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CONTENT

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PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
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Prevalence of the Infinite Tone Phenomenon After the Submaximal PWC170 Test in Adolescent Male Athletes Aged 11–17 Years

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Abstract

Purpose. The infinite tone phenomenon (ITP), defined as the absence of Korotkoff phase V during blood pressure measurement, is observed more frequently in sports medicine following controlled physical exercise than in general clinical practice. Despite reported prevalence rates of up to 57.5% among athletes, its clinical significance and the need for individual clinical assessment remain debated. The aim of this study was to determine the prevalence of ITP following submaximal PWC170 testing in adolescent male athletes aged 11–17 years.

Materials & Methods. A retrospective cross-sectional study was conducted using data from routine medical examinations at the Zaporizhzhya Medical and Sports Dispensary (2021–2022). The study included 471 male athletes aged 11–17 years (soccer, swimming, handball) divided into two groups: ITP group (n=249) and non-ITP group (n=222). Physical work capacity was assessed using the PWC170 submaximal test. HR and BP were measured at rest, after each exercise bout, and during recovery.

Results. ITP was identified in 249 (52.9%) of 471 pubertal male athletes. Athletes exhibiting ITP demonstrated significantly higher absolute (208.3 [171.6; 236.1] vs. 175.7 [142.9; 220.4] W; p<0.001) and relative (3.0 [2.5; 3.3] vs. 2.7 [2.3; 3.2] W/kg; p=0.002) physical work capacity compared with the non-ITP group. ITP prevalence was significantly higher among athletes aged 18–36 years than in adolescents aged 11–17 years (OR=1.35; 95% CI 1.07–1.71; p=0.013). ITP was significantly more frequent among athletes with higher athletic qualification (1st class – MS: 60.7%) compared with lower qualification (3rd–2nd class: 39.8%) (OR=2.34; 95% CI 1.60–3.42; p<0.001).

Conclusions. The dystonic response with ITP following submaximal PWC170 test was identified in 249 (52.9%) of 471 male athletes aged 11–17 years, with significantly higher prevalence among athletes aged 18–36 years, confirming that pubertal age is not a primary factor contributing to ITP occurrence. High physical work capacity in ITP athletes may indicate the absence of overtraining and does not necessitate withdrawal from training. ITP occurrence was associated with higher athletic qualification; the higher prevalence among swimmers was attributable to the greater proportion of highly qualified athletes within this group.

Keywords: infinite tone phenomenon, pubertal period, adolescent male athletes, physical work capacity, athletic qualification.

Introduction

The infinite tone phenomenon (ITP), which involves "spontaneous audibility of the brachial artery without any compression by the sphygmomanometer cuff", was first described by Yanovsky in 1911 [1]. However, scientific works dedicated to the appearance of dystonic response to exercise with the ITP in young individuals or young athletes aged 11–17 years are scarce. One of the earliest reports of ITP in young people appears in Stein [2], citing Wilburne [3], who described a "benign cardiovascular syndrome characterized by transient 'zero' diastolic pressure, normal or elevated systolic pressure, tachycardia, and nervous tension, typically occurring in young individuals". Wilburne believed that this syndrome had a psychosomatic nature and that, although the true diastolic blood pressure (DBP) was likely not zero, it was most likely lower than normal. The reduced DBP in the brachial arteries, according to Wilburne, was likely due to vasodilation of peripheral vessels [3].

Ukrainian authors have reported the appearance of the ITP in children and adolescents during the pre- and pubertal periods [4-6], as well as in individuals who had suffered infectious diseases, overtraining, and strenuous exercise [4-9]. Some studies suggest that the increased vasomotor lability associated with impaired neural regulation, which is common in autonomic nervous system disorders and overtraining, is the cause of this phenomenon in athletes [3-9]. However, other works indicate that DBP is rarely below 50 mm Hg, and the so-called ITP, often observed following brief, intense exercise, is essentially an auscultatory phenomenon. When present, the true DBP measurement never has a zero value, and the dystonic response should be considered an atypical response [10, 11].

Several studies propose that the physiological status of such athletes should be evaluated as unsatisfactory or low, and the dystonic response should be considered a pathological type of cardiovascular system response to exercise [12]. They recommend conducting more thorough clinical examinations to exclude hidden pathology. Specifically, most authors report that for the dystonic response, the heart rate (HR) is markedly increased — more than 100%; there is a substantial increase in systolic blood pressure (SBP), with values sometimes exceeding 200 mm Hg; the DBP drops to zero (infinite tone phenomenon), which lasts for more than two minutes (a duration of the phenomenon within two minutes is considered a variant of a physiological response); and there is a prolonged recovery period. Such a type of response is considered unfavorable and may indicate excessive vasomotor lability, which is attributable to a marked impairment of vascular regulation [4-9, 12-16].

According to Pickering [17], this phenomenon has limited physiological significance. Voors et al. [18] reported its occurrence in children and pregnant women. There are isolated reports from international studies on the behavior of blood pressure during physical exercise in children and adolescents, and even fewer publications on young high-class athletes after exercise testing on a cycle ergometer [19]. Only De Mey [20] and Glenning et al. [21] reported the presence of the ITP during such testing.

