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# Association between Sugar Intake and an ECG Parameter: A Case Study on Young Athletes

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**Abstract:** In many recent studies, high sugar intake has been shown to have harmful effects on the cardiovascular system, especially in children. This study aimed to check the association between sugar intake and T-peak to T-end interval, an electrocardiogram (ECG) parameter associated with a higher risk of early afterdepolarizations and ventricular arrhythmias in young athletes. The study participants were 96 young athletes aged 7–15, 34 girls and 62 boys trained in various sports. ECGs were performed on all participants and analyzed for the duration of the period from the peak of the T-wave to the end of the T-wave. The data on years of training and training hours per week, type of sport, age, height, and weight were taken, as well as the child's sugar intake per day. The cut-off was a minimum of 30 g of concentrated sugar in sweets or drinks. The group of children that consumed sugar had, on average, a significantly longer duration of the T-peak to T-end (TpTe) interval. There is an association between sugar intake and the duration of the T-peak to T-end (TpTe) interval. In our case study, it was demonstrated that the benefit of playing sports cannot compensate for the harm of overconsumption of sugar, so an important public health target would be to lower sugar intake in children's diets (particularly in the diets of young athletes). It would be necessary to determine interventions and activities that would affect the reduction in sugar intake from early childhood. Aside from the fact that overconsumption of sugar is associated with human health issues, there are many environmental benefits of reducing sugar production and consumption.

**Keywords:** public health; sugar reduction policy; young athletes; sugar; ECG



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## 1. Introduction and Background

### 1.1. Risks of Sugar

As the most critical risk factor for cardiovascular disease, controlling hypertension was, historically, a significant focus of public health initiatives. However, the evidence began to accumulate showing that it is not sodium, but added sugar, that is related to hypertension and coronary heart disease [1]. Some effects of added sugar intake are higher blood pressure, inflammation, weight gain, diabetes, and fatty liver disease, and these are all linked to an increased risk of heart attack and stroke [2]. High sugar intake harms the cardiovascular system, especially in children [3]. The American Heart Association recommends that children consume $\leq$ 25 g (100 cal or $\approx$six teaspoons) of added sugars per day, and that children < 2 years of age avoid added sugars completely [3]. The recommendations for both adults and children by the WHO are to reduce the intake of free sugars to less than 10% of total energy intake (strong recommendation), and a further reduction in the intake of free sugars to below 5% of total energy intake (conditional recommendation) [4]. A recent study [5] concluded that children generally have high sugar intake during their growth, and that dietary education and coordination between families and institutions would be crucial. One of the primary sources of added sugar is fructose, which is contained in fructose-containing sweeteners, sucrose, and corn syrup in sugar-sweetened beverages and food additives [6]. It is indicated that high fructose intake contributes to inflammation and provokes metabolic disorders, inducing cardiac arrhythmogenesis and aggravating its negative effects on cardiac remodeling and arrhythmia [6]. Other studies also link sugar intake with metabolic and inflammatory markers that can lead to cardiac arrhythmias [7,8]. A recent study [9] on 12,454 children indicated a higher risk of symptom complaints among children who consume 75 mL or more daily sugar-sweetened beverages.

Not only does sugar have destructing effects on human health, but its impact on the environment is also considered to be extremely damaging across a number of indicators [10]. Sugar production uses large amounts of water and agrochemicals, and often replaces natural environments on a large scale to achieve economic aims. The area under cultivation of sugarcane continues to expand, leading to the loss of biodiversity, deforestation, and habitat destruction [10].

### *1.2. Tp-Te Duration, an ECG Parameter*

The duration from the peak to the end of the T-wave is an ECG parameter representing the transmural dispersion of repolarization. This is when ventricular cells are most vulnerable to early afterdepolarizations and ventricular arrhythmias of the heart in young athletes [11]. In healthy children and adolescents, in the standard 12-lead electrocardiogram, TpTe intervals vary between individual leads, with the longest in lead V3 (73.2 ± 21.34 ms) and the shortest in the lead III (51.0 ± 11.01 ms) [12]. In a study on 46 children, aged 4 to 18, with ventricular arrhythmias of unknown etiology, and a control group of 34 healthy children of the same age without confirmed arrhythmias, the duration of the TpTe interval was significantly longer in children with ventricular arrhythmias compared to that in the healthy children from the control group [13].

