

Occurrence of dystonic-type response to physical stress in soccer players

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Abstract

Purpose: to investigate the occurrence of dystonic type response to physical activity in the form of submaximal PWC₁₇₀ test in soccer players.

Material & Methods: 741 soccer players divided into 3 groups according to their sports qualification were examined. The data of 68 high-class soccer players with "infinite tone" and 69 high-class soccer players without "infinite tone" were compared, 251 advanced soccer players with "infinite tone" with 179 advanced soccer players without "infinite tone", and 69 intermediate soccer players with "infinite tone" with 105 similarly qualified soccer players without "infinite tone". Blood pressure was measured by the Korotkoff method using an aneroid sphygmomanometer (Romed, Netherlands) on the right arm. Three measurements were taken 5 minutes apart, and the lowest reading was used. Physical working capacity was assessed on a bicycle ergometer (Corival, Netherlands).

Results: it was found that physical working capacity didn't differ significantly between athletes with and without "infinite tone", and in the group of advanced athletes was significantly higher in players with "infinite tone". The same number of soccer players with signs of metabolic cardiomyopathy was found with and without "infinite tone" (p=0.916).

Conclusions: dystonic type of reaction of cardiovascular system to physical load in the form of submaximal PWC₁₇₀ test with "infinite tone" is found in 52,4% of examined soccer players, more often in advanced athletes aged 19 (18; 22) years – 64,7%, in comparison with intermediate players aged 16 (15; 17) years – 17,8%, p<0,001, which doesn't confirm the opinion about occurrence of "infinite tone" in adolescents during puberty. The absence of significant differences in most of the studied indicators, in particular, the relative value of physical working capacity and blood pressure at 5 minutes of recovery period, indicates the unrelated appearance of "infinite tone" in soccer players of different sports qualification. The opinion of scientists that the dystonic type of reaction to physical load with "infinite tone" is physiological and the reaction is atypical is confirmed with the recommendation to make corrections in the section "Functional tests" of the national textbook "Physical Rehabilitation. Sports Medicine".

Keywords: soccer players, "infinite tone", PWC₁₇₀ test, physical performance, metabolic cardiomyopathy.

Introduction

In the section "Functional tests with physical load" of the national

textbook "Physical Rehabilitation, Sports Medicine" for students of medical universities, published in 2014, it is reported that there are 5 main types of cardiovascular system reaction to physical load when evaluating the Martinet-Kushelevsky test (test of 20 squats in 30 s). One type of reaction is the dystonic type, in which after 20 squats there is a significant (more than 100%) increase in heart rate, increase in systolic blood pressure (SBP) (over 170-180 mmHg) and decrease in diastolic blood pressure (DBP) down to zero (the phenomenon of "infinite tone" is auscultated). The authors believe that the appearance of this phenomenon indicates excessive lability of the circulatory system due to a drastic disruption of the nervous regulation of the peripheral vascular system. The dystonic type of reaction is recognized as adverse, and the functional state is recognized as poor or low. Such athletes and physical trainers are recommended to take training in a preparatory (in the absence of any contraindications) or special medical group, starting with a sparing-training or sparing motor regimen (Abramov et al., 2014). Taking into account such recommendations it is necessary to exclude athletes with the phenomenon of "infinite tone", which according to some authors (Virus, 1985), as well as according to our data (Mykhalyuk et al., 2022a; Mykhalyuk et al., 2022b), more than 50%, from sports, offering exercises according to the program of therapeutic physical training. However, in practice it looks different. Besides, it is likely that such and similar conclusions are acceptable to everyone, because the interest in this problem among scientists and sports physicians, despite the urgency in the issues of contraindications for sports when this phenomenon is detected, is absent. Moreover, we haven't found any studies describing accidents in athletes with the phenomenon of "infinite tone" or exclusion of athletes from participation in training or competition in the available literature. And yet, it is time to bring some clarity to the question of the causes of the phenomenon of "infinite tone" in physical trainers and athletes, as well as its assessment.