The origin of Korotkoff sounds remains a subject of debate for over a century. Korotkoff described three, and later five, phases of the arterial sound: appearance (K1), softening (K2), sharpening (K3), muffling (K4), and disappearance (K5). According to Beevers et al. [22], the first phase consists of clear tapping sounds heard for at least two consecutive beats (systolic blood pressure), the second phase involves the softening of the tapping sounds and the addition of a whistling sound, the third phase returns to the tapping sounds as in the first phase, but with increased sharpness and intensity, the fourth phase involves the sharp muffling of the sounds with the appearance of softness and a blowing quality, and the fifth phase is the complete disappearance of all sounds (diastolic blood pressure). In international sources, it is accepted that if Korotkoff sounds are auscultated to zero pressure in the cuff, i.e., phase K5 is absent, the DBP is taken as the pressure in the cuff at the beginning of phase K4 (muffling of the sound) [23]. Figure 1 schematically illustrates the phases of DBP in athletes exhibiting ITP [24].

According to O'Sullivan et al. [25], among 70 children aged 11 years, 40% exhibited all five phases. Alpert et al. [26] suggest using phase K4 in the absence of phase K5 in children aged 3 to 18 years. Freedman et al. [27] consider the relative importance of phases K4 and K5 as indicators of DBP in children to be uncertain. By ex-

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Vol. 11 No. 3, 2026

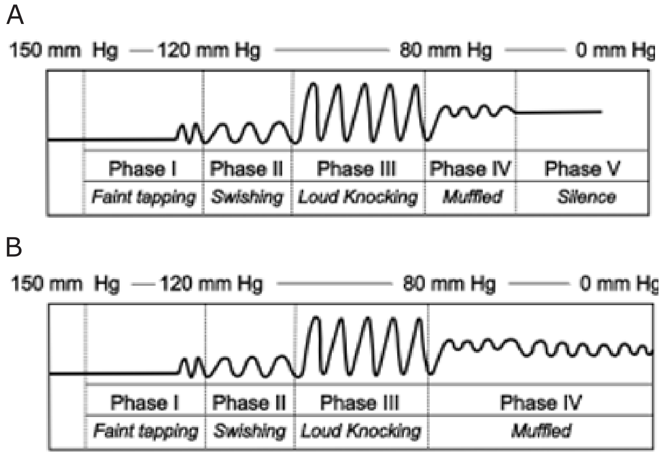

Figure 1. **Graphic representation of Korotkoff sounds during blood pressure measurement (A); when the infinite tone phenomenon is present, Korotkoff phase V (K5) is absent (B).**

amining 11525 adolescents aged 5 to 17 years, they investigated inter-rater differences and the correlation of these two phases with blood pressure levels and hypertension in adulthood. A retrospective analysis was conducted among 2156 children who were re-examined at the age after 25. Phase K4 demonstrated lower inter-rater variability compared to phase K5, and 7% of children had at least one (of six) K5 values equal to 0 mm Hg. The analysis showed that phase K4 was more strongly associated with blood pressure levels and hypertension in adulthood. In a correlation analysis of 1848 participants who did not take antihypertensive medications in adulthood, phase K4 was more strongly correlated with DBP in adulthood than phase K5 ($r=0.22$ vs. 0.17; $P<0.01$). The studies conclude that compared to phase K5, phase K4 exhibits lower inter-rater variability and is more strongly associated with hypertension in adults. Moreover, the development of hypertension in these individuals at the age after 25 represents scientific interest in terms of preventive measures for hypertension.

Exercise testing on a cycle ergometer of 90 children (mean age 12.3±3.5 years) conducted according to Bruce's protocol (R. Bruce, 1971) showed that 29% exhibited phase K4 after exercise, and 37% exhibited phase K5. Notably, physical work capacity was associated with more frequent absence of phase K5 after the test, and reliable DBP values based on K5 could not be obtained in 59% of cases ($p<0.001$) [23].

It is known that the absence of phase K5, referred to as the ITP in clinical medicine, is relatively rare. However, in sports medicine, it is observed more frequently after controlled physical exercise. According to Viru [28], from 8% to 58% of adults and children exhibit this phenomenon, and in the examination of 3914 athletes of both sexes and sports veterans, it was observed in 57.5% of cases [11, 16]. Published data demonstrate the occurrence of this phenomenon in children and adolescents without emphasizing sex, the frequency of its appearance in the age range of puberty. There are reports where the ITP is often observed in the examination of apparently healthy athletes, and the interpretation of the phenomenon solely as a sign of fatigue has not been supported by physiologists. The fact that the ITP can occur in athletes in good physical condition necessitates a strict individual assessment by the physician, thus requiring a re-evaluation of commonly accepted views in sports medicine. Moreover, non-zero DBP values are determined using the oscillometric method [16].

The aim of the study was to determine the prevalence of the infinite tone phenomenon following submaximal PWC170 testing in pubertal male athletes.

Materials and methods

Study design

A retrospective cross-sectional study was conducted using data from medical examinations of athletes undergoing routine health checkups at the Zaporizhzhya Medical and Sports Dispensary, Zaporizhzhia, Ukraine, during 2021-2022. The study was conducted in accordance with the principles of the Declaration of Helsinki (WMA, 2024) and current Ukrainian legislation. All participants or their legal representatives (for individuals under 18 years of age) provided written informed consent for routine medical examination and the use of anonymized data for scientific purposes. Ethical review was waived for this study as it involved retrospective analysis of completely anonymized routine clinical data, with no patient identifiers retained.

