QT interval and in the cases of biphasic T-wave, the lead V_5 was used for the measurement of QT interval. All mentioned electrocardiographic intervals were also calculated automatically by the electrocardiogram machine, and those were also used to compare with manual measurements. For measuring the degree of QRS electrical axis, the QRS complex in leads II and aVF were evaluated.

Some points were also considered in the identification of electrocardiographic abnormalities. Early repolarization pattern in electrocardiograms has been associated with sudden cardiac death, but clear criteria for separating at-risk patients from the normal population are lacking.[30] We considered early repolarization as a normal finding in our population. Minimal pre-excitation patterns comprised of those without ful pre-excitation. Sinus pause as a minor finding was defined as pause duration $<$ 3 s.[31] In patients with incomplete right bundle branch block, repolarization criteria were used to differentiate it from epsilon wave.[32] In addition to the measurement of electrocardiographic parameters, all traces were evaluated by a paediatric cardiologist certified with a fellowship in electrophysiology. He was unaware of clinical examination and students' condition, except for age and sex. All electrocardiograms with major abnormalities were again evaluated by an electrophysiologist.

Statistical analysis

For electrocardiographic parameters, descriptive values were reported based on age and sex groups. All participants were categorised into four age groups, including 6–8-year-old, 9–11-year-old, 12–14-year-old, and 15–18-year-old age groups. Continuous and categorical values are presented as mean ± SD and number (percentage),

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respectively. Moreover, 95% confidence interval values were also provided. One-way ANOVA and chi-squared tests were applied to compare values between groups. The Tukey's test was also used for pairwise multiple comparisons. The multivariate logistic regression analysis was used to find the predictors of electrocardiographic abnormalities, and results were reported as odds ratio along with 95% confidence interval. All p values refer to two-sided tests, and those less than 0.05 were considered statistically significant. All statistical analyses were performed using STATA software (StataCorp, TX, USA).

Results

Baseline characteristics

A total of 15 084 students with readable electrocardiographic traces were entered, and 52% were boys. All anthropometric values, including height, weight, body mass index, waist circumference, systolic blood pressure, and diastolic blood pressure steadily increased from 6–8 to 15–18 age group ($p < 0.001$). The highest rates of generalised overweight (17.7%) and obesity (18.5%) were detected in 15–18 and 12–14 years old age groups, respectively. On the other hand, the highest rate of central obesity by waist circumference (10.4%) values was identified in 6–8 and 9–11 years old age groups, respectively. The highest rate of hypertension was detected in 6–8 years old age group (Table 1). There were significant differences between boys and girls regarding the prevalence of obesity by waist circumference (10.4 versus 6.1%, respectively) and body mass index categorisation (20 versus 11.9%, respectively) (both $p < 0.001$).

Electrocardiographic intervals

The inter- and intra-observer variabilities for electrocardiographic intervals were good to excellent among four readers (intraclass correlation coefficients for heart rate, PR interval, QRS complex, and QT interval were 0.805, 0.925, 0.757, and 0.950, respectively). The means of heart rate, PR interval, QRS complex duration, and QT interval corrected for heart rate (QTc) were 90.7 ± 15.4 bpm, 125.9 ± 18.8 ms, 79.1 ± 12.7 ms, and 399.7 ± 28.2 ms, respectively. The values of QRS complex duration and PR interval decreased with increasing ages ($p < 0.001$), and the amounts of heart rate and QTc were significantly decreased by advancing ages ($p < 0.001$). The number of students with the left axis deviation in the QRS electrical axis significantly increased with advancing age, and those with the right axis deviation decreased with advancing age ($p = 0.030$). Moreover, we summarised these values measured by the automated software of device (CP 150 model, Welch Allyn, USA) which was available for 12 365 individuals. The automated values for heart rate, QRS complex, and QTc were significantly larger than those measured manually (Supplementary Table 1).

The duration of QRS complex increased with advancing ages, and it was significantly higher in boys than girls in age groups ($p < 0.001$). Heart rate steadily decreased with advancing ages, and girls had significantly greater values than boys. PR interval was significantly higher in boys than girls in 6–8 and 15–18 age groups ($P < 0.001$). The duration of QTc interval was comparable between genders in 6–8 and 9–11 age groups, while girls had significantly higher values than boys in both 12–14 and 15–18 age groups (Fig. 1).

