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OCCURRENCE OF A DYSTONIC RESPONSE TO GRADED PHYSICAL EXERTION IN YOUNG ATHLETES IN TEAM SPORTS

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Abstract
This study is present current data on the phenomenon of "infinite tone" observed after physical activity in young athletes participating in team sports. *Material and methods.* A total of 191 athletes were examined, including 174 football players with a sports qualification of 3rd to 2nd class athlete (mean age 15.82 ± 0.15 years) and 17 handball players with a sports qualification of 2nd class athlete (mean age 14.2 ± 0.29 years). Blood pressure was measured using the Korotkov method with an aneroid sphygmomanometer. Physical performance was assessed on a bicycle ergometer following the established protocol, with measurements of heart rate (HR) and blood pressure (BP) taken at rest while seated on the bicycle ergometer, after the first and second levels of physical exertion, as well as at the 5th minute of the recovery period. *Conclusions*. In young athletes participating in soccerand handball, the phenomenon of "infinite tone" following the submaximal PWC170 test is observed in 39.65% and 35.29% of cases, respectively. The comparison of the relative physical work capacity in soccer and handball players exhibiting the "infinite tone" phenomenon did not reveal statistically significant differences from similar indicators in athletes without this phenomenon (soccer players: 2.88 ± 0.06 W·kg⁻¹ vs. 2.86 ± 0.07 W·kg⁻¹, p = 0.842; handball players: 2.40 ± 0.37 W·kg⁻¹ vs. 2.58 ± 0.15 W·kg⁻¹, p = 0.564). This suggests the absence of signs of physical overstrain in the studied athletes and does not constitute a contraindication for their participation in the training process. The review of scientific literature indicates a limited understanding of the hemodynamic causes of "infinite tone" after graded physical activity, as most studies have focused on the empirical assessment of its detection frequency without considering various factors such as sport, sex, age, health status, and skill level. Consequently, it is difficult to concur with the opinion of some authors who assess the functional state of such athletes as unsatisfactory or low and recommend their training in a special medical group.

Key words: *blood pressure, phases of Korotkoff tones, "infinite tone" phenomenon, physical performance, soccer players, handball players*.

1. Introduction

During the initial medical examination of athletes, particular attention is given to the measurement of resting heart rate (HR) and blood pressure (BP). These measurements are also performed following graded physical exertion: in less skilled athletes, typically using the Martinet-Kushelevsky test (20 squats in 30 seconds), and in high-performance athletes, often after the Rufier test or the submaximal PWC170 test conducted on a bicycle ergometer or treadmill. Some researchers have observed that athletes may exhibit a dystonic type of reaction characterized by the

phenomenon of "infinite tone" following such physical activity (Viru, E.A., 1985; Mykhaliuk, Y. et al., 2022; Abramov V.V. et al., 2014; Mykhaliuk, Y., et al., 2024). Several authors emphasize the necessity of ensuring the proper technical condition of blood pressure measuring devices to prevent inaccuracies (Sharman, J.E. & La Gerche, A, 2015). Currently, blood pressure is primarily measured using manual and automated sphygmomanometers (Tocci, G. et al., 2022). While automatic blood pressure monitors employing the oscillometric method have become widespread, concerns regarding their accuracy due to the underlying measurement algorithms have been raised (Ihm, S.H. et al., 2022).

Despite the availability of numerous validated blood pressure monitors, Murthy S. et al. (2023) highlight existing gaps in their geographical representation, specifically concerning particular target populations, diseases or conditions, and arm circumference. Furthermore, strategies to expedite the adoption of the European Society of Hypertension/International Organization for Standardization's universal standard for the validation of automated blood pressure monitors should be developed.

This relatively detailed discussion of blood pressure measurement methodologies is prompted by reports questioning the very existence of the "infinite tone" phenomenon. Since 1984, the prevailing view has been that true diastolic pressure rarely falls below 50 mm Hg, and the so-called "infinite tone" is, in fact, an auscultatory artifact where the measurement of true blood pressure does not reach zero. Consequently, the dystonic type of response was considered an "atypical" response (Chogovadze, A.V., & Butchenko, L.A., 1984). Moreover, Ivanov S.M. (1970) and Karpman V.L. (1980), considering diastolic pressure to never be zero, did not investigate its origin, regarding this phenomenon as a common finding in the examination of healthy athletes.