Participants

A total of 1231 male athletes aged 11 to 36 years were examined (soccer players — 741, handball players – 220, swimmers – 270). A convenience sample was selected from the overall cohort, comprising 471 adolescents aged 11 to 17 years (median age 16 [15; 17] years), corresponding to the pubertal age range in males (11-17 years) according to [29]. The adolescent athletes participated in handball (n=45), soccer (n=249), swimming (n=177), and had athletic qualifications ranging from 3rd class athlete to Master of Sport (MS). Inclusion criteria included completion of a comprehensive medical examination. Participants were divided into two groups based on the presence or absence of the ITP after 2nd exercise bout: the ITP group (n=249) and the comparison (non-ITP) group (n=222).

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FIZICNA REABILITACIA TA REKREACIJNO-OZDOROVCI TEHNOLOGII
Vol. 11 No. 3, 2026

Assessment of Physical Work Capacity

Physical work capacity was assessed using the PWC170 submaximal test according to Karpman on a Corival (Lode) cycle ergometer. The subject was instructed to perform two successive moderate-intensity exercise bouts on the cycle ergometer Corival (Lode) at a pedal cadence of 60–80 rpm, separated by a 3-minute rest interval. Prior to testing, the handlebar and, particularly, the saddle height of the cycle ergometer were adjusted to match the participant's height. The saddle height was set such that the foot of the subject was slightly flexed at the knee joint in its lower position, thereby neutralizing their body height. Each exercise bout lasted 5 minutes. The 1st exercise bout was selected based on body mass, physical fitness level, and training orientation [16].

The 2nd exercise bout was determined as follows: if, after the initial workload of 50, 67, 83, 100, 117, 133, and 150 W, HR was within the range of 100–109 beats·min^{-1}, then the 2nd workload was set at 157–152, 182–177, 215–210, 248–243, 282–277, 298–293, and 315–310 W. If HR after the initial workload was within the range of 110–119 beats·min^{-1}, then the second workload was set at 132–127, 148–143, 182–177, 215–210, 248–243, 265–260, and 282–277 W [30].

The PWC170 index is calculated using the following formula:

$$PWC170 = W_1 + (W_2 - W_1) \times (170 - f_1) / (f_2 - f_1),$$

PWC170 – the physical work capacity at a heart rate of 170 beats·min^{-1};

W_1 and W_2 – the power output during the first and second exercise bouts, W;

f_1 and f_2 – the HR at the end of the first and second exercise bouts.

Measurement of Heart Rate and Blood Pressure

Heart rate (HR) and blood pressure (BP) were measured at rest while seated on a cycle ergometer (HR_0, BP_0), after the 1st (R_1, BP_1) and 2nd (R_2, BP_2) exercise bouts, as well as during the 5-minute recovery period (HR_3, BP_3). At the end of each exercise bout, heart rate was measured by auscultation over 30 seconds. The resulting heart rate values were doubled to obtain HR per minute (beats·min^{-1}). BP was measured using an aneroid sphygmomanometer (Romed, Netherlands) on the right arm while seated after 5 minutes of rest. The cuff size was selected based on individual arm circumference measured at mid-bicep: a paediatric cuff (9×18 cm) for arm circumference<22 cm, a small adult cuff (12×22 cm) for 22–26 cm, a standard adult cuff (16×30 cm) for 27–34 cm, and a large adult cuff (16×36 cm) for 35–44 cm, in accordance with AHA Council on High Blood Pressure Research recommendations [31]. The procedure involved palpating the brachial artery to position the cuff correctly, followed by inflating the cuff to 20–30 mmHg above the level at which the radial pulse disappeared. Deflation of the cuff occurred at a rate of 2–3 mmHg per second. BP was measured three times, with the lowest reading used for analysis [5]. All BP measurements were performed by the same physician, thus excluding inter-rater variability.

Statistical Analysis

Statistical analysis was performed using R (version 4.5.3; R Core Team, Vienna, Austria). The normality of the distribution of quantitative variables was assessed using the Shapiro–Wilk test separately for each group. As the assumption of normality was not met for the majority of variables, data are presented as median, 1st, and 3rd quartile (Me [Q1; Q3]). Between-group comparisons of quantitative variables were performed using the Mann–Whitney U test. The rank-biserial correlation coefficient (r) was used as a measure of effect size for the Mann-Whitney U test; values of $r<0.3$, 0.3–0.5, and >0.5 were interpreted as small, medium, and large effects, respectively.

The association between the ITP and categorical variables was assessed using Fisher's exact test. For two-group comparisons, a standard 2×2 Fisher's exact test was applied, with results reported as odds ratio (OR) with 95% confidence interval (CI). For multi-group comparisons, Fisher's exact test for r×c contingency tables was applied with Monte Carlo simulation (B=10000 permutations) to obtain p-values. Pairwise post-hoc comparisons were performed using Fisher's exact test with Bonferroni correction for multiple comparisons.

To assess whether the ITP was equally distributed within each age subgroup, an exact binomial test was applied (H_0: $p_0=0.5$). To account for multiple comparisons across age subgroups, the Bonferroni correction was applied. Results for categorical variables are expressed as absolute numbers and percentages. Differences were considered statistically significant at $p<0.05$.

Results

Among the 471 adolescents aged 11–17 years, 249 (52.9%, 95% CI [48.4%; 57.4%]) athletes exhibited a dystonic response with the ITP to graded physical exercise during the submaximal PWC170 test, whereas 222 (47.1%) did not exhibit this phenomenon (exact binomial test, p=0.209), indicating no statistically significant difference from an equal distribution.