Electrocardiographic abnormalities

Based on the interpretation of electrocardiographic traces, 2900 students (19.2%, 192.2/1000 persons; 95% confidence interval 186–198.6) had abnormal findings. Three most common electrocardiographic abnormalities were incomplete right bundle branch block or right ventricular conduction delay (1071 [7.1%], 71/1000 persons; 95% confidence interval 66.95–75.21), sinus arrhythmia (887 [5.9%], 58.8/1000 persons; 95% confidence interval 52.10–62.67), and sinus tachycardia > 120 bpm (562 [3.7%], 37.25/1000 persons; 95% confidence interval 34.29–40.40). Premature ventricular contraction (44 [0.29%], 2.91/1000 persons; 95% confidence interval 2.12–3.91) and prolonged QTc > 470 ms (22 [0.15%], 1.46/1000 persons; 95% confidence interval 0.91–2.20) were also identified. Other electrocardiographic abnormalities were summarised in Table 2. The rates of electrocardiographic abnormalities (21.5 versus 16.8%, $p < 0.001$) were significantly higher in boys than those in girls. Electrocardiographic abnormalities were significantly different between genders in 12–14 and 15–18 age groups (Fig. 2).

The rate of electrocardiographic abnormalities in obese individuals was lower than that in non-obese ones ($p < 0.001$ and $p = 0.019$ for generalised and central obesity, respectively). In addition, when comparing individuals based on blood pressure status, there was a trend towards individuals with hypertension to have more electrocardiographic abnormalities ($p = 0.063$) compared with those with normal blood pressure (Fig. 3). When compared in subgroups by sex, the results for boys were similar to total population; however, among girls, electrocardiographic abnormalities were comparable between groups by obesity status. Moreover, girls with hypertension had higher rates of electrocardiographic abnormalities compared to those without it ($p = 0.004$; Data are not reported).

Multivariable analysis

Based on the multivariable analysis, individuals with electrocardiographic abnormalities were less likely to be girls (odds ratio 0.745, 95% confidence interval 0.682–0.814, $p < 0.001$), and had lower body mass index levels (odds ratio 0.961, 95% confidence interval 0.944–0.979, $p < 0.001$). The results of analysis are depicted in Figure 4.

Comment

This is the first population-based study to evaluate the electrocardiographic abnormalities and their relation to hypertension and obesity status among Iranian children and adolescents, from 6 to 18 years old. We found that the rateof electrocardiographic abnormalities among children and adolescents was 192.2/1000 persons (95% confidence interval 186–198.6). The electrocardiographic abnormalities were significantly higher in boys than girls among 12–14 and 15–18 age groups. A higher value of body mass index and female gender were less likely to have the electrocardiographic abnormalities. Moreover, this study revealed the feasibility and the applicability of community-based investigation for electrocardiographic evaluations among Iranian children and adolescents.

Prior studies have been mainly conducted among young athletes in an effort to maintain cardiovascular health and prevent sudden cardiac death in such a vulnerable population.[8,10,11,15,33] Based on a meta-analysis, the electrocardiographic screening for detecting potentially lethal cardiac disorders in athletes is 10 times

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Table 1. Comparing baseline characteristics and electrocardiographic parameters in age groups

