Михалюк Євген, Гороховський Єгор, Босенко Анатолій, Хорошуха Михайло. Особливості автономної регуляції серцевої діяльності юних спортсменів із ювенільною ЕКГ

**Анотація.**

Мета роботи – вивчити виникнення ювенільної ЕКГ-ознаки та особливостей автономної регуляції серцевої діяльності у юних спортсменів із цією ознакою ЕКГ.

**Матеріали та методи.** Проведено електрокардіографічне дослідження та реєстрацію варіабельності серцевого ритму (ВСР) у дітей та підлітків обох статей, які займаються різними видами спорту.

Для оцінки стану механізмів нейрогуморальної регуляції серця, діяльності сегментарних і надсегментарних відділів вегетативної нервової системи (ВНС) використовували математичні та спектральні методи аналізу ВСР.

**Висновки.** Юнацька картина ЕКГ у вибірці обстежених юних спортсменів виглядала майже однаково як у хлопців, так і у дівчат. В окремих вікових групах найбільша кількість юних спортсменів мала ювенільні ознаки ЕКГ. Такими ЕКГ-ознаками є неповна блокадою правої ніжки пучка Гіса та синдромом укороченого інтервалу QT. Аналіз ВСР свідчить про тенденцію до переваги парасимпатичних впливів ВНС у хлопчиків і лише у незначній кількості обстежених хлопчиків і дівчаток показники вегетативного тонусу відповідали нормотонії.

**Ключові слова:** юнацька ЕКГ, юні спортсмени, варіабельність серцевого ритму, вікові групи.

Назва журналу: M. Khoroshukha_ISC_FZFVS

**MINISTRY OF EDUCATION**
**ECOLOGICAL UNIVERSITY OF BUCHAREST**
**FACULTATY OF PHYSICAL EDUCATION AND SPORT**

**International Scientific Conference**
"ACTUALITIES AND PERSPECTIVES OF PHYSICAL EDUCATION AND
SPORT SCIENCES"
5$^{th}$ edition

April, 04$^{th}$, 2024
**Romania, Bucharest, Doina Cornea, no. 1G**

FEATURES OF AUTONOMOUS REGULATION OF CARDIAC ACTIVITY IN YOUNG ATHLETES WITH JUVENILE ECG PATTERN

Mykhaliuk Yevhen[1], Horokhovskyi Yehor[2], Bosenko Anatolii[3], Khoroshukha Mykhailo[4]

[1]Department of Physical Rehabilitation, Sports Medicine, Physical Education and Health Zaporizhzhia State Medical University, Ukraine

[2] Department of Physiology, Immunology, and Biochemistry with a Course of Civil Defense and Medicine Zaporizhzhia National University, Ukraine

[3] Department of Biology and Health Protection, The State Institution "South Ukrainian National Pedagogical University named after K. D. Ushynsky", Ukraine

[4]Department of Physical Therapy and Ergotherapy, Borys Grinchenko Kyiv Metropolitan University, Ukraine.

**Abstract.**

The aim of the work is to study the occurrence of juvenile ECG pattern and characteristics of autonomous regulation of cardiac activity in young athletes with this ECG feature.

**Materials and methods.** Electrocardiographic study and recording of heart rate variability (HRV) in children and adolescents of both genders engaged in various sports were carried out. Mathematical and spectral methods of HRV analysis were used to assess the state of mechanisms of neurohumoral regulation of the heart, activity of segmental and suprasegmental parts of the autonomous nervous system (ANS).

**Conclusions.** Juvenile ECG pattern in the sample of examined young athletes was found almost equally in both boys and girls. In certain age groups, the largest number of young athletes with juvenile ECG pattern was registered. This ECG feature was combined with incomplete blockade of the right bundle branch of Gis and shortened QT interval syndrome. The analysis of HRV indicates a tendency to predominance of parasympathetic influences of ANS in boys, and a certain number of examined boys and girls had the indices of vegetative tone corresponding to normotonia.