It is known that the phenomenon of "infinite tone" was first identified by Yanovsky in 1911. However, scientific works devoted to its appearance and interpretation appeared much later. Among recent studies, we can highlight the work of Pickering et al. (2005), who believes that this phenomenon has a limited physiological significance and, according to some authors, occurs in children as well as in pregnant women (Glennings et al., 2021; De Mey, 1995; Voors et al., 1979; Shennan et al., 1996). The interest of scientists in this phenomenon is related to the supposed association of an increased blood pressure response in children and adolescents with the risk of cardiovascular disease and mortality (Alvarez-Pitti et al., 2022). This is confirmed by the study (Freedman et al., 2014), in which the authors report the association of the phenomenon of "infinite tone" in children and adolescents with the development of hypertension in

them at the age of 25 years, which is of scientific interest in terms of preventive measures for the development of hypertension.

There are a few reports that focus on the behavior of blood pressure during exercise and specifically during bicycle ergometer testing in young elite athletes (Wuestenfeld et al., 2022; Romanchuk et al., 2023). In adults and athletes, we found no studies on the occurrence of this phenomenon except for a few studies (Virus, 1985; Wilburne, 1945) and our works (Mykhalyuk et al., 2022a; Mykhaliuk et al., 2023).

Many authors (Yushkovska et al., 2023; Sokrut (Ed.), 2019; Abramov et al., 2014; Zubenko, 1959; Kachorovska, 1952; Wilburne, 1945) consider changes in the tone of the peripheral circulatory apparatus as the cause of this phenomenon in athletes; at the same time, there is a paper in which the author reports that the violation of vascular tone in such athletes was not confirmed and suggested a methodological origin of this phenomenon. It is reported that diastolic blood pressure is almost never less than 50 mmHg, and the so-called "infinity tone" phenomenon, which often occurs after the end of short-term intensive exertion, is actually only an auscultatory phenomenon, and in its presence the measurement of real blood pressure never has a zero value, and the dystonic type should be considered an atypical reaction (Romanchuk, 2010; Yushkovska et al., 2023). Abramov et al. (2014) consider the functional state of such athletes as unsatisfactory or low, and the dystonic type of reaction as a pathological type of reaction of the cardiovascular system to physical stress, and suggest to always conduct a more thorough clinical examination of the athlete to exclude hidden pathology.

Most authors consider the duration of the "infinite tone" to be a physiological or favorable reaction not more than 2 minutes (Shakhlina (Ed.), 2019; Sokrut (Ed.), 2019). If the duration of the "infinite tone" is 3 or more minutes and is combined with other unfavorable indices of the functional test (without specifying which ones), it indicates a deterioration of the functional state and is evaluated as an adverse or unsatisfactory reaction (Yushkovska et al., 2023; Shakhlina (Ed.), 2019; Sokrut (Ed.), 2019; Abramov et al., 2014).

Some authors are convinced that the occurrence of the phenomenon of "infinite tone" in the first 10-20 s after the Harvard Step Test, which is known to last 5 minutes, isn't a deviation from the norm. However, the methodology of the Harvard Step Test doesn't include measurement of blood pressure, so it is very problematic to assess this phenomenon without measuring blood pressure.

The Korotkoff sounds heard when measuring blood pressure are caused by the formation of "vortices" (turbulent fluid flow) in the blood flowing in the artery constricted by the cuff. As soon as the lumen of the vessel returns to normal, the blood

flow in it normalizes and the movement becomes laminar. Thus, the occurrence of turbulent blood flow is explained by the discrepancy between the diameter of the vessel and the volume of blood flowing through it. When measuring resting blood pressure, this occurs because the diameter of the vessel is artificially narrowed by the cuff on the shoulder. During exercise, when the volume of blood flow velocity increases sharply, turbulent flow may occur in a normal diameter vessel. Therefore, if you listen to the sound of the arteries in the area of the elbow bend with a phonendoscope, the sound phenomenon will naturally manifest itself at any sufficiently intense load. Thus, the "infinite tone" is a normal phenomenon after physical activity and at the beginning of the recovery period. It is generally accepted that this type of response becomes clinically significant when it is observed after light exercise (20 squats) or persists for more than 2 minutes after the cessation of more intense exercise. The "infinity tone" phenomenon can occur normally in adolescents and young men. It can be heard in athletes after heavy muscular work. In these cases the dystonic type of reaction can be a consequence of fatigue, diseases, vegetative neuroses (Yushkovska et al., 2023).