	All subjects n = 15,084	6–8 n = 2136	9–11 n = 3982	12–14 n = 4880	15–18 n = 4086	P value
Boys	7847 (52)	1622 (75.9)	2025 (50.9)	2433 (49.9)	1767 (43.2)	<0.001
Height, cm	151.4 ± 17.2	125.4 ± 7	140.4 ± 9	157.8 ± 9.6	167.6 ± 9.1	<0.001
Weight, kg	48.5 ± 18.8	26 ± 6.7	37.3 ± 10.9	54 ± 14.7	63.9 ± 15.7	<0.001
BMI, kg/m^2*	20.4 ± 4.9	16.4 ± 3.1	18.7 ± 4.2	21.5 ± 4.7	22.6 ± 4.7	<0.001
WC, cm†	70.2 ± 11.4	59.5 ± 7	66.5 ± 9.4	73.2 ± 10.6	75.8 ± 10.7	<0.001
SBP, mm Hg	113.9 ± 12.2	109.3 ± 11.9	111.5 ± 11.6	114.8 ± 11.8	117.6 ± 12.3	<0.001
DBP, mm Hg	72.3 ± 7.7	70.3 ± 8.1	71.5 ± 7.6	72.6 ± 7.6	73.7 ± 7.3	<0.001
Generalised obesity						<0.001
Underweight	1212 (8.2)	281 (13.5)	362 (9.4)	270 (5.6)	299 (7.3)	
Healthy weight	8597 (57.9)	1262 (60.4)	2160 (56.2)	2655 (54.8)	2520 (61.9)	
Overweight	2642 (17.8)	234 (11.2)	664 (17.3)	1022 (21.1)	722 (17.7)	
Obesity	2395 (16.1)	312 (14.9)	660 (17.2)	895 (18.5)	528 (13)	
Central obesity						
WC ≥90th	1252 (8.4)	220 (10.4)	336 (8.5)	412 (8.5)	284 (7)	<0.001
BP status						<0.001
Normal	8859 (59.4)	996 (46.8)	2105 (54.6)	3026 (62.4)	2732 (67)	
Elevated BP	2307 (15.5)	317 (14.9)	559 (14.5)	816 (16.8)	615 (15.1)	
Hypertension stage 1	3271 (21.9)	659 (31)	1055 (27.3)	918 (18.9)	639 (15.7)	
Hypertension stage 2	472 (3.2)	154 (7.2)	139 (3.6)	88 (1.8)	91 (2.2)	
ECG intervals						
Heart rate, bpm	90.7 ± 15.4	97.9 ± 15.4	94 ± 14.4	89.9 ± 14.9	84.8 ± 14.7	<0.001
PR interval, ms	125.9 ± 18.8	120.8 ± 17.4	123.5 ± 17.1	126 ± 18.7	130.9 ± 20.1	<0.001
QRS complex, ms	79.1 ± 12.7	75.9 ± 10.7	77.2 ± 11.2	80.2 ± 12.4	81.4 ± 14.7	<0.001
QTc, ms	399.7 ± 28.2	408 ± 26.2	409.2 ± 25.1‡	396.1 ± 28.6	390.4 ± 27.7	<0.001
QRS electrical axis						0.030
Normal	13,998 (92.9)	1969 (92.2)	3734 (93.8)	4517 (92.6)	3778 (92.5)	
LAD	140 (0.9)	13 (0.6)	35 (0.9)	44 (0.9)	48 (1.2)	
RAD	926 (6.1)	150 (7)	212 (5.27)	312 (6.4)	252 (6.2)	
Indeterminate	20 (0.1)	4 (0.2)	1 (0.03)	7 (0.1)	8 (0.2)	

*It was available in about 99% of subjects.
†It was available in about 97% of subjects.
‡All paired comparisons between 6 and 8 and other age groups by the Tukey's test were significant ($p < 0.05$) except for this single comparison.
BMI = body mass index; BP = blood pressure; bpm = beats per minute; DBP = diastolic blood pressure; ECG = electrocardiogram; LAD = left axis deviation; ms = millisecond; RAD = right axis deviation; SBP = systolic blood pressure; WC = waist circumference.