Thus, a review of the literature concerning the reaction of athletes to physical activity with the occurrence of the "infinite tone" phenomenon reveals existing challenges in the recording and interpretation of diastolic blood pressure.

The aim of this study is to present current data on the phenomenon of "infinite tone" observed after physical activity in young athletes participating in team sports.

2. Material and Methods

A cycling ergometric study was conducted involving 191 athletes, comprising 174 soccerplayers with a sports qualification of 3rd to 2nd class athlete (mean age 15.82 ± 0.15 years) and 17 handball players with a sports qualification of 2nd class athlete (mean age 14.2 ± 0.29 years).

Considering the absence of validated automatic blood pressure monitors for professional athletes, blood pressure was measured manually according to the Korotkov method using an aneroid sphygmomanometer (Romed, the Netherlands). Measurements were taken on the right arm three times with 5-minute intervals, and the lowest recorded value was used for analysis (Abramov V.V. et al., 2014). Physical performance was assessed using the Corival Lode ergometer following the

established protocol (Mykhaliuk, Y. et al., 2022; Abramov V.V. et al., 2014; Mykhaliuk, Y. et al., 2022). During this assessment, heart rate (HR) and blood pressure (BP) were recorded at the following stages: at rest while seated on the ergometer (resting HR - HR0, resting BP - BP0), after the first level of physical exertion (HR1, BP1), after the second level of physical exertion (HR2, BP2), and at the 5^{th} minute of the recovery period (recovery HR - HR3, recovery BP - BP3).

Statistical analysis of the obtained data was performed using the Statistica 6.0 for Windows software package (StatSoft Inc.) employing parametric statistical methods. Data are presented as mean (M) ± standard error of the mean (m). A significance level of $p \leq 0.05$ was used to determine statistical significance.

3. Results and Discussion

In 75 of the 191 athletes examined (39.26%), a dystonic type of reaction characterized by the "infinite tone" phenomenon was observed on the ergometer following the second level of physical exertion. To facilitate the interpretation of the obtained data, the athletes were categorized by sport and by the presence or absence of this phenomenon.

Age comparisons were conducted between 69 soccerplayers (mean age 15.79 ± 0.21 years) exhibiting the "infinite tone" phenomenon and 105 soccerplayers (mean age 15.84 ± 0.21 years; $p = 0.895$) who did not. Similarly, comparisons were made between 6 handball players (mean age 14.5 ± 0.68 years) with the "infinite tone" phenomenon and 11 handball players (mean age 14.0 ± 0.30 years; $p = 0.566$) without it. No statistically significant age differences were found between the respective groups of athletes.

The proportion of soccerplayers displaying the "infinite tone" phenomenon was 39.65%, while among handball players, it was 35.29%. This difference was not statistically significant. Thus, the occurrence of the "infinite tone" phenomenon in the studied sample of young soccerand handball players did not appear to be dependent on the sport.

Comparison of the relative physical work capacity (PWC170/kg) yielded the following results: in soccer players, 2.88 ± 0.06 $W \cdot kg^{-1}$ versus 2.86 ± 0.07 $W \cdot kg^{-1}$ ($p = 0.842$), and in handball players, 2.40 ± 0.37 $W \cdot kg^{-1}$ versus 2.58 ± 0.15 $W \cdot kg^{-1}$ ($p = 0.564$). No statistically significant differences in relative physical work capacity were observed between the groups with and without the "infinite tone" phenomenon. It is worth noting that the average values of relative physical performance in these young athletes were relatively high in both groups.