**Keywords:** juvenile ECG pattern, young athletes, heart rate variability, age groups

## 1.   Introduction.

Nowadays in the world of sports there are big competitions such as Gymnasiade, Youth Olympic Games, etc. in which athletes between 15 and 18 years of age participate. It is known that it takes an average of 6.5-7.5 years of hard training to achieve high results and successful participation in competitions at this level, so most coaches want to make an earlier selection of children in sports sections. Existing age standards for sports activities are based on the passport age, but due to the phenomenon of acceleration, there are cases of discrepancy between the passport age and the biological age, when a child is 1-2 years ahead or behind his or her peers [16]. For example, children from the age of 7 are admitted to the initial training groups of children's and youth sports schools in gymnastics, artistic gymnastics, swimming, figure skating, tennis and table tennis. In such cases, during the initial medical examination, the sports physician encounters features of the ECG of young athletes in the form of a juvenile ECG pattern, better known as the "T-infantile" phenomenon.

"T-infantile" phenomenon is a reflection of epicardial repolarisation of the right ventricle [13]. The "T-infantile" is characterized by the following features: 1) the negative T-wave or the negative phase of the biphasic T wave progressively decreases from lead V1 to lead V4; 2) the peaks of the negative T waves or the peaks of the negative phases of the biphasic T-waves in the right thoracic leads coincide with or slightly precede the peaks of the positive T-waves in the left thoracic leads;

4) the ST segment in the right thoracic leads is on the isoelectric line and does not have an upward convex arc shape.

Sandrucci & Bono [13] found "T-infantile" in 30% of healthy children and adolescents aged up to 14 years, and Shiyan [14] found this phenomenon in 21.7% of children aged 7-9 years and in only 1.5% of children aged 13-15 years. Attisani et al [3] found "T-infantile" in 132 (7.1%) of 1858 adolescents aged 6-18 years, and Basu et al [4] found it in 430 (6.0%) of 7162 adolescents aged 13-16 years.

Migliore et al [10], in a study of 2765 children (1914 males and 851 females) aged between 8 and 18 years (mean age 13.9±2.2 years), found T-wave inversion localized in the right precordial leads in 131 of the subjects studied, i.e. 4.7%. According to their results, the prevalence of "T-infantile" decreased significantly with increasing age (8.4% of children younger than 14 years compared to 1.7% of those older than 14 years, p<0.001). Of 158 children with T-wave inversion, 4 individuals (2.5%) were diagnosed with cardiomyopathy, including arrhythmogenic right ventricular cardiomyopathy in 3 children and hypertrophic cardiomyopathy in 1 child. The authors believe that T-wave inversion is a common ECG abnormality in inherited cardiomyopathies such as hypertrophic cardiomyopathy and arrhythmogenic right ventricular cardiomyopathy, which are the leading causes of sudden cardiac death in young athletes. These cardiomyopathies are genetically determined and show age- related phenotypic expression. As early manifestations of the disease usually occur after puberty, the persistence of T-wave inversion in post-pubertal age raises the problem of differential diagnosis between developing myocardial disease and benign juvenile repolarization type. In this age group, T-wave inversion, localized predominantly in the right precordial leads, was documented in 5.7% of cases, decreased significantly with increasing age and pubertal maturation and, most importantly, reflected the primary cardiomyopathy, such as arrhythmogenic right ventricular cardiomyopathy and hypertrophic cardiomyopathy in 2.5% of cases. These results suggest that T-wave inversion is much less common after full pubertal development than previously thought, and its persistence may indicate myocardial disease at risk of sudden cardiac death. Consequently, the demonstration of post- pubertal persistence of T-wave inversion in athletic children justifies an echocardiographic study that may lead to the presymptomatic detection of early cardiomyopathy.

The incidence of T-wave inversion in the anterior leads V1-V3 varies widely not only in non-athletic children and adolescents, but also in athletes. For example, according to Abramova [2], in young athletes "T-infantile" is observed in 25% of girls aged 11-12 years, and in boys in two age groups: 11–12 years — in 16.6% and 13–14 years — in 12.5%. Calò et al [7], in a study of 2,261 football players aged 8- 18 years, found this phenomenon in 136 (6.0%) players. Abela et al [1] found this phenomenon in 5.0% of Maltese adolescents examined, with an average age of 15 years. McClean et al [9] found "T-infantile" in 418 Arab and 314 African athletes aged 11-18 years, representing 15.8% of the total number of athletes studied.