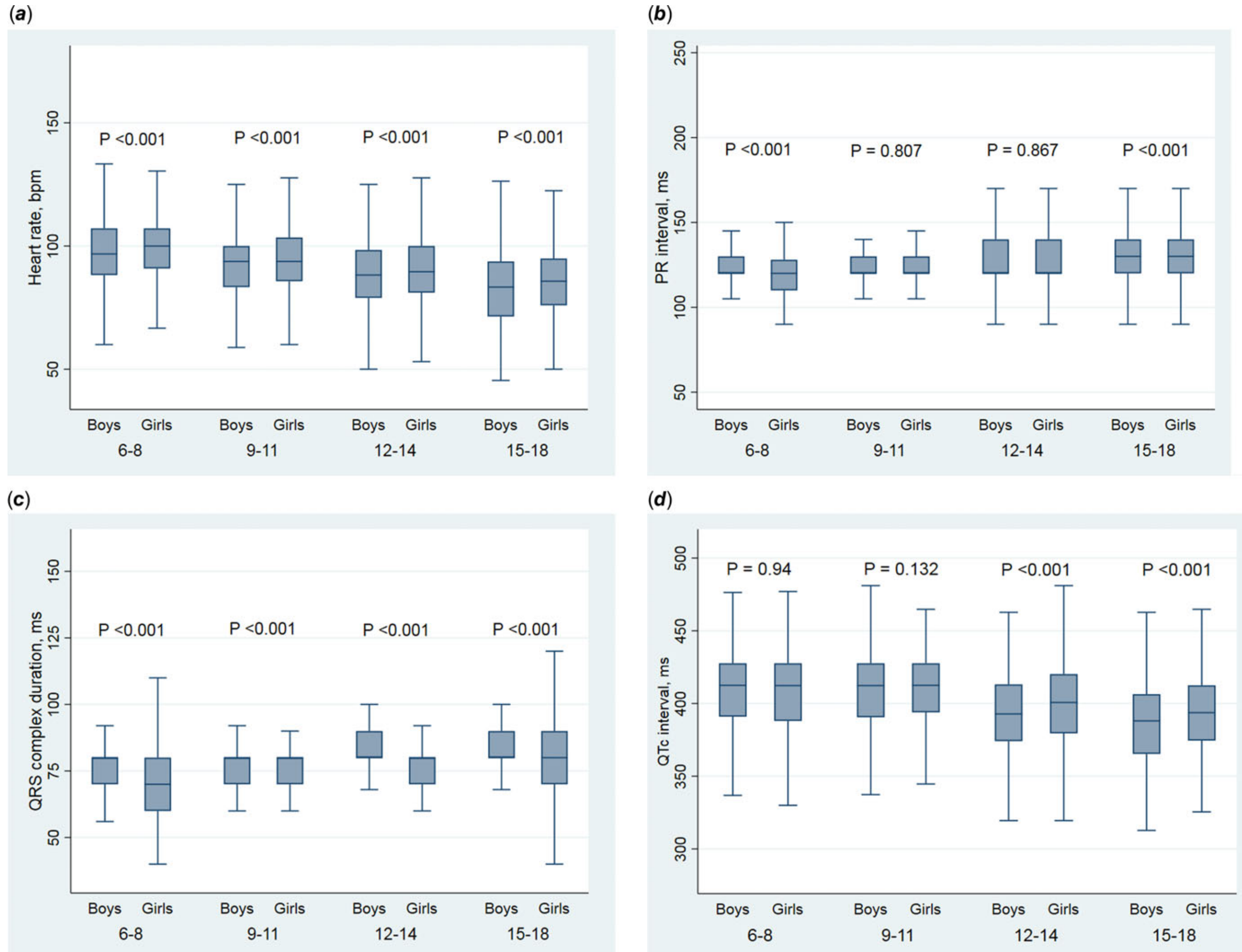

Figure 1. The comparisons of (A) heart rate, (B) PR interval, (C) QRS complex duration, and (D) QTc interval based on genders in age groups.

more sensitive than physical examination alone for detecting cardiovascular diseases.[34] The implementation of electrocardiographic screening can be pursued with regard to the magnitude of abnormal electrocardiograms among children and adolescents, the clinical outcomes of targeted population, and the cost-benefit ratio for such a screening protocol in any community. Given our study, we found that electrocardiographic abnormalities requiring further evaluations are relatively high, so it underscores further large-scale studies to find high-risk individuals requiring robust clinical evaluations to prevent sudden cardiac death and improve the prognosis of afflicted children and adolescents.

A population-based study was conducted among 24 062 healthy non-selected adolescents in Italy, aged 12–19 years old. Santini et al.[16] showed that major and minor electrocardiographic abnormalities were found in 1.7 and 20.3%, respectively, and both findings were higher in males than those in females (2. versus 0.6% and 24.5 versus 16.6%, $p < 0.001$, respectively). In another large-scale study among 32 561 USA adolescents, 14–19 years old, the rates of abnormal electrocardiograms were 2.5% and the most common abnormalities in males and females were left ventricular hypertrophy (24.9%) and Wolff-Parkinson-White syndrome (6.8%), respectively.[33] These findings are relatively similar to our findings. However, our population is somehow different from those of the studies in the USA and Italy. First, our study represents a mixed population of children, aged 6–11 years, and adolescents, aged 12–18 years, which might be associated with lower rates of electrocardiographic abnormalities compared to only adolescents and young athletes. Second, the adolescents are associated with higher rates of some abnormalities compared to children, as the prevalence of right bundle branch block increases with height,[16] left ventricular dominancy enhances with advancing age and athletic activities,[33] and major cardiac conduction disorders rise with increasing age.[35] In a community-based study among Japanese school-age children during 1980s,[36] the prevalence of electrocardiographic abnormalities with high-risk conditions was found to be 0.029%. The low rate of high-risk abnormalities compared to our study may be explained by the implementation of old criteria for identifying electrocardiographic abnormalities. We think that the lack of comprehensive clinical evaluations of electrocardiographic abnormalities in children and the absence of consensus on criteria for categorising electrocardiographic abnormalities might preclude us from conclusion about the true impacts of such findings on screening protocols and further clinical consequences.