The question of whether this tone is physiological or a consequence of pathology should be decided on a case-by-case basis and requires a medical examination of the athlete to identify the causes of its occurrence (Abramov et al., 2014).

There is an opinion that the assessment of "infinite tone" should be carried out in each specific case on the basis of a thorough medical examination and pedagogical observations, taking into account all those factors that may cause the occurrence of this phenomenon. In cases where the "infinite tone" is audible only immediately after the physical load and isn't combined with other changes in the body's reaction to the functional test, this phenomenon shouldn't be categorized as a negative shifts, considering it an auscultatory phenomenon.

Thus, the study of literature regarding the causes, frequency of occurrence, age and gender features, type of sport and other cases of dystonic type of reaction to physical activity with the phenomenon of "infinite tone" allows us to state that all sides of this phenomenon have been described, but that the mechanisms haven't been revealed.

The relevance of studying this phenomenon is determined by its theoretical and practical significance in sports medicine. Especially since there are opinions to consider the dystonic type of reaction

unfavorable, and the functional state unsatisfactory or low with recommendations of training in a preparatory or special medical group.

The aim of the work is to determine the causes of the dystonic type of response to dosed physical load in the form of the submaximal PWC₁₇₀ test in soccer players.

Material and methods of research

Participants

A total of 741 soccer players aged 11 to 35 years were examined. All athletes were divided into 3 groups taking into account the level of sports achievements. The first group (high-class athletes) included 137 athletes with the sports qualifications Master of Sports and Master of Sports of International Class; the second group (advanced athletes) – 430 athletes with the sports qualifications Candidate Master of Sports and 1st class athlete; the third group (intermediate athletes) – 174 athletes with the sports qualifications 2nd and 3rd class athlete. Table 1 summarizes the general characteristics of the examined soccer players.

The study was carried out in compliance with the main provisions of the Council of Europe Convention on Human Rights and Biomedicine (04.04.1997), the World Medical Association Declaration of Helsinki on Ethical Principles for Research Involving Human Subjects (2008-2013), and the Ministry of Health of Ukraine Orders No. 690 of 23.09.2009, No. 944 of 14.12.2009, and No. 616 of 03.08.2012. Each participant was informed of their rights and the possibility to withdraw from the study at any time without any explanation.

Procedure

According to the anamnesis, the examined soccer players didn't have exhausting training before the test, they didn't suffer from infectious diseases, and blood pressure was within the age norms. It is known that the most common methods of blood pressure measurement include manual sphygmomanometers and automatic arm blood pressure monitors (Tocci et al., 2022). Automatic monitors using the oscillometric method are quite widespread, but there are a number of questions about their accuracy due to the algorithm of blood pressure measurement (Guzii & Romanchuk, 2021; Ihm et al., 2022). It is also necessary to consider certain specific characteristics of the study group. For example, a number of hemodynamic changes specific to pregnant women require specially validated arm blood pressure monitors (Bello et al.,

Table 1. General characteristics of the examined soccer players (Me(Q1;Q3))

Group	Number of athletes	Age, years	Body height, cm	Body weight, kg
High-class athletes	137	25 (23; 29)	184 (179; 188)	77 (72; 82.4)
Advanced athletes	430	19 (17; 22)	181 (176; 185)	73 (68,275; 78)
Intermediate athletes	174	16 (15; 17)	176,5 (171; 180)	66 (58,625; 72)

Table 2. The values of physical load on a bicycle ergometer, kgm/min (Me (Q1; Q3))

Group	1 st load	2 nd load
High-class athletes	750 (675; 900)	1500 (1350; 1650)
Advanced athletes	675 (600; 750)	1350 (1125; 1500)
Intermediate athletes	525 (450; 607,5)	1050 (825; 1275)

2018). Thus, despite the large number of validated automatic monitors, Murthy et al., 2023, note that there are gaps in the research, especially in relation to specific populations and diseases. As we were unable to find automatic arm blood pressure monitors validated for professional athletes, we used the commonly accepted method of measuring blood pressure according to the Korotkoff method using an aneroid sphygmomanometer (Romed, Netherlands). Blood pressure was measured on the right arm three times with an interval of 5 minutes, using the lowest result (Abramov et al., 2014). Physical working capacity was assessed using a Corival cycle ergometer (Lode, Netherlands) (Mykhalyuk, 2007; Mykhaliuk et al., 2020), measuring heart rate and blood pressure at rest sitting on the cycle ergometer, heart rate and blood pressure after the first and second physical load (Table 2), as well as heart rate and blood pressure at 5 minutes of the recovery period (Mikhalyuk & Gunina, 2017; Mykhalyuk et al., 2022a).