It is established that physical performance typically declines in athletes experiencing physical overstrain or overtraining. In our study, we did not find a statistically significant reduction in physical performance in the young athletes exhibiting the "infinite tone" phenomenon, suggesting the absence of signs of physical overstrain or overtraining in this group. Therefore, there is no evidence to suggest that decreased physical performance is a causative factor for this phenomenon.

In our previous research, conducted on a larger cohort of athletes (n = 741), including adult highly skilled soccer players (Master of Sports - International Master of Sports) and second to third category soccer players, we observed a trend towards higher PWC170/kg values in athletes with the "infinite tone" phenomenon. Specifically, among first category and candidate master of sports soccerplayers, the PWC170/kg value was statistically significantly higher in the group with the "infinite tone" phenomenon compared to the group without it (3.18 ± 0.03 $W \cdot kg^{-1}$ vs. 3.05 ± 0.04 $W \cdot kg^{-1}$; $p = 0.016$) (Mykhaliuk, Y. et al., 2024).

In clinical practice, the "infinite tone" phenomenon is relatively uncommon, whereas it is detected considerably more frequently in sports medicine settings following graded physical exertion. According to Viru E.A. (1985), in adolescents aged 11-16 years, this phenomenon was observed in 16-30% of boys and 21-27% of girls after physical activity (20-35 squats, adjusted for age).

In our broader study involving 3914 athletes of both sexes and sports veterans, the "infinite tone" phenomenon was detected in 57.46% of cases (Mykhaliuk, Y. et al., 2022). Among 741 soccerplayers of varying skill levels (from 3rd class athlete to Master of Sports International Class), the prevalence was 52.36%, with the lowest frequency in second to third category athletes (37.7%), followed by Master of Sports and International Master of Sports (49.64%), and the highest in first category and Candidate for Master of Sports soccer players (58.24%) (Mykhaliuk, Y. et al., 2024).

We found no scientific publications by Ukrainian authors reporting complaints or any pre-pathological or pathological conditions in athletes exhibiting the "infinite tone" phenomenon, nor any prospective studies indicating contraindications for sports participation. Conversely, the Ukrainian textbook for higher medical education students in Ukraine, "Physical Rehabilitation, Sports Medicine," states that a dystonic response to physical activity with the "infinite tone" phenomenon is unfavorable, indicating an unsatisfactory or low functional state. It recommends that such athletes or physical education instructors train in a preparatory (in the absence of contraindications) or special medical group with a reduced training or movement regimen (Abramov V.V. et al., 2014).

It is important to note that in our study, the "infinite tone" phenomenon was observed in young athletes after graded physical activity in the form of a submaximal PWC170 test. However, the descriptions in some of the cited works make it unclear regarding the athletes' engagement in sports and the presence or absence of a preceding testing load.

Furthermore, historical disagreements exist concerning the appropriate level of diastolic pressure. These inconsistencies may suggest that the auscultatory method does not always provide a precise measurement of diastolic blood pressure (Moss A.J., 1983).

4. Conclusions

In young athletes participating in soccer and handball, the phenomenon of "infinite tone" following the submaximal PWC170 test is observed in 39.65% and

35.29% of cases, respectively. The comparison of the relative physical work capacity in soccerand handball players exhibiting the "infinite tone" phenomenon did not reveal statistically significant differences from similar indicators in athletes without this phenomenon (soccer players: 2.88 ± 0.06 $W \cdot kg^{-1}$ vs. 2.86 ± 0.07 $W \cdot kg^{-1}$, p = 0.842; handball players: 2.40 ± 0.37 $W \cdot kg^{-1}$ vs. 2.58 ± 0.15 $W \cdot kg^{-1}$, p = 0.564). This suggests the absence of signs of physical overstrain in the studied athletes and does not constitute a contraindication for their participation in the training process. The review of scientific literature indicates a limited understanding of the hemodynamic causes of "infinite tone" after graded physical activity, as most studies have focused on the empirical assessment of its detection frequency without considering various factors such as sport, sex, age, health status, and skill level. Consequently, it is difficult to concur with the opinion of some authors who assess the functional state of such athletes as unsatisfactory or low and recommend their training in a special medical group.

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