Based on Italian population-based study, the heart rate and the QTc declined with advancing age, and the QTc interval was longer

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Table 2. Electrocardiographic abnormalities in studied population

	Frequency (%)	Crude rate, per 1000 persons	95% confidence interval
Incomplete RBBB or RVCD	1071 (7.1%)	71	66.95–75.21
Sinus arrhythmia	887 (5.9%)	58.8	52.10–62.67
Sinus tachycardia	562 (3.7%)	37.25	34.29–40.40
Sinus bradycardia	162 (1%)	10.74	9.15–12.51
Early repolarization	52 (0.34%)	3.45	2.57–4.51
PAC	50 (0.33%)	3.31	2.46–4.36
PVC	44 (0.29%)	2.91	2.12–3.91
Sinus pause	44 (0.29%)	2.91	2.12–3.91
Pseudo delta wave	35 (0.22%)	2.32	1.61–3.22
Ventricular pre-excitation	30 (0.20%)	1.99	1.34–2.83
ST segment changes*	29 (0.19%)	1.92	1.28–2.76
Atrial rhythm	28 (0.18%)	1.86	1.23–2.68
QTc interval > 470 ms	22 (0.15%)	1.46	0.91–2.20
Tall T-wave	19 (0.12%)	1.26	0.75–1.96
Complete RBBB†	10 (0.066%)	0.66	0.31–1.21
PR interval > 200 ms	9 (0.059%)	0.6	0.27–1.13
Non-conducted PAC	8 (0.053%)	0.53	0.22–1.04
SND‡	6 (0.04%)	0.40	0.14–0.86
LPFB§	4 (0.026%)	0.26	0.07–0.67
Pathological Q wave	3 (0.02%)	0.2	0.04–0.58
Paced rhythm¶	2 (0.013%)	0.13	0.01–0.47
Epsilon wave	1 (0.007%)	0.07	0.002–0.36

LPFB = left posterior fascicular block; ms = millisecond; PAC = premature atrial contraction; PVC = premature ventricular contraction; RBBB = right bundle branch block; SND = sinus node dysfunction; RVCD = right ventricular contraction delay.
*ST segments > 1 mm and < −0.5 mm are considered to be elevated and depressed, respectively.
†Without concomitant prolonged PR interval or right/left posterior hemiblock.
‡Suspicious for sinus node dysfunction requiring further evaluations presented as pause > 3 s.
§Without concomitant right bundle branch block.
¶Patients with paced rhythm had cardiac block and sinus node dysfunction causing bradyarrhythmia which were counted once as mentioned diagnoses in this table.