Statistical analysis

Statistical analysis was performed using the Statistica 13.0 (StatSoft, USA, license number JPZ804138212130ARCN10-J). All data were checked for normality using the Shapiro-Wilk test; the null hypothesis that the data have a normal distribution was rejected if the calculated p-value was less than 0.05. The obtained results are presented as the median (1st quartile; 3rd quartile). A two-tailed Mann-Whitney test was used for analysis of independent samples. To determine a statistically significant association between two categorical variables, two-tailed Fisher's exact test was used. Differences between the two subsets of data were considered statistically significant at $p < 0.05$.

Results of the study

After the second physical load "infinite tone" was detected in 388 (52.4%) soccer players. In the first group ($n=137$) there were 68 (49,6%) persons with "infinite tone", in the second group ($n=430$) – 251 (58,4%), and in the third group ($n=174$) – 69 (39,7%) soccer players (Fig. 1). That is, statistically significant prevalence of advanced athletes with "infinite tone" was found in comparison with intermediate athletes ($p < 0.001$).

In accordance with our recommendations on the correct formation of comparison groups (Mykhalyuk, 2015; Mikhalyuk & Gunina, 2017; Mykhaliuk et al., 2022b), in order to establish beyond doubt the origin of "infinite tone" in soccer players, groups of athletes with the same sports qualification and age were formed with the occurrence of "infinite tone" after dosed physical activity in the form of the

submaximal PWC₁₇₀ test and with its absence. For this we compared the data of 68 high-class soccer players with the presence of "infinite tone" and 69 high-class soccer players with the absence of "infinite tone", 251 advanced soccer players with "infinite tone" and 179 advanced soccer players with the absence of "infinite tone", and 69 intermediate soccer players with "infinite tone" with 105 soccer players of similar skill level with the absence of "infinite tone".

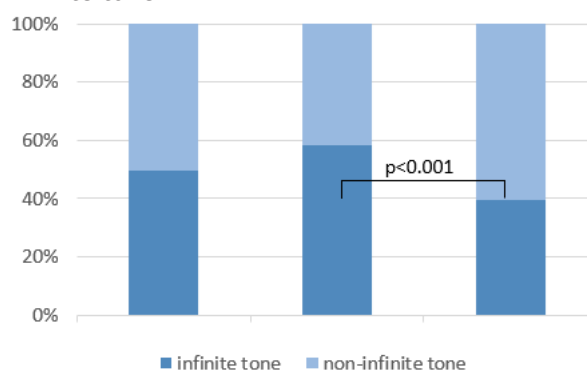


Figure 1. Ratio of athletes with and without the phenomenon of "infinite tone" in athletes with different sports qualifications.

High-class soccer players with and without the "infinite tone" phenomenon, in terms of age (25 (23; 28) years vs. 26 (23; 30) years, $p=0.404$, body length (184 (180; 188) vs. 183 (178; 188) cm, $p=0.529$) and body weight (78 (73; 82) vs. 76 (71; 83) kg, $p=0.736$), as well as baseline heart rate (60 (60; 66) vs. 66 (60; 72) beats·min⁻¹, $p=0.081$), measured directly at rest sitting on a cycle ergometer didn't differ significantly between the groups. They also had significantly higher resting systolic blood pressure (SBP) (125 (120; 130) vs. 120 (110; 130) mmHg, $p=0.014$) and diastolic blood pressure (DBP) (80 (70; 83) vs. 70 (70; 80) mmHg, $p=0.011$), SBP after first (160 (150; 161) vs. 145 (140; 160) mmHg, $p < 0.001$) physical load [n cycle ergometer, as well as SBP at 5 minutes of the recovery period (130 (120; 140) vs. 120 (110; 130) mmHg, $p=0.016$) were within the normal range. One of the important indicators is physical working capacity, the value of which was at a sufficiently high level and had no significant differences in athletes – 20,68 (18.61; 22.16) vs. 20.34 (18.44; 22.67) kgm·min⁻¹·kg⁻¹, $p=0.460$. Thus, almost identical PWC_{170/kg} values cannot indicate the previous exhausting training sessions, phenomena of overtraining or infectious diseases, which could affect the appearance of the phenomenon of "infinite tone" in high-class soccer players.

