The Evaluation of Electrocardiographic Findings in 6-17 Year-Old Competitive Athletes in Zanjan City, Iran

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Abstract

Background: Sudden cardiac death occurs with higher prevalence in competitive athletes than general population. Thus, the purpose of this study was to evaluate the Electrocardiographic (ECG) patterns among 6 – 17 year-old competitive athletes in Zanjan city.

Methods: 241 competitive athletes aged 6-17 years old were enrolled in this cross sectional study. ECG was performed for all study participants. Information including age, sex, height, weight, medical history and medications was collected. Heart axis, QRS pattern, PR interval and QTC interval were evaluated.

Results: In this study, out of 241 patients, 49 (20.3%) of them had at least one abnormality in their electrocardiogram, and 5 had two abnormalities at the same time. Abnormal axis deviations (right or left) were the most common abnormal patterns and were seen among 35 (14.5%) participants. QRS complex abnormality, prolonged QTC interval, rhythm abnormality (Non-sinus rhythm), and prolonged PR interval were seen in 34 (14.1%), 26 (10.8), 5 (2.1%), and 2 (0.8%) of participants, respectively. Frequency of electrocardiogram abnormalities in athletes over 13 years old was 28.1% (n=25) and in athletes under 13 years old was 15.8% (n=24), (p=0.022). This frequency was 18.2% (n=28) among boys and 24.2% (n=21) among girls. Finally, the frequency of electrocardiogram abnormalities was 23.8% (n=37) among athletes performing dynamic exercises and 14% (n=12) among athletes performing static exercises.

Conclusion: Our study showed that about one fifth of the studied athletes showed some type of electrocardiographic disorder. Abnormal heart axis, QRS complex abnormalities, prolonged QTc interval, sinus rhythm abnormalities, and prolonged PR interval were the most common electrocardiographic findings among our study population, respectively. According to the results of the study, age and electrocardiographic abnormalities had a significant relationship. Given the greater frequency of ECG disorders among athletes aged 6-17, it is recommended to use ECG as a routine screening tool in the same community (athletes 6-17 years old).

Keywords: Athletes, Electrocardiography (ECG), Sudden cardiac death

Introduction

Competitive athletes are those who repeatedly compete against opponents as a team or person (1). Events like sudden death of athletes during a competition have enormous effect on society since it is believed that professional athletes have the healthiest life amongst people (2-5). Cardiovascular reasons are the leading cause of sport-related death (6). At the 26th Bethesda Conference, athletes' sudden cardiac death was defined as an unexpected non-traumatic, non-aggressive death that occurs within one hour after manifestations of the symptoms. Sport-related sudden cardiac deaths are those that their symptoms begin to appear within an hour of starting the exercise (6). The most common death-related disorders include hypertrophic cardiomyopathy, WPW (Wolff-Parkinson-White), and long QT syndrome (7). ECG has 100% sensitivity in diagnosis of these three causes, although having high false positives has been reported (8). The mechanism of death for most of these causes is ventricular tachycardia, with the exception of Marfan syndrome and other abnormalities associated with aortic dilatation, where sudden death usually occurs in the area of aortic dissection or rupture (9). Most deaths occur in team sports such as football and basketball (10). Ion channel abnormalities are potentially fatal and are termed fatal arrhythmia syndrome, which are important causes of sudden cardiac death in young athletes; other rhythms and conduction disorders can indicate underlying cardiac problems (11,12). In people over 40 years of age, atherosclerosis is an early finding which is then complicated during exercise, but in younger people, hereditary cardiovascular diseases are primarily responsible for such events (13). ECG has 100% sensitivity in diagnosis of these three causes, although high false positives have been reported (8).

ECG pattern created by exercise should be distinguished from patterns associated with cardiovascular diseases. First degree atrioventricular block, sinus bradycardia, and early depolarization are the most common patterns observed in athletes' ECGs (14,15). ECG is capable of detecting various disorders including long Q-T syndrome, Brugada syndrome, pre-excitation syndrome, dilated cardiomyopathy, short Q-T syndrome and hypertrophic cardiomyopathy (7). According to ECG's capability of diagnosing the structural heart disorders, its use in screening athletes is recommended (16-18). Standardized history taking and physical examination in athlete screening indicates high rates of false positive results and low sensitivity in diagnosing people at risk for sudden cardiac arrest; however, ECG screening has low false positive rates and high diagnostic ability for detecting early ECG changes which can put people at risk of sudden cardiac arrest (6). Characteristics of an effective screening program are as following: 1- Prevalence of the disease in the community should be high enough. 2- Screening test should be available in high resolution. 3- Illness or disorder is serious. 4- Treatment reduces complications and mortality in asymptomatic people more than symptomatic patients. These features may indicate the effectiveness of ECG in identifying disorders that cause sudden cardiac death in asymptomatic children (19-22). Many countries do the screening test prior to competitions in order to find those who are at risk. Screening test is also applied by Sports Medicine Federation of Iran to those participating in important competitions such as Olympics or Asian championship. These tests including complete individual history taking and complete physical examination are performed by cardiologists, internists, sports-medicine specialists, orthopedics and ophthalmologists; moreover, routine tests and ECGs are carried out as well (6). The results show that screening leads to medical follow-up for a large population of athletes when it is done before entering professional sports academies at the age of 12; there are few athletes who do not qualify for competitive sports (2). According to studies, it seems reasonable to support and encourage epidemiological research on prevalence and causes of Sudden Cardiac Death (SCD) in different Asian countries (23). Our main goal in this study was to determine the frequency of Electrocardiographic (ECG) findings in competitive athletes younger than 17 years old in Zanjan city, Iran in 2017. The second purpose was to determine the frequency of electrocardiographic findings in competitive athletes younger than 17 years old in Zanjan city, Iran in terms of sex, age group and type of exercise.