Adolescents exhibiting the ITP demonstrated a marginally higher age (16.0 [15.0; 17.0] vs. 16.0 [14.0; 17.0] years, p=0.018; rank-biserial r=0.122), greater body height (179.0 [173.0; 183.0] vs. 175.5 [168.2; 181.0] cm, p<0.001), and greater body mass (68.0 [63.0; 75.0] vs. 66.0 [60.0; 72.8] kg, p=0.004) compared to those without the ITP.

Resting HR was significantly different between the ITP and non-ITP groups (72.0 [60.0; 78.0] vs. 72.0 [66.0; 78.0] beats·min^{-1}, p=0.017), although the effect size was small (rank-biserial r=0.125). The difference was driven primarily by a lower first quartile in the ITP group (Q1=60 vs. 66 bpm), suggesting a higher proportion of athletes with lower resting HR among those exhibiting the ITP. SBP (120.0 [110.0; 130.0] vs. 120.0 [110.0; 120.0] mm Hg, p=0.164) and DBP (75.0 [70.0; 80.0] vs. 75.0 [70.0; 80.0] mm Hg, p=0.444) measured while seated on a cycle ergometer showed no statistically significant differences between the two groups.

Average power output during the 1st and 2nd exercise bouts of the cycle ergometer test was significantly higher in athletes with ITP — specifically, 98.0 [85.7; 122.5] vs. 85.7 [73.5; 98.0] W (p<0.001) and 208.2 [166.6; 232.7] vs. 171.5 [134.7; 196.0] W (p<0.001), respectively. Significantly higher HR (170.0 [162.0; 170.0] vs. 165.5 [160.0; 170.0] beats·min^{-1}, p<0.001) and SBP (170.0 [150.0; 180.0] vs. 160.0 [140.0; 170.0] mm Hg, p<0.001) in athletes with ITP were explained by the greater power output during the 2nd exercise bout.

However, by the 5th minute of recovery, no significant between-group differences were observed for HR (90.0 [84.0; 102.0] vs. 90.0 [84.0; 99.5] beats·min^{-1}, p=0.407) or DBP (70.0 [60.0; 80.0] vs. 70.0 [60.0; 80.0] mm Hg, p=0.912) in either the ITP or comparison group. A statistically significant difference in SBP was observed between the groups at the 5th minute of recovery (120.0 [110.0; 130.0] vs. 120.0 [110.0; 125.0] mm Hg, p=0.017), although the effect size was small (rank-biserial r=0.144).Absolute physical capacity (PWC170) was significantly higher in athletes with the ITP: 208.3 [171.6; 236.1] vs. 175.7 [142.9; 220.4] W (p<0.001). Relative physical capacity (PWC170/kg) was also significantly higher in this group: 3.0 [2.5; 3.3] vs. 2.7 [2.3; 3.2] W/kg (p=0.002).

Comparison of the frequency of the ITP in adolescents aged 11–17 years (Figure 2) was performed using the exact binomial test (H_0: equal proportions, p_0=0.5); a Bonferroni correction was applied for multiple comparisons (α=0.007). At age 11, the ratio was 3 vs 2 (p=1.000); at age 12, it was 2 vs 4 (p=0.688); at age 14, it was 27 vs 26 (p=1.000); at age 15, it was 45 vs 38 (p=0.510); at age 16, it was 73 vs 55 (p=0.133); and at age 17, it was 92 vs 71 (p=0.117), indicating that the number of athletes with and without the ITP did not differ significantly. The exception was the group of 13-year-olds, where the ITP was significantly less frequent: 7 vs 26 (p=0.001).

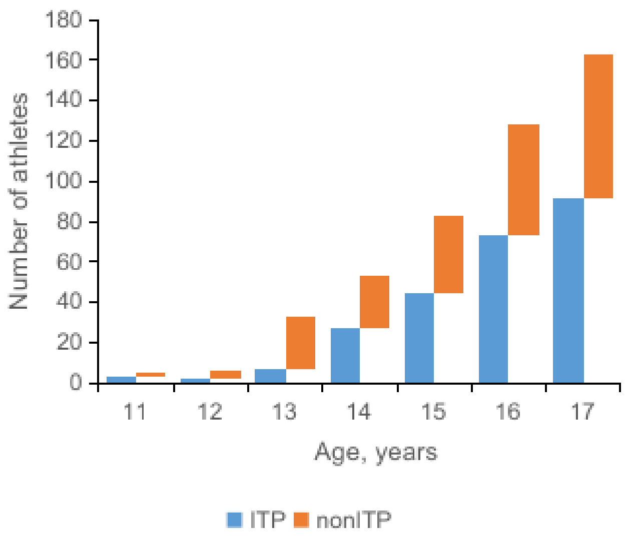

Figure 2. Number of athletes aged 11–17 years with and without ITP.

Figure 2 illustrates a trend toward an increased incidence of the ITP with advancing age. To test the hypothesis that pubertal age is not a primary factor contributing to the occurrence of this phenomenon, the frequency of the ITP was compared between adolescents aged 11–17 years and adult athletes aged 18–36 years. Among 760 athletes aged 18–36 years (handball and soccer players, and swimmers), the ITP was identified in 458 cases (60.3%). Comparison of the frequency between the groups aged 11–17 years (249 out of 471; 52.9%) and 18–36 years (458 out of 760; 60.3%), using Fisher's exact test, showed a statistically significantly higher frequency in the older group (OR=1.35; 95% CI 1.07–1.71; p=0.013). Thus, the data suggest that ITP is not more prevalent during the pubertal period; on the contrary, its prevalence was significantly higher in adult athletes, indicating that pubertal age is not a primary contributing factor.