### *1.3. Aims of the Study*

The present study aimed to check the association between sugar intake and the duration of the period from the peak of the T-wave to the end of the T-wave (TpTe), as well as, in this way, to check whether children who consume more sugar are at a higher risk of early afterdepolarizations and ventricular arrhythmias.

We hypothesized that sugar intake and the duration of T-peak to T-end interval are associated, indicating that even sports activities in children cannot mitigate the harm of high sugar intake.

## 2. Materials and Methods

### *2.1. Participants of the Study*

The participants in this observational study were 96 young athletes aged 7–15, 34 girls and 62 boys trained in various sports. They were examined at a pre-participation examination by a sports physician between 16 August 2021 and 10 September 2021 at Novi Sad Health Care Centre, Sports Medicine Centre. The participants were all children athletes (independently of the sport in which they were trained) who came to the pre-participation examination during the mentioned period, considering inclusion and exclusion criteria. The inclusion criteria for all study participants were healthy children that had trained regularly in the previous six months. Children and their parents gave the informed content to participate in the study. The exclusion criteria were any ECG irregularity: abnormalities in the P wave, in QRS complex, in ST-segment, in T-waves, in QT interval, or rhythm and conduction abnormalities, as well as metabolic disorders such as diabetes mellitus, impaired fasting glycemia, or other chronic diseases.

Ethical approval: The study was approved by the Ethical Committee of the Novi Sad Health Care Centre, approval no. 21/1-1 of 21 January 2021.

*2.2. Description of Procedures*

The data on years of training and weakly training duration, type of sport, age, height, and weight were taken as usual in the pre-participation examination of children by the children and their parents.

The height of the participants was measured with a wall-mounted stadiometer. The weight of the participants was measured with a medical-grade beam balance scale.

The shoes of the participants were removed before measurement. For measuring the height, a participant was standing against the stadiometer with heels together, legs straight, arms at the sides, and looking straight ahead. The headpiece of the stadiometer was placed to touch the top of the participant's head, and the measurement was read parallel to the headpiece. The measurement was repeated until two measurements within 1 cm were agreed upon, and the average of the two was recorded. For weight measurements, the participant stood in the center of the platform. The measurement was repeated until two weights agreed within 0.1 kg, and the average of the two was recorded.

ECG examination of all children was done by the HeartScreen 60-IKO (Innomed, Inc., Savannah, GA, USA). ECG was performed on all participants and analyzed for the duration of the period from the peak of the T-wave to the end of the T-wave (Figure 1). The duration was measured in V3 (the right pre-cordial lead in ECG), the TpTe duration was measured in 5 cycles, and the average value was calculated.

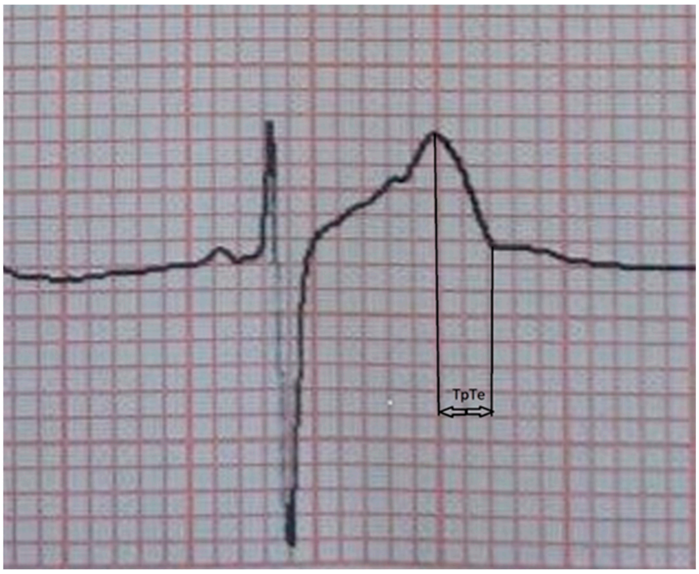


**Figure 1.** Measuring of TpTe interval.

The TpTe interval was measured using the magnifying glass with a scale. The T-peak is the point at the 0 slopes, i.e., the point between the increase and the decrease. The T-end is the point before the line becomes horizontal (the precise moment is taken at the slope of 45 degrees).