Materials and Methods

This study was a cross-sectional study to find potentially dangerous abnormalities in athlete's ECG. After coordinating with the Research Deputy of Zanjan University of Medical Sciences, a letter of cooperation with the Physical Education Organization was obtained, and a list of competitive athletes was then arranged. Those competitive professional athletes, aged 6 to 17 years old, who participated in city-level teams exercising regularly, were enrolled into the study. Our inclusion criterion involved all athletes aged 6 to 17 years who are training or regularly competing under the supervision of Zanjan's Department of Physical Education and the exclusion criterion was those who refused to take part in the study. After obtaining permission from the mentioned organization and obtaining informed and written consent from all samples, the study was conducted. In order to collect data, ECG was performed at the site of exercise in all 12 leads while at rest in supine position. ECGs were read and reported by pediatric cardiologists. Demographic and anthropometric data and illness history were then collected. After data collection and allocation of appropriate data, SPSS software was used for analysis. Long PR interval is defined as a PR interval longer than 200 *milliseconds*. Normal heart axis is defined as -30 degrees to 110 degrees. Left Axis Deviation (LAD) is when the heart's axis is deviated between -30 to -90 degrees. Right Axis Deviation (RAD) is defined when heart's axis is deviated between 110 and 180 degrees. Corrected QT (QTc): QT interval is divided by the square of the RR interval; abnormal QTc is defined above 450 milliseconds, which is divided into groups of borderline and long; the borderline group is defined as QTc interval of 450-480 *milliseconds*, the long group is defined as a QTc interval over 480 *milliseconds*. QRS complex disorders: Disorders can be categorized into two groups, Left Ventricular Hypertrophy (LVH) and Right Bundle Branch Block (RBBB). Individuals with LVH are subdivided into mild and severe types with only severe LVHs to be considered as a pathological state. It should be noted that based on the available information (1), sports were divided into two categories of static (Gymnastics, taekwondo and karate) and dynamic (Football, futsal, ping pong, running, swimming, volleyball and badminton). In this study, Body Mass Index (BMI) percentile was determined with BMI being calculated and classified based on BMI distribution chart specialized for gender and age in children. In this study, percentiles below 5 and above 95 were considered to be abnormal. A researcher-made questionnaire was used to determine validity and reliability in which history of illness (including heart disease, diabetes, *etc*), the type of competitive exercise and EEG findings were recorded as well as demographic information (including age, sex) and anthropometric information (including height, weight). Data were then entered into SPSS software and analyzed with appropriate codes. In descriptive statistics, mean and standard deviation for continuous quantitative data, and percentages and frequency for qualitative and nominal data were reported in charts and tables. In Inferential statistics, parametric tests were used to compare the means (Independent t-test) in two groups and one way ANOVA was used for several groups only if distribution of data corresponded. In case of discrepancy of data distribution, Mann-Whitney test was used for comparing groups of two and Kruskal-Wallis test was used for several groups. Chi-square test was used to determine the relationship between the qualitative variables. All analyzes were performed using SPSS software and significance level was considered 5 percent.

Results

In this study, with 241 athletes aged between 6 to 17 years old with an average age of 11.15 years old, average height of 146 *cm* and average weight of 39 *kg* , the following results were achieved:

LVH was the most frequent QRS complex related disorder (13.7%) whilst RBBB had the least frequency (0.4%).

Our study showed that there was no significant relationship between gender and frequency of axis-related disorders (p=0.904), QTc disorders (p=0.16), rhythm abnormality (p=0.516), and QRS complex disorder (p=0.547).

In the present study, no significant relationship was found between athletes' age and rhythm disorders (p=0.428), QRS complex disorder (p=0.547), and frequency of axis-related disorder (p=0.055).