When analyzing the distribution of the phenomenon among athletes aged 18–36 years (Figure 3) using the exact binomial test (H_0: p_0=0.5) with Bonferroni correction applied to account for multiple comparisons (k=19; $α_{adj}$=0.0026), no statistically significant differences were found between the number of athletes with and without the ITP in any age group. The highest proportions of the phenomenon were observed at ages 18 (102 out of 165; 61.8%), 20 (59 out of 91; 64.8%), and 19 (68 out of 112; 60.7%). In smaller

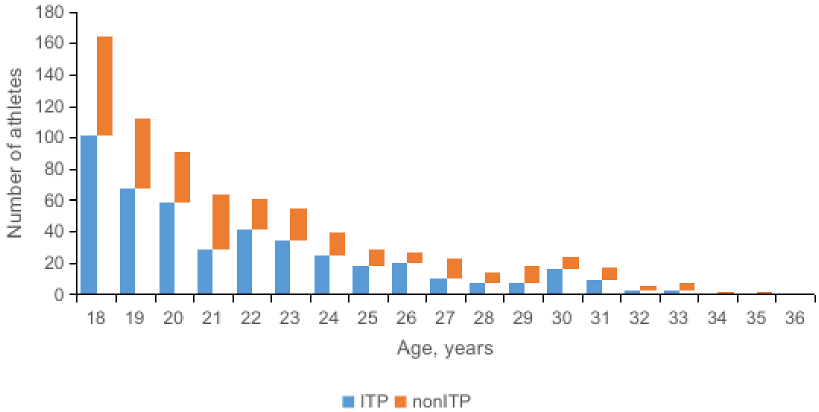

Figure 3. Number of athletes aged 16–36 years with and without ITP.

groups – age 22 (42 out of 61; 68.9%) and age 26 (20 out of 27; 74.1%) – the proportions were also notably higher, but after Bonferroni correction the differences remained non-significant ($p=0.004$ and $p=0.019$, respectively; threshold $p<0.003$).

Comparison of the frequency of the ITP according to athletic qualification in adolescents (11–17 years, n=471) revealed the following results. Among athletes with low qualification (3rd–2nd class, n=176), the ITP was identified in 70 cases (39.8%), whereas among athletes with high qualification (1st class – MS, n=295), it was identified in 179 cases (60.7%). The difference was statistically significant (Fisher's exact test: OR=2.34; 95% CI 1.60–3.42; $p<0.001$): the odds of having the ITP were more than twice as high in highly qualified athletes compared to those with low qualification. Detailed analysis by qualification revealed a trend toward increasing frequency of the phenomenon with higher qualification: 3rd class – 35.2% (19 out of 54), 2nd class – 41.8% (51 out of 122), 1st class – 56.9% (95 out of 167), Candidate Master of Sports (CMS) – 65.6% (59 out of 90), and MS – 65.8% (25 out of 38). This association was confirmed by Fisher's exact test for r×c tables ($p<0.001$).

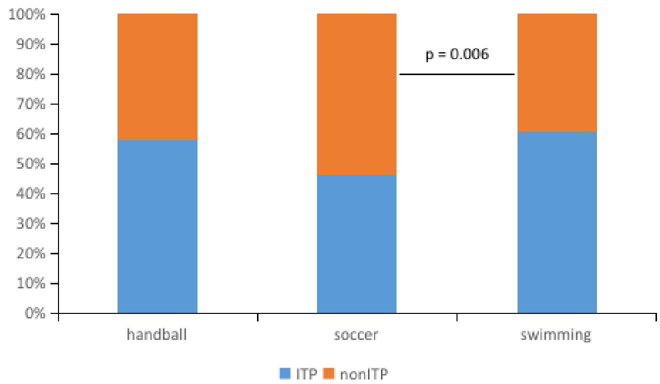

Figure 4. Frequency of the infinite tone phenomenon (ITP) by sports specialization (%). Fisher's exact test: $p=0.015$; post-hoc pairwise comparison: soccer vs swimming, $p=0.006$ (Bonferroni correction).

The potential influence of sports specialization on the occurrence of the ITP was assessed using Fisher's exact test for r×c tables. As illustrated in Figure 4, among 45 handball players, the ITP was identified in 26 cases (57.8%); among 249 soccer players, in 116 cases (46.6%); and among 177 swimmers, in 107 cases (60.5%). The overall Fisher's exact test revealed a statistically significant difference between sports ($p=0.015$). Pairwise comparisons with Bonferroni correction ($\alpha=0.017$) identified a significant difference between soccer and swimming (OR=0.571; 95% CI 0.386–0.843; $p=0.006$), indicating that soccer players had significantly lower odds of having the ITP compared to swimmers. No significant differences were found between handball and soccer (OR=1.569; 95% CI 0.826–2.981; $p=0.196$) or between handball and swimming (OR=0.895; 95% CI 0.461–1.739; $p=0.737$).