Similar comparisons in advanced soccer players showed no significant differences in age (19 (18;

22) vs. 19 (17; 21) years, $p=0.524$), body length (180 (176,5; 185) vs. 181 (175,75; 185) cm, $p=0.847$), body weight (73 (68,75; 78) vs. 73 (68; 78) kg, $p=0.450$), baseline SBP (120 (110; 130) vs. 120 (115; 130) mmHg, $p=0.982$) and DBP (80 (70; 80) vs. 80 (70; 80) mmHg, $p=0.748$). After submaximal PWC_{170} test in the compared groups heart rate had no significant differences and was 168 (162; 170) vs. 165 (156; 170) $\text{beats}\cdot\text{min}^{-1}$ ($p=0.075$), respectively, and SBP was significantly higher in athletes with "infinite tone" (170 (160; 180) vs. 170 (150; 180) mmHg, $p<0.001$). At 5 minutes of the recovery period, heart rate (84 (78; 96) vs. 90 (78; 100) $\text{beats}\cdot\text{min}^{-1}$, $p=0.185$) and SBP (130 (120; 140) vs. 120 (120; 136,25) mmHg, $p=0.172$) weren't significantly different, while DBP was significantly lower in subjects with "infinite tone" (80 (70; 80) vs. 80 (70; 90) mmHg, $p=0.019$). It should be noted that the $PWC_{170/\text{kg}}$ value in advanced soccer players with "infinite tone" was significantly higher than in soccer players with its absence (19.72 (17.09; 21.71) vs. 18,85 (15.95; 21.27) $\text{kgm}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ ($p=0.015$).

Thus, the obtained results indicate that at 5 minutes of the recovery period BP in soccer players with "infinite tone" didn't differ significantly from the BP of soccer players who didn't have "infinite tone" and corresponded to the normal values for their age, which indicates the same recovery process. A significantly greater value of relative physical working capacity excludes exhausting physical loads, phenomena of fatigue or overtraining, which could be the cause of the "infinite tone" in advanced soccer players.

Comparison of the studied parameters in intermediate soccer players with and without the "infinite tone" showed no significant differences in age (16 (15; 17) vs. 16 (15; 17) years, $p=0.664$), body length (177 (172; 181) vs. 176 (170; 180) cm, $p=0.252$) and body weight (67 (61; 73) vs. 64 (57; 71) kg, $p=0.135$), baseline heart rate (72 (66; 78) vs. 72 (66; 78) $\text{beats}\cdot\text{min}^{-1}$, $p=0.756$) and resting SBP (120 (110; 125) vs. 120 (110; 120) mmHg, $p=0.105$), but resting DBP was higher in athletes with the "infinite tone" (70 (70; 80) vs. 70 (65; 80) $p=0.040$). SBP after the first exercise on the cycle ergometer, was higher in players with "infinite tone" (150 (140; 160) vs. 140 (130; 150) mmHg, $p<0.001$), and DBP was higher in players without "infinite tone" (60 (50; 60) vs. 60 (60; 70) mmHg, $p=0.022$). It should be noted that SBP at 5 minutes of recovery period was completely normalized and was 120 (105; 120) vs. 120 (110; 120) mmHg, $p=0.611$, respectively. There were also no significant differences between $PWC_{170/\text{kg}}$ values (18.06 (15.27; 19.51) vs. 16.67 (14.11; 20.54) $\text{kgm}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$, $p=0.418$) in athletes with and without the "infinite tone" phenomenon.

The results demonstrate that the studied indicators, including blood pressure at 5 minutes of the recovery period and the relative value of physical working capacity, in intermediate soccer players

with the "infinite tone" phenomenon after the submaximal PWC_{170} test show similar results to those obtained in players with the absence of "infinite tone", which is consistent with the results we obtained in high-class and advanced soccer players.