Analysis of ECGs with similar phenomena performed on young athletes shows that they can develop cardiomyopathy. In these cases, according to Butchenko [6],

the ECG shows the following changes 1) there is no progressive decrease in the negative T-wave or the negative phase of the biphasic T-wave from lead V1 to lead V4, but there is an increase in the negative T-wave or the negative phase of the biphasic T-wave up to lead V3; 2) there is a negative or flat positive T waveform in one of the leads, usually in V3, V4; 3) there is a terminal negative T-waveform; 4) the ST segment is shifted above the isoelectric line and becomes an upwardly curved arc. These signs of cardiomyopathy in young athletes may occur in different combinations.

Skuratova [15] reports that "T-infantile" is characterized by: 1) coincidence (or slight advance) of the peaks of the negative T-wave in the right thoracic leads and the positive T-wave in the left thoracic leads; 2) decrease in the depth of the negative phase of the T-wave from V1 to V4; 3) coincidence of the central depression of the T-wave (at the bicuspid) in the right thoracic leads with the peak of TV5 and TV6; no arc-shaped ST-segment elevation in the thoracic ECG leads. The described ECG changes in young athletes are a normal variant and have nothing in common with the ECG manifestations of cardiomyopathy due to chronic physical overexertion [2, 6]. Papadakis et al [12] studied 1710 adolescent athletes and 400 non-athletic children. There were no significant differences in the overall prevalence of T-wave inversion between athletes and controls. T-wave inversion in leads V1-V3 was mostly limited to the age of the subjects (older than 16 years) in both groups. Only 0.1% of athletes aged 16 years and older showed T-wave inversion outside V2. T-wave inversions in the inferior and/or lateral leads and deep T-wave inversions were rare in athletes (1.5 and 0.8%, respectively) and were associated with a high prevalence of left ventricular hypertrophy or congenital heart disease. Despite intensive further investigation, no athlete was diagnosed with cardiomyopathy.

**The aim of the study** was to quantify the incidence of the juvenile ECG pattern in athletic individuals aged between 6 and 17 years, and to elucidate the role of autonomic regulation in this electrocardiographic phenomenon.

### 2. *Materials and Methods.*

Electrocardiographic recording of heart rate variability were performed in 3720 children and adolescents aged 6–17 years, including 74.6% (n=2774) boys and 25.4% (n=946) girls, involved in various sports. Of the total number of athletes, the "T-infantile" phenomenon was detected in 56 people, or 1.5%, including 40 (1.44%)

boys and 16 (1.69%) girls.

The state of the neurohumoral regulatory mechanisms of the heart, the activity of segmental and suprasegmental divisions of the autonomic nervous system (ANS) were assessed using mathematical and spectral methods of heart rate variability (HRV) analysis [11]. Short (5-minute) recordings were used for HRV analysis [8]. ANS parameters were analyzed using an integral index of HRV, the stress index (SI). According to Bayevskiy [5], the vagotonic state is observed when the SI is less than 50 conventional units (c.u.), the eutonic state — in the range of 51–199 c.u., and the sympathicotonic state — when the SI is more than 200 c.u.

Statistical analysis of the data was performed using Statistica 6.0 (StatSoft Inc.) using parametric methods. Values are expressed as mean (M) ± standard error of the

mean (SE). Differences in values were considered statistically significant at a significance level p<0.05.

### 3. Results and discussion.

There were ten (25%) boys at age 9, eight (20%) at age 10, six (15% each) at ages 8 and 11, four (10%) at age 7, three (7.5%) at age 12, two (5%) at age 6, and one (2.5%) at age 15. There were four (25%) girls at age 11, three (18.8% each) at ages 9 and 12, and one (6.25% each) at ages 7, 8, 10, 13, 16 and 17. Boys were involved in martial arts (karate, taekwondo, jujitsu, kickboxing, hand-to-hand combat) — 22 (55%), sports games (football, hockey, table tennis) — 8 (20%),

horting — 4 (10%), diving — 3 (7.5%), swimming — 2 (5%), fencing — 1 (2.5%). Girls were involved in sports games (basketball, handball, volleyball) — 5 (31.3%), swimming — 5 (31.3%), martial arts (wushu, karate) — 2 (12.5%) and one (6.25%) each in diving, sports aerobics, rhythmic gymnastics and archery.