The information on sugar intake was obtained orally from the children and their parents. A minimum of 30 g of concentrated sugar in sweets or drinks per day (during the period of the whole day, i.e., 24 h) was taken as the cut-off. It was explained to the children and parents that one glass (0.25 L) of cola or a similar soft drink contains approximately 25 g of sugar; 100 g of milk chocolate contains about 50 g of sugar, and 100 g of candies includes 70 g of sugar. They were asked to declare whether the child consumes more than 30 g of concentrated sugar per day or not. During the procedure, the child and at least one of the parents were together in the room with the doctor. The doctor asked the children first whether they consumed sweets each day, explaining to them what quantity was approximately 30 g. After obtaining this information, the doctor asked the parents the same question (i.e., to confirm the data obtained by the child). The doctor entered this information into the Excel file if the answers from the children and their parents were identical.

*2.3. Statistical Procedures*

Statistical analyses were performed using Dell Inc. (2016) Dell Statistica (data analysis software system, version 13, software.dell.com), and MedCalc Statistical Software version 18.2.1 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2018, accessed on 1 April 2022).

Variables chosen for the analysis were:

1. A binary variable showing the sugar intake (if a child consumes more than 30 g of concentrated sugar in sweets or drinks, then the value is 1; otherwise, it is 0).

2. A continuous variable showing the interval between the peak of the T-wave to the end of the T-wave [Figure 1].

3. Continuous variables showing the value of height (in cm), the value of weight (in kg), the value of BMI (in kg/m$^2$), and a binary variable indicating whether a child is overweight or obese according to the body mass index-for-age percentile chart [14].

4. Two discrete variables showing the number of years of training and the number of training hours per week.

5. The nominal variable presenting the sport type, according to a modified Mitchell's sports classification, based on combined static and dynamic components [15].

The data were analyzed using Student's *t*-test, the Mann–Whitney test, analysis of variance (ANOVA), the Chi-squared test, Pearson, and the biserial correlation coefficient.

The two groups (children who consume and those who do not consume sugar) were compared according to age, height, weight, training hours per week, years of training, and the ECG parameter TpTe. Moreover, the two groups were compared according to their BMI (i.e., it was determined whether there were more overweight or obese children in the group that consumed sugar) and type of sport.

The correlation analysis between the ECG parameter TpTe and all the characteristics was performed. In cases where the variable was continuous, the Pearson coefficient of correlation has been calculated, and in cases where the variable is binary, the biserial correlation coefficient has been taken into account.

In the analysis, the significance level was assumed to be 0.05. The assumption of normality was confirmed by the D'Agostino–Pearson test for normal distribution when applicable. In cases where a variable was not normally distributed, non-parametric tests were performed.

The records with missing data (and the data where the opposite information on sugar intake was obtained from the child and their parents) were excluded from the study.

## 3. Results

A comparison of characteristics between two groups (the group of children that consumed sugar and the group of children that did not consume sugar) is given in Table 1. In the study group, 44 children consumed sugar, of which 12 were girls and 32 were boys, and 52 children did not consume sugar, of which 22 were girls and 30 were boys. The Chi-squared test showed no significant difference between the proportions of boys and girls who consumed sugar ($p = 0.09$) (Table 1). Moreover, there was no statistical difference between the two groups in age, height, training hours per week, or years of training (Table 1).