In this study, there was no significant relationship between the type of exercise and rhythm disorder (p=0.671), frequency of axis-related disorder (p=0.183), PR interval abnormality (p=0.671), prolonged QTc interval (p=0.064) and QRS complex disorder (p=0.32).

Table 1 shows the frequency of ECG abnormalities among participants. The most frequent one was axis-related disorders with 14.5% (n=35) frequency and LVH was in the second place with 13.7% (n=33); further information is available in the table.

Table 2 shows the significant relationship between gender and prolonged PR interval (p=0.043), also indicating a greater prevalence of this disorder among girls in this study.
Table 3 shows the frequency of electrocardiogram abnormalities in the study. According to the data, 20.3% (n=49) had at least one of the discussed abnormalities in their ECG.
Table 4 shows the significant relationship between age and the frequency of electrocardiogram abnormalities (p=0.022), indicating a frequency rise in athletes older than 13 years of age.

Table 1. The frequency of ECG abnormalities among participants

Parameter	Status	(Number), Frequency	Overall
Rhythm	Sinus	(236) 97.9%	(241) 100%
	Non sinus	(5) 2.1%	
PR	Normal	(239) 99.2%	(241) 100%
	Abnormal (Prolonged)	(2) 0.8%	
Axis	Normal	(206) 85.5%	(241) 100%
	Right deviation	(20) 8.3%	
	Left deviation	(15) 6.2 %	
QTC	Normal	(215) 89.2%	(241) 100%
	Borderline	(20) 8.3%	
	Long	(6) 2.5%	
Past medical history	None	(239) 99.2%	(241) 100%
	Hypothyroidism	(1) 0.4%	
	VSD	(1) 0.4%	
Drug history	None	(240) 99.6%	(241) 100%
	Levothyroxine	(1) 0.4%	
QRS complex	Normal	(207) 85.9%	(241) 100%
	LVH	(33) 13.7%	
	RBBB	(1) 0.4%	
Heart murmur		(1) 0.4%	(241) 100%

Table 2. Relationship between gender and prolonged PR interval

Gender	P-R interval	Frequency, (Number)	Significance level
Female	Normal	97.7% (84)	0.043
	Abnormal	2.3% (2)	
Male	Normal	100% (155)	
	Abnormal	0	

Table 3. Frequency of electrocardiogram abnormalities

ECG	Frequency	No.
Normal	79.7%	192
Abnormal	20.3%	49

Table 4. Relationship between age and the frequency of electrocardiogram abnormalities

Age	ECG report	Frequency, (Number)	Significance level
Under 13	Normal	84.2% (128)	0.022
	Abnormal	15.8% (24)	
Above 13	Normal	71.9% (64)	
	Abnormal	28.1% (25)	

Table 5 shows the frequency of electrocardiogram abnormalities by type of exercise, with no significant relationship between them (p=0.67).

Discussion

In this survey, the abnormal electrocardiographic findings were studied in children aged 6 to 17 years who were engaged in competitive sports. Our results showed that about 20% of examined people had a kind of ECG disorder. Observed abnormalities included axis deviation, prolonged PR interval, prolonged corrected QT interval, abnormal rhythm (non-sinusoidal), and abnormal QRS complex (ventricular hypertrophy). Axis deviation, ventricular hypertrophy and abnormal QT interval were the most common ECG abnormalities, respectively.

Salehi *et al* reported that 21% of examined athletes had abnormal electrocardiography in a study on wrestlers in Iran in 2015; however, first degree heart block was reported as the most common disorder (8). This conflict could be due to the difference in population's age average as Salehi's research population was older. It is worth mentioning that important causes of prolonged PR interval include increased vagal tone, myocardial infarction, electrolyte imbalances such as hypokalemia and usage of certain medicine, all of which being more common in the elderly.

As noted above, in the present study, axis deviation was highly present as an electrocardiographic finding, with 8.3% (n=20) of athletes having right axis deviation and 5.8% (n=14) having left axis deviation. In a study in 2010, Farahani *et al* reported right axis deviation to be 6.2% (15), which is in line with the findings of our study. In 2006, Ma *et al* reported a 0.2% incidence of right-axis deviation (7), which is much lower than the Farahani's and our study. This difference in prevalence could be due to racial differences between the different study populations.

The high prevalence of heart axis deviation in young athletes should be of concern. Although 33 (13.7%) cases of left ventricular hypertrophy were found in this study, a high incidence of heart axis deviation may indicate a higher incidence of left or right ventricular hypertrophy. It can be assumed that low accuracy of ECG on detecting LVH is responsible for less reported cases than they really are. This disorder (abnormal heart axis deviation) is sometimes associated with other heart diseases, such as coronary heart diseases and congenital heart diseases, which emphasize the need for additional tests (especially echocardiography).