The highest number of young athletes with this ECG phenomenon was found in boys at the ages of nine and ten years, and in girls at the ages of nine, eleven and twelve years.The sports most commonly engaged in by both boys and girls were predominantly martial arts and athletic games, though in recent times, an earlier initiation into sports is common for all forms of gymnastics (artistic, competitive, aesthetic), figure skating, tennis, swimming, and diving. Some variations in the presence of "T-infantile" in youthful sportspeople, when contrasted with the findings of other researchers, might be attributed to the examination of different sports that the scrutinized athletes partake in, as well as elements that consider the child's gender.

The next stage of our research was to analyze the ECG characteristics of young athletes with the "T-infantile" phenomenon. In boys with "T-infantile" (n=40), normal sinus rhythm was found in 80% (n=32) and right atrial rhythm in 20% (n=8). Regular rhythm was found in 80% (n=32) and sinus respiratory arrhythmia in 20% (n=8). Normal ECG amplitude was recorded in all boys. In the boys with "T-infantile" in 30% (n=12) the electrical axis of the heart was not deviated and was in a semi-vertical position, in 25% (n=10) it was vertical, in 7.5% (n=3) the axis was deviated to the right, in 5% (n=2) it was semi-horizontal and in one (2.5%) the heart axis was deviated to the left. Bradycardia was detected in 15% of the examined athletes (n=6), 42.5% (n=17) had heart rate in the range 61–79 bpm$^{-1}$ and the remaining 42.5% (n=17) had heart rate 80 bpm$^{-1}$ or more. ECG changes were present in 49 cases, i.e. in addition to T-infantile in 5 (10.2%) athletes in combination with incomplete right bundle branch block, in 3 (6.1%) with shortened PQ syndrome and in one (2.0%) with early ventricular repolarization syndrome.

In girls with T-infantile (n=16), normal sinus rhythm was found in 87.5% (n=14) and right atrial rhythm in 12.5% (n=2). Regular rhythm was found in 75% (n=12) and respiratory sinus arrhythmia in 25% (n=4). Normal ECG amplitude was recorded in all girls. In 43.8% (n=7) of the young female athletes the electrical axis of the heart had a semi-vertical position, in 25% (n=4) the electrical axis of the heart was not deviated and had a vertical position and in one (6.25%) the electrical axis of the heart was deviated to the right. Bradycardia was detected in 12.5% (n=2), heart rate in the range of 61-79 bpm$^{-1}$ in 50% (n=8) and in 37.5% (n=6) heart rate was 80 bpm$^{-1}$ or more. ECG changes were observed in 20 cases, i.e., in addition to "T- infantile",

three girls (18.8%) additionally had incomplete right bundle branch block and one (6.3%) had shortened PQ syndrome.

A comparative analysis of HRV indices in boys and girls with the "T-infantile" phenomenon showed that boys, who were younger than girls (9.3±0.27 years vs. 11.1±0.68 years, p=0.02), had a significantly higher D value, reflecting the activity of vagus regulation of heart rate (0.403±0.028 s vs. 0.311±0.025 s, p=0.019). They also showed a tendency to decrease the following indices AMo, a measure of the mobilising influence of the sympathetic arm of the autonomic nervous system (36.321±2.059% vs. 40.20±4.465%, p=0.425), AMo/D, an index of the ratio between sympathetic and parasympathetic activity (122. 80±16.18%/s vs. 167.97±37.58%/s, p=0.269), autonomic rhythm index (ARI), indicating the balance of autonomic regulation of the sinus node (4.363±0.376 $1/s^2$ vs. 5.307±0.761 $1/s^2$, p=0.265), adequacy of regulation processes (ARP) — reflecting the correspondence between the activity of the sympathetic arm of the ANS and the leading level of sinus node function (52.869±3.577 %/s vs. 58.814±8.566 %/s, p=0.517), SI — stress index indicating the degree of centralisation of heart rate control (90.835±12.904 c.u. vs. 127.226±32.763 c.u., p=0.300) and LF/HF-sympatho-vagal index (1.159±0.188 c.u. vs. 1.413±0.282 c.u., p=0.450). The data obtained indicate a trend in the prevalence of parasympathetic influences of the ANS in boys.