Thus, since in intermediate, advanced and high-class soccer players with and without the phenomenon of "infinite tone" there were no significant differences in the value of physical working capacity (and in advanced soccer players this index was greater), as well as heart rate and blood pressure at 5 minutes of the recovery period, we can exclude the influence of exhausting physical training loads, overtraining and infectious diseases that could contribute to the occurrence of this phenomenon in the examined athletes.

The reason for choosing the submaximal test PWC_{170} to identify the "infinite tone" is the findings of Viru (1985) showed that during work lasting 3-5 minutes more often than during work lasting 30-60 s (meaning the test of 20 squats in 30 s) the phenomenon of "infinite tone" can appear. According to the majority of literature sources, most authors suggest that the phenomenon of "infinite tone" after physical activity in the form of 20 squats in 30 s should be positively assessed when it is registered for 2 minutes. We suppose that after physical activity of much greater power and duration in the form of submaximal PWC_{170} test requires much longer recovery time, so we chose a 5-minute recovery period, after which all soccer players (100%) showed the absence of "infinite tone", i.e. diastolic blood pressure appeared.

Sources in the scientific sports medicine literature on "infinite tone" indicate that the dystonic type of reaction with "infinite tone" is more common in young athletes, young men and adolescents during puberty (Yushkovska et al., 2023; Sokrut (Ed.), 2019). Viru (1985), specifies the age of appearance of "infinite tone", indicating that at the age of 9-10 years it is absent, in adolescents 11-16 years it occurs from 16 to 30% of cases, and in adults – in 8-58% of cases. Our results based on a study of 3914 athletes, sports veterans and students of both genders showed the occurrence of "infinite tone" in 57.5% of cases (Mykhalyuk et al., 2022a), i.e. we obtained results close to those obtained by Viru (1985). Furthermore, out of 147 soccer players aged 11-16 years, 61 (41.5%) were found to have "infinite tone", and compared to the total number of players examined ($n=741$), their number was 8.2%, which is quite less compared to the results obtained by Viru (Fig. 2).

The data obtained after the submaximal PWC_{170} test in intermediate soccer players, whose age is 16 (15; 17) years, show that among 174 athletes of this group, 69 athletes had "infinite tone", that is, 39.7%, and among 430 advanced athletes (age 19 (17; 22) years), 251 soccer players had "infinite tone", that is, 58.4% ($p<0.001$), i.e. significantly more. Thus, the opinion of most authors about the occurrence of "infinite tone" in children and adoles-

cents during puberty wasn't confirmed in our study, because according to our results, the phenomenon of "infinite tone" is more frequent in advanced soccer players, whose age is 19 (17; 22) years.

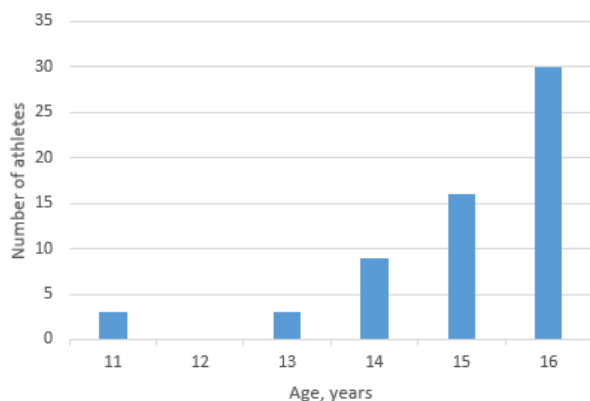


Figure 2. Number of soccer players aged 11-16 years with the "infinite tone" phenomenon.

Discussion

Viru (1985) believes that in more trained individuals "infinite tone" appears more often than in less trained individuals, and against the background of significant fatigue, for example, after a long cross-country race (25-30 km), the probability of occurrence of "infinite tone" decreases. Here again we should focus on sports terminology in the definition of the concepts "well-trained", "more trained", "less trained". It is known that fitness is the state of the organism that determines the level of physical preparedness of the athlete in the competitive period, which is most often at the top of the "sports form" (Mykhalyuk, 2015). Therefore, we can only guess what some scientists put into the concept of "well-trained", "more" or "less trained" athletes, but the author has shown that against the background of significant fatigue the probability of occurrence of this phenomenon in athletes decreases.