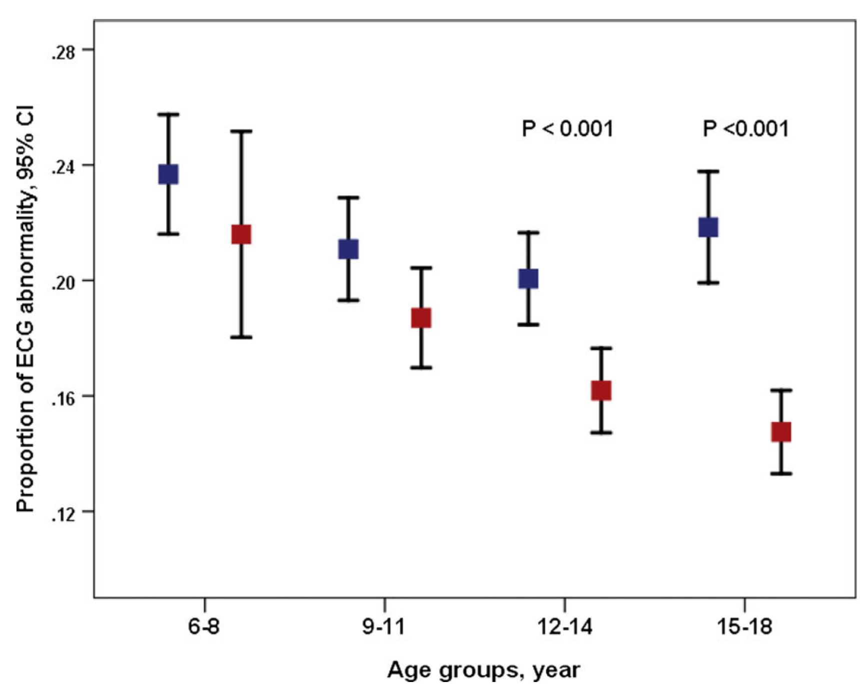

Figure 2. Differences between both genders in age groups regarding electrocardiographic abnormalities. Blue and red colours denote boys and girls, respectively.

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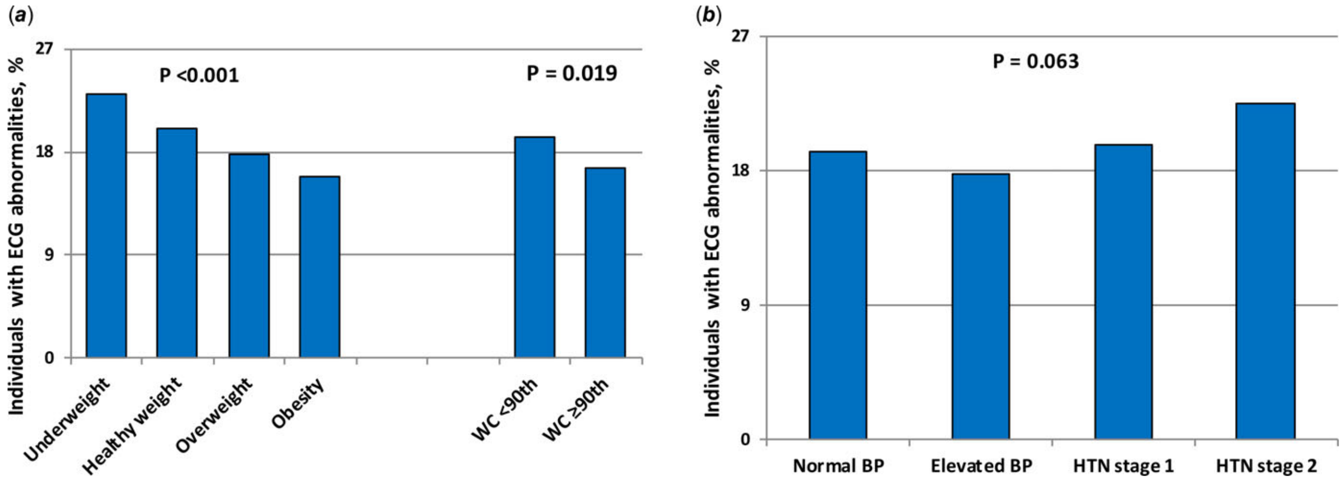

Figure 3. The prevalence of electrocardiographic abnormalities among groups by (A) generalised and central obesity and (B) blood pressure status.

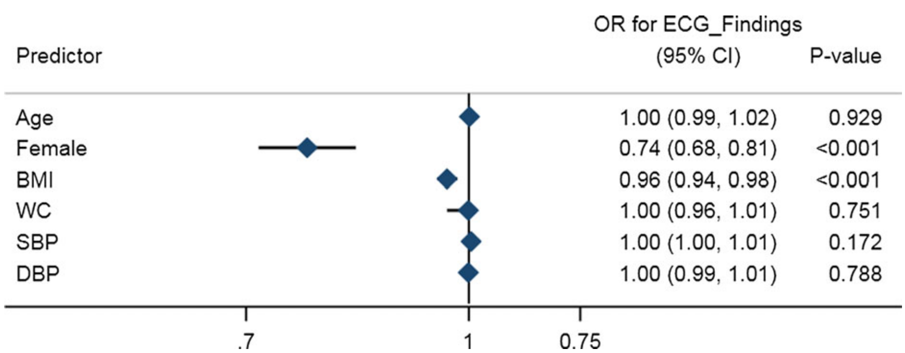

Figure 4. The multivariate analysis showing the predictors of electrocardiographic abnormalities among studied population.