T-wave inversion in two adjacent anterior leads (V1-V3) in individuals younger than 16 years of age is associated with electrical right ventricular predominance in infancy, which gradually resolves with T-wave normalization after puberty [1, 3, 4], is more common in females [1, 4], and is statistically more frequent according to [4].

According to Calò et al [7], T-wave inversion is associated with mild cardiac pathology in 4.8% of cases and persists in only 0.2% of cases in 16-year-olds [1], and according to Papadakis [12] in only 0.1% of cases. 1% of cases, and itspersistence after 16 years of age should raise suspicion of underlying cardiac disease, warrant second-level diagnostic evaluation and annual surveillance [3], and be a hallmark of arrhythmogenic cardiomyopathy [4, 7]. Recent international guidelines for interpreting the electrocardiographic pattern in athletes recommend against further evaluation of the juvenile ECG in the absence of symptoms or a significant family history of heart disease [4].

Analysis of the autonomic nervous system tone according to the classification of Bayevskiy [5] showed that there were 16 (40%) boys with vagotonia, 20 (50%) with eutonia and 4 (10%) with sympathicotonia, showing a tendency for eutonia to predominate compared to vagotonia (p=0.549) and sympathicotonia (p=0.140). In girls, there were 5 (31.3%), 8 (50%) and 3 (18.8%) athletes, respectively, indicating a tendency for eutonia to predominate compared to vagotonia (p=0.506) and sympathicotonia (p=0.348), i.e. there were more individuals with eutonia (50% each) in the groups studied, corresponding to an SI value between 51–199 c.u.

## 4. Conclusions

1.The "T-infantile" phenomenon was observed in 1.4% of male and 1.7% of female young athletes aged between 6 and 17 years, showing no significant gender difference (p=0.945).

2.The peak prevalence of the "T-infantile" phenomenon among young athletes was identified in boys of 9 and 10 years old, and girls of 9, 11, and 12 years old.

3.Predominantly, boys engaged in oriental martial arts and sports games, whereas girls were more involved in sports games and swimming.

4.The occurrence of the T-infantile phenomenon in both boys and girls was linked with incomplete right bundle branch block and short QT syndrome.

5.HRV analysis indicated a trend towards parasympathetic ANS influences being more common in boys, and a state of eutonia was identified in 50% of cases for both genders.

*References*

1.      Abela, M., Yamagata, K., Buttigieg, L., Xuereb, S., Bonello, J., Soler, J. F., Camilleri, W., Grech, N., Xuereb, R., Sapiano, K., Abela, E., Callus, A., Farrugia, M., Felice, T., Burg, M., Sammut, M., Xuereb, R. G., & Grech, V. (2023). The juvenile ECG pattern in adolescent athletes and non-athletes in a national cardiac screening program (BEAT-IT). *International journal of cardiology, 371*, 508–515. https://doi.org/10.1016/j.ijcard.2022.09.005

2.      Abramova, V.R. (2006). *Morfofunktsional'nyye osobennosti adaptatsii i uroven' fizicheskoy podgotovlennosti organizma yunykh sportsmenov 11-16 let korennogo naseleniya Respubliki Sakha (Yakutiya)* [Morphofunctional adaptation features and physical fitness level of young athletes aged 11-16 of the indigenous population of the Republic of Sakha (Yakutia] [PhD thesis, Tyumen State University].Attisani G., Faiola F., Luciani U., Bianchi G., Veicstenas A., & Casasco M. (2011). Negative T waves in right precordial leads in pre-adolescent subjects: a personal experience. *Medicina dello Sport, 64*(4), 423-34.