However, this difference is likely attributable to the markedly different qualification structure across sports — the proportion of highly qualified athletes among swimmers (88.1%) was significantly higher compared to soccer players (44.6%; $p<0.001$) and handball players (62.2%; $p<0.001$) — suggesting that athletic qualification, rather than sports specialization per se, may be the primary factor underlying the observed sport-specific variation in ITP prevalence (Table 1).

Table 1. ITP prevalence and qualification structure by sport

Sport	n	ITP (%)	Low qualification: 3rd – 2nd class (%)	High qualification: 1st class – MS (%)
Soccer	249	46.6%	55.4%	44.6%
Handball	45	57.8%	37.8%	62.2%
Swimming	177	60.5%	11.9%	88.1%

Collectively, the data suggest that the occurrence of the ITP in adolescents aged 11–17 years does not depend on age and is primarily associated with athletic qualification, with highly qualified athletes showing more than twice the odds of having the ITP compared to those with lower qualification (OR=2.34; 95% CI 1.60–3.42; p<0.001). The apparent sport-specific difference in ITP prevalence likely reflects the confounding effect of qualification structure rather than an independent influence of sports specialization.

Discussion

Sports physiologists have shown that the ITP occurs during intense muscle activity in elite athletes with hearts possessing high contractility. This interesting phenomenon should be considered physiological, resulting from a large stroke volume, elevated peak SBP, and reflex vasodilation. The dystonic response associated with ITP is frequently observed in adolescents and young men during puberty (i.e., the pre- and pubertal periods) [4-6], but is very rarely found in middle-aged and elderly individuals. It is important to note that none of the studies provide data on the frequency of this phenomenon among athletes aged 11–17 years, the types of sports they engage in, or its distribution between boys and girls, except for Viru [28]. Following an exercise test consisting of 20–35 squats (depending on age), she found the phenomenon in 16% of boys aged 11–12 years, 26% of those aged 13–14 years, and 30% of those aged 15–16 years. She further demonstrated that among older athletes, ITP was more frequently observed during a 3– to 5–minute cycle ergometer test than during a 30– to 60–second exercise test (the Martine-Kushelevsky test) [28].

Based on these findings, it can be assumed that when a sports physician administers the Martine-Kushelevsky test to children and adolescents, the dystonic response characterized by ITP is observed less frequently, owing to the lower exercise intensity compared with submaximal PWC170 cycle ergometer test. In our previous study involving 285 athletes of both sexes aged 11–16 years, the dystonic response with the ITP was found in 58.2% after the submaximal PWC170 test [32]. Regarding international literature on changes in BP in young athletes during physical exercise for functional assessment, Wuestenfeld et al. [19] report that currently only a few studies focus on the BP response to physical exercise in children and adolescents, and even fewer involve testing high-level young athletes on a cycle ergometer. In this regard, Wilburne [3] observed transient "zero" DBP in young individuals, though the type of physical exertion was not specified. Previous studies justifiably emphasize that studying the correlation between elevated BP following exercise testing and potential cardiovascular pathology in children and adolescents is paramount, as this non-invasive procedure yields additional information on cardiovascular risk profiles [23, 25].

According to Alvarez-Pitti et al. [33], exercise stress testing can detect elevated BP responses in children and adolescents; consequently, it is suitable for widespread use in athlete assessment. Several reports indicate that interpreting BP values during physical exercise in childhood and adolescence requires age– and sex–specific reference ranges, and they emphasize the need for further research due to elevated BP reactivity, the risk of developing cardiovascular disease, and increased mortality in later life.

A large cohort study (n=739) established percentiles for BP during cycle ergometer exercise testing in young athletes aged 10–20 years (mean age: 15.8 years; males: 442, females: 297) from various sports. These data allow for more precise evaluation of BP regulation in young athletes at different ages and sexes [19]. It should be noted that a sports medicine physician may encounter the ITP during exercise testing in young athletes; in Western literature, this phenomenon is more commonly described as the absence of Korotkoff phase V [2, 27]. In such cases, it is crucial to determine whether this phenomenon may indicate underlying cardiovascular pathology, as this will dictate whether the athlete should continue sports training and competition. According to most authors [4, 7, 8], one cause of the dystonic BP response characterized by ITP is a recent infectious illness (most often viral respiratory infection). In our cohort, anamnestic data, physical examinations by specialists, and resting 12-lead ECGs excluded this etiology and confirmed the absence of contraindications for exercise ECG testing.

Confirming the association between the emergence of this phenomenon and previous infectious diseases, previous studies consider that a dystonic response to physical exercise accompanied by the ITP is unfavorable, indicating an unsatisfactory or low functional status. Such athletes are recommended to engage in preparatory (provided there are no contraindications) or special medical groups training under gentle training regimens [5]. When ITP occurs in athletes, Klapchuk et al. [13] suggest adjusting training loads; however, no specific implementation guidelines are provided.

Given such recommendations, and considering that ITP prevalence ranges from 16% to 30% among adolescents aged 11–16 years [28], 57.5% among 3914 athletes across 13 sports [11, 16], 52.4% among 741 soccer players [16, 34], and 52.9% in the present study, affecting over half of the athletes, these individuals should be withdrawn from training and competition and offered a therapeutic exercise program. This issue has received limited attention among Ukrainian scientists and sports medicine physicians, despite its clinical relevance regarding restrictions and contraindications for sports participation following ITP detection. Furthermore, no scientific works describing accidents involving athletes with the ITP or their exclusion from training and competitive processes have been found in the literature. It should be noted that the causes of this phenomenon described by Ukrainian authors are primarily based on assumptions regarding the development of cardiovascular pathology, without reporting actual consequences.