in females than in males over 14 years. In addition, the PR and QRS intervals were steadily increased by advancing age, and males had greater values compared to females in age groups.[16] Reports from small-scale children population have demonstrated similar results with regard to the electrocardiographic intervals' changes by age and sex in different regions around the world.[3,4,6,7] Moreover, the rate of prolonged QTc defined as > 460 ms in accordance with Bazett's formula was found to be 0.3% in British young athletes, about 0.3% among USA adolescents,[33] and as low as 0.002% among Italian adolescents[16]. A recent report among USA children and adolescents (1 month–18 years) showed that QT intervals differed from prior reports and differences in mean values correspond with significant clinically important differences in the 98th percentile that represent the practical criteria for identification of prolonged QT.[6] Given substantial differences in the prevalence of prolonged QTc, it warrants further studies with regard to the digitalised measurement of the heart rate and the QT interval versus manual measurements, the criteria used for calculating QT interval (i.e., tangent or threshold criteria),[37] the effect of different age groups studied, and the clinical consequences of prolonged QTc in individuals and their families.

The impacts of obesity and hypertension on electrocardiographic findings have been investigated only in one non-selected adolescent in Italy. Santini et al.[16] found that minor electrocardiographic abnormalities (mostly including incomplete right bundle branch block, sinus bradycardia, and repolarization features) were higher among adolescents with normal body mass index and thins compared to obese ones. In contrast, the major electrocardiographic abnormalities (mainly including complete right bundle branch block and left anterior fascicular block) have been found with a higher prevalence in taller subjects compared with normal or short subjects. However, they did not find any association between hypertension and electrocardiographic findings. In our study, we also found that electrocardiographic abnormalities were comparable between those with and without hypertension. On the other hand, similar to Italian report, the electrocardiographic abnormalities were significantly higher among individuals with low or normal body mass index compared with those having central or generalised obesity. This finding can be explained by a high rate of incomplete right bundle branch block, more than one-third of electrocardiographic abnormalities, in our population that has been found more in individuals with low or normal body mass index compared to obese individuals. We think that given the paramount role of obesity and hypertension in cardiovascular and metabolic parameters of children and adolescents, the relationship between electrocardiographic abnormalities, as a marker of cardiovascular diseases, and the obesity and hypertension status can be used as concomitant risk stratification tools during the screening protocols among young people.

Study limitations

Despite being a large-scale non-selected population of children and adolescents, it has some shortcomings that need to be considered during the interpretation of results. First, we recruited population

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from an urban area with different nutritional and behavioural features compared to rural and small cities; however, we implemented multi-stage cluster sampling method to select targeted population. Second, all diagnoses were performed based on a single electrocardiogram at single visit. Moreover, the absence of data on probable symptoms and follow-up outcomes can prevent us from providing the true impacts of electrocardiogram screening in big communities and show how much benefit can be proposed by such a screening programme. Third, as presented in the figures, electrocardiographic features have some overlaps in their values so we cannot absolutely consider that these values relate to a specific age range. Finally, all electrocardiograms were assessed by a single cardiologist with a fellowship in electrophysiology; however, it is worth noting that all electrocardiograms with major abnormalities were re-evaluated by electrophysiologist.

Conclusions

In this large-scale study among young Iranian population, there was a high prevalence of electrocardiographic abnormalities. In addition, the electrocardiographic intervals and rhythm abnormalities were gender-dependent and significantly changed with increasing age. Moreover, electrocardiographic abnormalities were also influenced by the presence of obesity and hypertension. This community-based study revealed the implications of electrocardiographic screening among healthy young population to apply preventive modalities and to improve care delivery and quality of life by early detection.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1047951123004304.

Data availability. The data underlying this article were provided by the National Institute for Medical Research Development and the Rajaie Cardiovascular Medical and Research Center by permission. Deidentified data will be shared on request to the corresponding author via email address with the permission of both institutions 12 months after the publication of all results, after approval of a proposal, and with a signed data access agreement.

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Author contribution. MRK, YR, AT, and NS conceptualised and designed the study. YR, AT, and SH drafted the initial manuscript. MRK, GH, YR, and MO performed the statistical analysis and interpreted analysis. All authors revised critically and approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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