**Table 1.** Comparison of parameters in groups with and without sugar.

| | The Group with Sugar Intake | The Group without Sugar Intake | *t*-Test, Mann–Whitney Test, or Chi-Squared Test *p*-Value |
|---|---|---|---|
| Sex | | | 0.06 |
| Male: 62 (65%) | 32 (52%) | 30 (48%) | |
| Female: 34 (35%) | 12 (35%) | 22 (65%) | |
| Age, years | 10.68 ± 2.11 | 10.17 ± 1.97 | 0.63 |
| Training hours per week | 3.55 ± 1.02 | 3.21 ± 0.69 | 0.18 |
| Years of training (years) | 3.43 ± 1.61 | 3.29 ± 1.64 | 0.60 |
| Height (cm) | 152.25 ± 15.24 | 146.08 ± 14.62 | 0.07 |
| Weight (kg) | 47.45 ± 16.88 | 39.44 ± 10.92 | 0.02 * |
| Weight status | | | 0.06 |
| Normal weight | 25 (39%) 64 (67%) | 39 (61%) | |
| Overweight or obese | 19 (59%) 32 (33%) | 13 (41%) | |
| Type of sport | | | 0.46 |
| IB 15 (16%) | 4 (27%) | 11 (73%) | |
| IC 17 (18%) | 9 (53%) | 8 (47%) | |
| IIC 36 (37%) | 17 (47%) | 19 (53%) | |
| IIIA 22 (23%) | 10 (45%) | 12 (55%) | |
| IIIC 6 (6%) | 4 (66%) | 2 (33%) | |
| TpTe (ms) | 73 ± 8 ms | 60 ± 8 ms | $p < 0.001$ ** |

* $p < 0.05$; ** $p < 0.01$.

Weight status was determined according to the body mass index-for-age percentile chart [14], and 32 children (out of 96) were overweight or obese. There were 19 overweight and obese children (out of 44) who consumed sugar and 13 overweight and obese children (out of 52) who did not consume sugar (Table 1). The Chi-squared test showed no significant difference between the proportions of children who consumed sugar and those who did not consume sugar in overweight and obese children ($p = 0.06$).

The group of children that consumed sugar had, on average, significantly higher weight and a significantly longer duration of the T-peak to T-end interval (Table 1).

The biserial coefficient of association between the variable that represents sugar intake and the duration of the T-peak to T-end interval in the group of all children was 0.63. The coefficients of association between the T-peak to T-end interval and other characteristics are given in Table 2. The coefficients of correlation between all other characteristics and the TpTe interval are much smaller.

**Table 2.** Association of TpTe interval with other factors.

| | TpTe |
|---|---|
| Age, years | r = 0.16 |
| Sex | r = 0.19 |
| Height (cm) | r = 0.20 |
| Weight (kg) | r = 0.29 |
| Weight status | r = 0.13 |
| Training hours per week | r = 0.08 |
| Years of training (years) | r = 0.07 |
| Sugar intake | r = 0.63 |

ANOVA did not reveal any association between the type of sport and the duration of the T-peak to T-end interval ($p = 0.915$).

## 4. Discussion

Our study showed an association between the duration of the T-peak to T-end interval, an ECG parameter representing higher vulnerability to ventricular arrhythmias, and sugar intake in young athletes. Our results align with several recent results showing the harmful effects of high sugar intake on the cardiovascular system in children [3,5]. It is indicated that the TpTe parameter, as a potential ECG repolarization predictor, is significantly higher in obese people [16], in patients with benign paroxysmal positional vertigo [17], and in patients with low iron storage without anemia [18]. Participants in the mentioned studies were adults. It has already been demonstrated that it is possible to identify blood sugar levels using ECG by the deep learning classifier [19,20]. One of the parameters used was the TpTe interval [20]. Our study demonstrates that the TpTe interval is connected to a higher sugar intake, and taking into account that sugar intake is also associated with inflammation [7,8], the TpTe interval might show a connection with subclinical inflammation. A higher sugar intake is associated with a longer T-peak to T-end interval, in which there is a higher risk of arrhythmias.

### *4.1. Implemented Measures to Reduce Sugar Intake, Primarily in the EU Countries*

Thirty-six interventions aimed at reducing sugar-sweetened beverage consumption among adolescents were investigated in the systematic review [21], out of which twenty interventions were classified as educational/behavioural, ten were classified as legislative/environmental, and six were classified as a combination of the two approaches.