Notably, Ukrainian scientific literature frequently reports a dystonic response to exercise accompanied by the ITP appearing after a load of 20 squats in 30 seconds, i.e., following the Martine-Kushelevsky test. Viru [28] demonstrated that this phenomenon occurred more frequently during high-intensity exercise on a cycle ergometer lasting 3–5 minutes compared to shorter durations (30–60 s), which provided the basis for testing athletes using the submaximal PWC170 test protocol. This protocol involves two exercise bouts on a cycle ergometer, each lasting 5 minutes. In the available scientific literature, only a few studies have reported the occurrence of ITP in adolescents during exercise testing, including Viru [28], Duff et al. [23], and O'Sullivan et al. [25]. While Viru [28] and O'Sullivan et al. [25] used a cycle ergometer for exercise testing, Duff et al. [23] used a treadmill with two protocols (original and modified Bruce protocol), which are recommended for clinical assessment of physical work capacity in children.

Previously, we demonstrated that among soccer players with higher athletic qualifications 1st class–CMS (n=251, 64.7%; mean age 20.1±0.22 years), who were older than those with the athletic qualification 3rd–2nd class (n=69, 17.8%; mean age 15.8±0.21 years, $p<0.001$), the ITP was observed more frequently. Therefore, it is not appropriate to claim that ITP predominantly appears in adolescents during puberty. Furthermore, we noted that the relative physical work capacity of soccer players with athletic qualification 1st class–CMS exhibiting the ITP was significantly higher than in athletes of the same qualification ranks without this phenomenon (3.188±0.036 vs 3.050±0.045 W·kg^{-1}, $p=0.016$) [34].

Freedman et al. [27] reported valuable data examining inter-rater differences between Korotkoff phases IV and V and their association with BP levels and hypertension in adulthood, based on a sample of 11525 children and adolescents aged 5–17 years. The analysis included 2156 individuals who were re-examined at after age 25; among them, 401 adults were diagnosed with hypertension based on either a report of antihypertensive medication use, or SBP ≥ 140 mm Hg, or DBP ≥ 90 mm Hg. Thus, the prevalence of arterial hypertension in this cohort was 18.6%. Scientific literature data, without emphasizing the presence or absence of the ITP, may indicate that in the age group of 18–39 years, arterial hypertension is observed in 22.4% [35]. According to Fryar et al. [36], prevalence was 23.4% for both men and women combined. In contrast, Hinton et al. [37] reported BP data for adults aged 20–29 years: 12.7% in men and 7.4% in women, increasing to 18.4% and 12.6%, respectively, at ages 30–39 years. Among urban residents of India aged 18–35 years, the prevalence of hypertension was 24.8% (28.3% among men and 20.4% among women) [38]. Thus, data from these studies suggest that within the age range cited by Freedman et al. [27], arterial hypertension occurs even slightly more frequently than in the 18.6% observed in their cohort. Therefore, there is no basis for linking the presence of the ITP in children and adolescents aged 5–17 years to the subsequent development of hypertensive disease beyond age 25.

It is of particular interest to determine which exercise bout preceded ITP occurrence in the examined children and adolescents, as well as their sex, given that significant differences were reported between males and females in the aforementioned studies. The results obtained suggest that the hypothesis proposed by existing evidence may indicate the cause of the ITP in young athletes is correct for the pre– and pubertal periods. However, compared with athletes without this phenomenon, the differences were not statistically significant; therefore, there is no basis to consider the pubertal period as the primary cause of this phenomenon's appearance. Viru [28] also concluded that the ITP is associated with "considerable mobilization of cardiovascular system function and its frequent occurrence against a background of high functional capacity of this system". Thus, the dystonic response characterized by ITP does indeed occur following graded submaximal PWC170 cycle ergometer testing in pubertal male athletes aged 11–17 years engaged in soccer, swimming, and handball. However, we do not consider pubertal age (10–17 years) to be the primary factor contributing to ITP occurrence, but rather view the dystonic response as an atypical response that does not appear to represent a health risk for athletes [16].

Conclusions

1. The dystonic response with ITP following the submaximal PWC170 test was identified in 249 (52.9%) of 471 pubertal male athletes and was absent in 222 (47.1%), with no significant

difference from an equal distribution (p=0.209), suggesting that age 11–17 years is not the primary factor contributing to ITP occurrence.

2. Among 760 male athletes aged 18–36 years, ITP was observed in 458 individuals (60.3%), a significantly higher prevalence than in adolescents aged 11–17 years (60.3% vs. 52.9%, p=0.013), providing direct evidence that pubertal age does not appear to represent a primary factor contributing to ITP occurrence.

3. High absolute and relative physical work capacity in athletes aged 11–17 years exhibiting ITP, compared with their age-matched peers without ITP, may indicate the absence of overtraining or physical overexertion and does not necessitate withdrawal from the training process.

4. The dystonic response with ITP in pubertal male athletes aged 11–17 years occurs significantly more frequently among individuals with higher athletic qualification. The observed higher prevalence of the ITP among swimmers compared to soccer players appears to reflect differences in qualification structure across sports rather than an independent effect of sports specialization.