The results obtained by Viru (1985) also don't agree with the conclusions that the presence of "infinite tone" indicates any disorders. However, they confirm the opinion that this phenomenon is associated with a significant mobilization of the cardiovascular system function against the background of a high level of its capacity.

Comparison of blood pressure in soccer players with and without "infinite tone" showed a significant prevalence of resting SBP and DBP in high-class athletes with "infinite tone", and resting DBP in intermediate athletes with "infinite tone". There were no differences in resting blood pressure in advanced soccer players and no differences in resting SBP in the intermediate soccer players. Despite these differences in blood pressure in the comparison groups their median values were within the age norms.

The absence of fatigue is also evidenced by the values of relative working capacity, which showed

practically no differences in both high-class and intermediate soccer players with and without "infinite tone", and in the group of advanced players was significantly higher in athletes with "infinite tone". It should be noted that our data are consistent with the results of testing 90 children (mean age 12.3 ± 3.5 years) on a bicycle ergometer, in which the "infinite tone" phenomenon was found in 37%, and higher physical working capacity was found in children with this phenomenon (Glennings et al., 2021).

The obtained relatively high values of physical working capacity, exclude fatigue and indicate a good functional state of soccer players. Despite this, some authors consider it necessary to strictly individualize the assessment of this phenomenon in athletes in a state of good fitness.

Taking into account the fact that some authors consider the appearance of "infinite tone" as a result of overtraining of athletes, we analyzed the combination of "infinite tone" with changes in the terminal part of the ventricular ECG complex, the so-called metabolic cardiomyopathy, which occurs against the background of chronic physical overstrain in athletes (Mykhalyuk, 2007; Mykhalyuk & Syvolap, 2007).

It is known that as a differential diagnosis of the presence of metabolic cardiomyopathy, experts recommend first of all after ECG screening to perform stress testing in the form of submaximal PWC₁₇₀ test (Mykhalyuk, 2007; Abramov et al., 2014; Shapovalova et al., 2008). In our study, 236 (31.9% of the total number of subjects) soccer players with changes in the terminal part of the ventricular complex on ECG were detected at rest. After submaximal PWC₁₇₀ test, most of them had ECG normalization, in 77 (32.6%) these changes remained or worsened, while in 39 (50.7%) athletes they were combined with "infinite tone", and in 38 (49.4%) – "infinite tone" was absent. The performed statistical analysis showed almost the same percentage ratio of the number of soccer players with signs of metabolic cardiomyopathy combined with "infinite tone" and soccer players with similar signs of metabolic cardiomyopathy without the phenomenon of "infinite tone" ($p=0.872$). The obtained results don't allow us to consider the change of the terminal part of the ventricular complex on ECG as a sign of chronic physical overstrain, which is the cause of "infinite tone" in soccer players. It should be noted that out of 39 athletes in whom changes in the ventricular end part of the ventricular complex were combined with "infinite tone", there were 9 (23.1%) from group 1 (high-class athletes), 25 (64.1%) from group 2 (advanced athletes) and 5 (12.8%) from group 3 (intermediate athletes). The results of statistical analysis clearly demonstrate a significant prevalence of advanced soccer players having signs of metabolic cardiomyopathy combined with "infinite tone" compared to high-class ($p=0.003$) and intermediate ($p<0.001$) soccer players.

The results of available studies on the dystonic type with the "infinite tone" phenomenon indicate that athletes experience a significant increase in heart rate after the Martinet-Kuschelewski functional test, with some authors specifying this increase in heart rate by reporting that it exceeds 100% relative to baseline (Sokrut (Ed.), 2019; Abramov et al., 2014; Shapovalova et al., 2008).

