Factors associated with terminal activation duration in young athletes

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INTRODUCTION

Electrocardiogram (ECG) changes in athletes are common and occur because of electrical and structural adaptations due to sports activities. The correct interpretation of ECG is essential because sometimes results indicating underlying cardiovascular disease may be misinterpreted as regular changes due to exercise [1]. Pediatric athletes have a greater prevalence of training-related or unrelated ECG changes than non-athletes [2]. In athletes, arrhythmogenic right ventricular cardiomyopathy (ARVC) is a symptom of myocardial damage and severe ventricular arrhythmias characterized by fibro-fatty replacement of the right ventricular myocardium. It is associated with sudden cardiac death [3]. ARVC is caused mainly by inherited mutations in proteins of the desmosomal complex [4]. It is unclear whether ARVC can be exercise-induced, but it has been recognized that extreme exercise can worsen the disease resulting in earlier and more severe phenotypic expression [5]. Physiological cardiac adaptation to regular exercise may create diagnostic overlap with this syndrome [6].

An indicator of activation delay — prolonged terminal activation of QRS (QRS delayed S-wave upstroke with a terminal activation duration [TAD] ≥55 ms in the right precordial leads) is a factor of superior sensitivity and high specificity, as it was included in the modification of Task Force Criteria for the clinical diagnosis of ARVC [7, 8]. Our observational study aimed to find factors associated with terminal activation delay in young athletes.

METHODS

This retrospective observational study was conducted at Novi Sad Healthcare Center, Sports Medicine Center. There were 254 participants, young, healthy athletes involved in regular training, aged 6–15 years, 168 males and 86 females. Characteristics of participants are given in Table 1. The study group consisted of healthy children who had regular pre-participation examinations performed by sports physicians consecutively from July 1 to November 1, 2020.

Exclusion criteria were COVID-19 or another infection in the previous three months, abnormalities in the P wave, QRS complex, ST-segment, T waves, and QT interval, or rhythm and conduction abnormalities. This research study was conducted retrospectively based on the data obtained for clinical purposes. The study was approved by the Ethical Committee of the Novi Sad Healthcare Center (approval no. 21/1-1 of 21.1.2021).

The ECG examination of all children was done using HeartScreen 60-IKO (Innomed, Inc., Savannah, GA, US). The speed of the ECG paper was 25 mm/s, and the gain was 10 mm/mV. The assessment of TAD was done by two independent investigators.

The training duration concerns only children involved in selected sports disciplines since every child has 5 hours of regular physical activity at school. This is the same for all children; only duration data on children in training were considered here.

Terminal activation duration of QRS was measured as the time from the nadir of the S wave to the end of all depolarization deflec-

tions in leads V1–V3. It is prolonged if it is greater than or equal to 55 ms in any of the V1–V3 leads in the absence of complete right bundle branch block [8].

The children were divided into three groups according to age, body mass index (BMI) status: normal, overweight, and obese, according to the BMI-for-age percentile chart [9], and duration of training per week and into four groups according to the years in training (Supplementary material, *Table S2*).

Statistical analysis

In the final analysis, 254 children were included. Nineteen participants were excluded due to missing data (3) and the exclusion criteria (16). Categorical variables were presented as numbers and percentages. Continuous variables were expressed as mean (SD) or median (interquartile range [IQR]). The Mann-Whitney U-test and Kruskal-Wallis tests with Dunn post-hoc test were used to compare the differences in TAD between groups. Spearman rank correlation was used to assess the relationships between numerical variables. The *P*-value of <0.05 was considered to be statistically significant. We analyzed the data using MedCalc® Statistical Software version 20.104 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2022), TIBCO Software Inc. (2020), Data Science Workbench, version 14 (http://tibco.com).

RESULTS AND DISCUSSION

The characteristics of the study participants are given in Table 1 (sports, age, sex, height, weight, BMI, physical activity level, and years in training). The distribution of TAD in the whole sample had a median (IQR) of 40 (30–40) ms. In the Supplementary material, *Table S1*, TAD is compared according to sex, age, body mass index (BMI) hours of training per week, and years in training.

There was a significant difference in TAD between males and females ($P = 0.02$). There was no significant difference in TAD in the three BMI status groups or in the three age groups.

Regarding activity level per week, there was a statistically significant difference among the three groups ($P < 0.001$). According to the Dunn post-hoc test, it was determined that there was no statistical difference between the first and the second groups, but there was a difference between the first (and the second) and the third groups ($P < 0.001$). Regarding the number of years in training, there was a statistically significant difference among the four groups ($P = 0.04$). Correlations between TAD and age, BMI, the number of hours of training per week, and the number of training years are presented in Supplementary material, *Table S2*.

A terminal activation duration of 55 ms or more is a minor criterion for diagnosing possible arrhythmogenic cardiomyopathy [10]. We determined factors associated with an increase in activation duration. We used a mathematical principle of continuity which assumes that the terminal activation duration increases gradually. Hence, the values close to 55 ms meant that they could be over 55 ms at some point if the tendency influenced by this factor persists. We found that TAD is associated with years in training and level of activity but not with the age of children or other characteristics. The question is whether the high intensity of exercise can influence the prolonged activation duration and the related physiological phenomena. In the group of 254 children, only 18 had prolonged TAD (≥55 ms), and they underwent further investigations at the cardiac department. On echocardiographic examination, all the results were normal. They did not have a genetic study, but the family history of cardiovascular disease was considered. Concerning further investigation, diagnosing myocarditis might be challenging. According to the cardiac protocol in Serbia, further analyses were not recommended, but the children were under close surveillance.

Table 1. Characteristics of study participants

	All
Number	254
Age, years, mean (SD)	10.63 (2.01)
Sports, n	
Soccer	33
Volleyball	15
Dancing	13
Basketball	11
Swimming	11
Martial arts	10
Athletics	4
Gymnastics	2
Handball	1
Height, cm, mean (SD)	149.80 (14.61)
Weight, kg, mean (SD)	44.07 (14.34)
BMI, kg/m^2, mean (SD)	19.19 (3.74)
Physical activity level, hours per week, median (IQR)	3 (3–4)
Years in training, years, median (IQR)	3 (2–4)

Abbreviations: BMI, body mass index

In order to establish ARVC or myocarditis diagnosis, it is necessary to perform magnetic resonance, so in our study, reaching any conclusions about the reason for abnormal TAD was impossible. We are planning to perform magnetic resonance of the heart in a further study, which would give us data about the size and state of the myocardium of the right ventricle.

The terminal activation delay of ≥55 ms was associated with larger right ventricle (RV) volume and lower RV ejection fraction [11] in patients with ARVC. Hence, TAD might be a factor connected to exercise-induced cardiac remodeling. It was indicated that endurance training influences the cardiac remodeling of male preadolescent athletes with increased RV dimensions and preserved RV function [12].

It was found that the terminal activation delay was the only ECG abnormality in the asymptomatic mutation carriers not fulfilling the 2010 Task Force Criteria and without a history of ventricular arrhythmias (in 26% of cases) [13]. The limitation of the study is that further testing (except

echocardiography) was not conducted on children with prolonged TAD.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska.

Article information

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