3.      Basu, J., Malhotra, A., Styliandis, V., Miles, H., Parry-Williams, G., Tome, M., Sharma, S., & Papadakis, M. (2018). 71 Prevalence and progression of the juvenile pattern in the electrocardiogram of adolescents. Heart, 104, A63. http://dx.doi.org/10.1136/heartjnl-2018-BCS.71

4.      Bayevskiy, R.M., & Berseneva, A.P. *Otsenka adaptatsionnykh vozmozhnostey organizma i risk razvitiya zabolevaniy* [Assessment of the body's adaptive capacity and risk of disease development]. Moscow: Meditsina.

5.      Butchenko, L.A., Kushakovskiy, M.S., & Zhuravleva, N.B. (1980). *Distrofiya miokarda u sportsmenov* [Myocardial dystrophy in athletes]. Moscow: Meditsina.

6.      Calò, L., Sperandii, F., Martino, A., Guerra, E., Cavarretta, E., Quaranta, F., Ruvo, E.d, Sciarra, L., Parisi, A., Nigro, A., Spataro, A., & Pigozzi, F. (2015). Echocardiographic findings in 2261 peri-pubertal athletes with or without inverted T waves at electrocardiogram. *Heart (British Cardiac Society), 101*(3), 193–200. https://doi.org/10.1136/heartjnl-2014-306110

7.      Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). *Circulation*, *93*(5), 1043–1065.

8.      McClean, G., Riding, N. R., Pieles, G., Sharma, S., Watt, V., Adamuz,

C., Johnson, A., Tramullas, A., George, K. P., Oxborough, D., & Wilson, M. G. (2019). Prevalence and significance of T-wave inversion in Arab and Black paediatric athletes: Should anterior T-wave inversion interpretation be governed by biological or chronological age? *European journal of preventive cardiology, 26*(6), 641–652. https://doi.org/10.1177/2047487318811956

9. Migliore, F., Zorzi, A., Michieli, P., Perazzolo Marra, M., Siciliano, M., Rigato, I., Bauce, B., Basso, C., Toazza, D., Schiavon, M., Iliceto, S., Thiene, G., & Corrado, D. (2012). Prevalence of cardiomyopathy in Italian asymptomatic children with electrocardiographic T-wave inversion at preparticipation screening. *Circulation, 125*(3), 529–538. https://doi.org/10.1161/CIRCULATIONAHA.111.055673

10. Mikhaylov, V.M. (2002). *Variabel'nost' ritma serdtsa: opyt prakticheskogo primeneniya metoda* [Heart rate variability: experience of practical application of the method]. Ivanovo: Ivanovo State Medical Academy.

11. Papadakis, M., Basavarajaiah, S., Rawlins, J., Edwards, C., Makan, J., Firoozi, S., Carby, L., & Sharma, S. (2009). Prevalence and significance of T-wave inversions in predominantly Caucasian adolescent athletes. *European heart journal, 30*(14), 1728–1735. https://doi.org/10.1093/eurheartj/ehp164

12. Sandrucci, M.G., & Bono, G. (1960). *Elettrocardiografia nell'età infantile con elementi di fonocardiografia e balistocardiografia* [Electrocardiography inchildhood with elements of phonocardiography and ballistocardiography]. Torino: Edizioni Minerva Medica.

13. Shiyan, A.V. (2005). *Osobennosti funktsional'nogo sostoyaniya serdechno- sosudistoy sistemy i vegetativnogo statusa u detey i podrostkov* [Features of the functional state of the cardiovascular system and vegetative status in children and adolescents] [PhD thesis, Kuban State University of Physical Culture, Sports and Tourism].

14. Skuratova, N.A. (2016). Sindrom ranney repolyarizatsii zheludochkov u detey i podrostkov: diagnosticheskiy algoritm pri dopuske k fizicheskim nagruzkam [Early Ventricular Repolarization Syndrome in Children and Adolescents: A Diagnostic Algorithm for Physical Exercise Tolerance]. *Problemy zdorov'ya i ekologii*, (4), 96-100.

15. Zhuravleva, A.I., & Grayevskaya, N.D. (1993). *Sportivnaya meditsina i lechebnaya fizkul'tura: rukovodstvo dlya vrachey* [Sports Medicine and Physical Therapy : A Manual for Physicians]. Moscow: Meditsina.