Comparison of the results of examination of 25 soccer players, in whom "infinite tone" appeared after the first cycle ergometric load, with the data of 351 soccer players without the phenomenon of "infinite tone", showed the following. The mentioned groups of athletes didn't differ significantly in age (19 (17; 23) vs. 19 (17; 22) years, $p=0.980$), baseline heart rate (66 (60; 72) vs. 68 (60; 78) $\text{beats}\cdot\text{min}^{-1}$, $p=0.664$), resting SBP (120 (105; 138) vs. 120 (110; 130) mmHg, $p=0.237$) and DBP (70 (70; 80) vs. 70 (70; 80) mmHg, $p=0.797$). After the first physical load, there was an 81.8% increase in heart rate in the group with "infinite tone" to 120 (120; 133) $\text{beats}\cdot\text{min}^{-1}$ and a 76.5% increase in heart rate in athletes without "infinite tone", (to 120 (114; 123) $\text{beats}\cdot\text{min}^{-1}$), $p=0.031$. Thus, the heart rate increase in soccer players with the phenomenon of "infinite tone" didn't reach 100%, therefore it is more correct to characterize the dystonic type of reaction to physical load with heart rate increase not exceeding 100%.

Taking into account the fact that the examined soccer players had sports qualifications and considerable training experience, and that the first physical load on a bicycle ergometer in the PWC_{170} test significantly exceeded the load in the test of 20 squats for 30 s, we can assume that the increase in heart rate after the functional test in beginners and intermediate athletes (for whom this test is intended) will be even less, i.e. in the definition of dystonic type it is more correct to speak about some increase in heart rate and SBP with zero value of diastolic pressure with the so-called "infinite tone", i.e. in the definition of the dystonic type it is more correct to speak about some increase in heart rate and SBP with zero value of DBP, the so-called "infinite tone".

After the second physical load, which was significantly higher in athletes with "infinite tone" (1350 (1080; 1500) vs. 1200 (1050; 1500) $\text{kgm}\cdot\text{min}^{-1}$, $p=0.047$), heart rate didn't differ significantly between groups – 170 (166; 170) and 165 (156; 170) $\text{beats}\cdot\text{min}^{-1}$, $p=0.06$, respectively, and SBP was significantly higher in the athletes with "infinite tone" (180 (160; 200) vs. 160 (150; 180) mmHg, $p=0.027$). The relative value of physical working capacity also showed no differences (17,33 (15.37; 19.30) vs. 18,85 (15.71; 21.35) $\text{kg}\cdot\text{m}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ ($p=0.294$)).

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Conclusions

1. Dystonic type of cardiovascular system reaction to physical load in the form of submaximal PWC_{170} test with the phenomenon of "infinite tone" is found in 388 (52.4%) soccer players, more often in advanced soccer players with sports qualification CMS-1st class athlete (251 persons, 64.7%, age 19 (18; 22) years) in comparison with intermediate soccer players with sports qualification 3rd-2nd class athlete (69 persons, 17.8%, $p<0.001$, age 16 (15; 17) years), which doesn't confirm the opinion about the predominant appearance of "infinite tone" in adolescents during puberty.
2. The absence of significant differences in most of the studied indicators, in particular, the relative value of physical working capacity and blood pressure at 5 minutes of the recovery period, indicates the absence of connection of the appearance of "infinite tone" in soccer players differing in sports qualification.
3. Almost equal number of soccer players with and without the phenomenon of "infinite tone", with suspicion metabolic cardiomyopathy, as an indicator of chronic physical overstrain, doesn't allow one to consider it as a cause of the phenomenon.
4. The scientific sports medicine literature evidence of significant heart rate increase (over 100%) after the functional test in athletes with dystonic type of reaction wasn't confirmed in our research, so when describing the dystonic type it is more correct to speak about some heart rate increase after the functional test.
5. The results of the study confirm the opinion that the dystonic type of reaction to physical load with "infinite tone" is physiological, and the reaction is atypical with the recommendation to make corrections in the section of sports medicine devoted to the appearance of the dystonic type of reaction in athletes after the functional test.

Author's contribution

Conceptualization, Y.M.; methodology, Y.M. and A.B.; check, Y.M., O.B.; formal analysis, Y.M. and O.B.; investigation, Y.M.; resources, N.O.; data curation, Y.M. and Y.H.; writing – rough preparation, Y.M.; writing – review and editing, Y.M., Y.H. and A.B.; visualization, N.O.; supervision, Y.M.; project administration, Y.M. All authors have read and agreed with the published version of the manuscript.

Conflict of Interest

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