Regarding food consumption in general, a repository of global data on nutrition and diet-related policy actions was developed by the World Cancer Research Fund International, called the NOURISHING database. It contains information on which governments around the world have implemented systems by which to encourage people to eat healthily [22]. According to this database, many world countries have already implemented measures to reduce sugar consumption in the population [23]. The most frequently implemented measures in Europe were the spreading of information through public awareness, nutritional education, and labels.

A review of systematic reviews [24] synthesized the evidence from systematic reviews published from 2005 to 2017 on interventions aimed at reducing sugar intake. All described studies focused on reducing sugar-sweetened beverages using price changes, interventions to alter the food available within specific environments, and health promotion and education programs. A scoping review [25] was conducted in order to identify the types of measures implemented after 2017, to decrease sugar intake, and to assess their impact. Measures primarily implemented in Europe were the spreading of information through public awareness, nutritional education, and labels.

### *4.2. Public Policies in Serbia*

A cross-sectional study [26] determined the overall prevalence of overweight (23.1%, including obesity) in Serbian primary school children, which was comparable to the relatively high rates reported in some other European countries. Even these results indicated the epidemic of obesity in Serbian children [27]; however, the results of a more recent cross-sectional study [27] were even worse regarding the percentage of obesity in children. In a nationally representative sample containing 3067 6–9-year-old children, the overall prevalence of overweight (including obesity) was 28.9%. In the WHO European region, one child out of three is overweight or obese [28], which is comparable with the present study, where 33% of children were overweight or obese. It is known [28] that overweight and obese children will likely stay obese into adulthood, and thus, develop non-communicable diseases such as diabetes and cardiovascular diseases at a younger age.

Considering these facts, developments in health policies for reducing sugar intake in Serbia would be significant. Nevertheless, there is no information in the NOURISHING database about measures taken in Serbia to mitigate the harmful effects of unhealthy food on the general population. Concerning policies on children's nutrition, two rulebooks were introduced recently on stricter conditions for organizing, achieving, and monitoring the nutrition of students in primary school and preschool institutions [29,30]. Serbia also participates in an EU-funded project, STRENGTH2FOOD: food quality for sustainability, which aimed to provide the EU and its member states with evidence-based recommendations, which will be implemented and verified through innovative pilot actions [31].

### 4.3. Limitations of the Study

In our study, the association between sugar intake and duration of TpTe interval was confirmed. However, it is impossible to claim that sugar intake influences the duration of the TpTe interval, since this kind of conclusion is impossible in cross-sectional studies. Further investigation is needed toward non-athletic children and adults to confirm the association between sugar intake and the duration of TpTe interval in a more general setting.

## 5. Recommendations and Conclusions

Our study determined an association between sugar intake in young athletes and ECG parameters showing vulnerability to arrhythmias. The harm of high sugar intake was already demonstrated in previous studies. Our study determined that the benefit of playing sports cannot compensate for the damage caused by overconsumption of sugar. Therefore, a significant public health target would be to lower sugar intake in children's diets (and, in particular, in the diet of young athletes). Taking into account the information on the habits of using sugar in the diet and the percentage of overweight children [27], it is necessary to regulate interventions and activities that would reduce sugar intake from early childhood. In this sense, synchronizing public health and education policies could have positive effects. Some of the measures that might have been implemented in Serbia have already been implemented in the EU and other countries: nutritional education for children, information through public awareness, labels on the products with high content of sugar, economic tools (taxation, artificial increases in selling prices, and price discounts on healthy food), restricting food advertising, and environmental measures aiming to offer healthy food in public institutions. Aside from these, we propose a specific measure for young athletes. This measure proposes that sports coaches who train children increase their levels of awareness. Since sports coaches usually have considerable authority over trainees, information and nutritional education of sports coaches, who would further educate children about the necessity of reducing sugar intake, would be a reasonable measure.

Aside from the negative effects on human health, sugar production has numerous environmental negative effects, as sugar mills produce wastewater, emissions, and solid waste that impact the environment. On the other hand, the production of sugar has a multiplier effect on employment in developing countries, so it is a very complex problem that needs to be solved together with other general sustainability problems.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study and their parents.

**Data Availability Statement:** The blinded data will be made available from the contact person upon reasonable request.

**Conflicts of Interest:** The authors declare no conflict of interest.

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