In this study, the frequency of abnormal electrocardiographic findings in terms of sex and type of exercise was also examined. In spite of our study that did not show a significant relationship between abnormalities in ECG and sex, Magalski *et al* and Salehi *et al* reported that ECG abnormalities were higher in men than women; difference in the average age of the populations in the studies may be the reason (8,23). Hormonal hypothesis to justify differences in frequency of electrocardiographic abnormalities in both sexes has been suggested; the effect of testosterone on repolarization status and ECG patterns has been reported in both human and animal models by some studies. Given that our statistical population is a young group of people, the hormonal theory does not apply to at least a large proportion of our population (24). The study of Basavarajaiah *et al* and Menafoglio *et al* showed no significant difference in case of QTc between the two sexes in children under 16, though, in the same study, a significant difference was found between the age 24 and 27 (16,20).

Regarding the frequency of ECG findings by type of exercise, although our study showed that these types of abnormalities are most prevalent in athletes performing dynamic exercises, this difference was not statistically significant. In the study of Salehi *et al*, no significant relationship was observed between electrocardiographic abnormalities and the type of exercise (8). It seems that the type of exercise has no effect on the occurrence of these disorders because

Table 5. Frequency of electrocardiogram abnormalities with type of exercise

Type of exercise	ECG report	Frequency, (Number)	Significance level
Static	Normal	86% (74)	0.067
	Abnormal	14% (12)	
Dynamic	Normal	76.1% (118)	
	abnormal	23.9 (37)	

most of these disorders are congenital and age and type of exercise do not affect its frequency. In the study of Salehi *et al*, there is a higher prevalence of abnormalities in men, most likely due to ventricular hypertrophy caused by greater cardiac muscle volume in men and physiological hypertrophy in athletes and the combined effect (8).

In the present study, approximately 10% of the population of athletes in childhood and adolescence had a prolonged QT interval. Studies in the general population report estimates of 5 to 66 per 10,000 people, much lower than the estimates in the present study. Even when the cut-off point for prolonged QT interval was conservatively considered 480 milliseconds, prolonged QT interval rate reached 2.5%, which again exceeded the general population. Studies have shown that athletes' QT intervals are higher than the general population; however, given the fact that in our study the frequency was much higher, it should be taken into consideration. Acquired causes of prolonged QT interval include bradycardia, metabolic disorders, and electrolyte imbalance, all of which are related to the intensity of athletes' trainings. On the other hand, prolonged QT syndrome is a genetic disorder in which potassium channels function is impaired and can potentially cause dangerous ventricular arrhythmia such as Torsades de pointes and ventricular fibrillation. Considering the importance and high incidence of a prolonged QT, annually ECG monitoring for athletes is highly suggested for ruling out this disorder (2). In the present study, approximately 13.7% of participants showed left ventricular hypertrophy (Severe or pathologic) in their ECG. Working on 3500 asymptomatic athletes, Menafoglio, *et al* (16) reported that the frequency of left ventricular hypertrophy was 1.5% among athletes, which is lower than the frequency of our study. Pathological LVH can raise suspicion of more serious underlying disorder such as hypertrophic cardiomyopathy. This disorder is the most common cause of sudden death among athletes. The prevalence of this congenital disease is about 0.2% in the general population, but its exact prevalence amongst athletes is unknown. The definitive diagnosis of the disease is by complementary tests (Echocardiography and MRI) and an increase in thickness of left ventricle greater than 12 *mm*. Therefore, echocardiography is advised for athletes with pathological LVH. In this study, by determining the heart axis of each athlete, it is concluded that, average heart axis is 43 degrees in our statistical society. In a study by Steriotis *et al*, average rate for heart axis was reported 60 degrees, which is almost consistent with the results of our study (19). In the present study, a significant relationship was observed between age and frequency of electrocardiogram abnormalities, showing the prevalence of these disorders was higher in participants older than 13 years old. In the study of Salehi *et al*, there was no significant relationship between age and ECG abnormalities (8). On one hand, with regard to the age range of our study, which included athletes from 6 to 17 years old, with the increase in age and duration of exercise in athletes, and possibly increased intensity of exercise, it could be expected that left ventricular hypertrophy may increase in athletes over time. On the other hand, left axis deviation related to ageing and also left ventricular hypertrophy can cause a higher incidence of disorders at an older age whether true or false positive. For confirming such finding, a larger number of samples and a prospective study besides follow-up of the patients are required.

Conclusion

Our study showed that about one fifth of the examined child athletes showed some form of electrocardiographic abnormality. Abnormal heart axis, QRS complex abnormalities, prolonged QTc intervals, sinus rhythm abnormalities and prolonged PR intervals were the most common electrocardiographic findings among the studied athletes, respectively. According to the results of the study, a significant direct relationship was observed between age and electrocardiographic abnormalities.

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