5. Analysis of the available literature reveals that the hemodynamic mechanisms underlying ITP occurrence following graded exercise testing in athletes remain poorly understood, owing to a lack of experimental evidence, with most researchers relying solely on empirical observations of its frequency. Consequently, it is difficult to concur with the views of certain authors who characterize the physiological status of such athletes as unsatisfactory or poor and recommend their referral to a therapeutic exercise program.

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Author Contributions

Yevhen Mykhaliuk: Conceptualization, Methodology, Investigation; **Yehor Horokhovskyi:** Software, Data curation; **Anatolii Bosenko:** Writing — Original Draft Preparation; **Mykhailo Khoroshukha:** Supervision, Validation; **Vira Bazylchuk:** Visualization, Writing — Reviewing and Editing. All authors have read and agreed with the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki (WMA, 2024) and current Ukrainian legislation. All participants or their legal representatives (for individuals under 18 years of age) provided written informed consent for routine medical examination and the use of anonymized data for scientific purposes. Ethical review was waived for this study as it involved retrospective analysis of completely anonymized routine clinical data, with no patient identifiers retained.

Data Availability

No information.

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References

1. Yanovskyi MV. Anomalii yavlenii Korotkova v sviazi s voprosom o ritmicheskikh sokrashcheniiakh sosudistoi stenki [Anomalies of Korotkoff phenomena in relation to the question of rhythmic contractions of the vascular wall]. Izv Voen-Med Akad. 1911;22(1):20–5.
2. Stein I. Transient "0" diastolic blood pressure (indirect) in the upper extremities. Ann Intern Med. 1949;30(3):615–8. https://doi.org/10.7326/0003-4819-30-3-615
3. Wilburne M. Transient "0" diastolic brachial pressure (indirect), associated with normal or elevated popliteal pressure, tachycardia, and nervous tension. Am Heart J. 1945;30(4):381–9. https://doi.org/10.1016/0002-8703(45)90303-6
4. Yushkovska OH, Plakida OL, Filonenko OV, Semenenko OV, Shakhnazarian KE. Osnovy sportyvnoi medytsyny [Fundamentals of sports medicine]. Odesa; 2023. 64 p.
5. Abramov VV, Klapchuk VV, Nekhanevych OB, Dziak HV, Smyrnova OL, Krynytskyi SS, et al. Fizychna reabilitatsiia, sportyvna medytsyna [Physical rehabilitation, sports medicine]. Dnipropetrovsk: Zhurfond; 2014. 456 p.
6. Sokrut VM, editor. Fizychna, reabilitatsiina ta sportyvna medytsyna [Physical, rehabilitative and sports medicine]. Kramatorsk: Kashtan; 2019. 480 p.
7. Zubenko OK. Dyspanseryzatsiia sportsmeniv [Dispensarization of athletes]. Kyiv: Derzhmedvydav URSR; 1959. 270 p.
8. Kachorovska OV. Likarskyi kontrol nad fizkulturnykamy i sportsmenamy [Medical supervision of physical education participants and athletes]. Kyiv: Derzhmedvydav URSR; 1952. 120 p.
9. Tsanko II, Antonova-Rafi YuV, Kurilo SM, Danko DI. Metody obstezhennia v fizychnii terapii, erhoterapii [Methods of examination in physical therapy and occupational therapy]. Kyiv: KPI im. Ihoria Sikorskoho; 2023. 162 p.
10. Romanchuk OP. Likarsko-pedahohichnyi kontrol v ozdorovchii fizychnii kulturi [Medical-pedagogical control in health-improving physical culture]. Odesa: Vydavets Bukaev VV; 2010. 206 p.
11. Mykhaliuk Ye, Horokhovskyi E, Bosenko A. Retrospektyvnyi ohliad definitsii "neskinchennyi ton" za umov funktsionalnykh prob u sportyvnii medytsyni [A retrospective review of the definition of "infinite tone" under the conditions of functional tests in sports medicine]. Nauka i osvita. 2022;(2):61–8. https://doi.org/10.24195/2414-4665-2022-2-9
12. Shapovalova VA, Korshak VM, Khaltaharov VM, Shymelis IV, Honcharenko LI. Sportyvna medytsyna i fizychna reabilitatsiia [Sports medicine and physical rehabilitation]. Kyiv: Medytsyna; 2008. 248 p.
13. Klapchuk VV, Dziak HV, Muravov IV, Hodishevskyi VM,

Khrominskyi Z. Likuvalna fizkultura ta sportyvna medytsyna [Therapeutic physical culture and sports medicine]. Klapchuk VV, Dziak HV, editors. Kyiv: Zdorovia; 1995. 310 p.

14. Abramov VV, Klapchuk VV, Smyrnova OL. Likuvalna fizkultura ta sportyvna medytsyna. Vybrani lektsii dlia studentiv [Therapeutic physical culture and sports medicine. Selected lectures for students]. Klapchuk VV, editor. Dnipropetrovsk: Medakademiia; 2005. 179 p.
15. Shakhlina LYa-H, editor. Sportyvna medytsyna [Sports medicine]. 2nd ed. Kyiv: Olimpiiska literatura; 2019. 424 p.
16. Mykhaliuk YL, Klapchuk VV, Apanasenko HL, Romanchuk OP. Sportyvna medytsyna [Sports medicine]. Mykhaliuk YL, editor. Lviv: Vydavets Marchenko TV; 2025. 418 p.
17. Pickering TG. Blood pressure measurement. In: Lip GYH, Hall JE, editors. Comprehensive hypertension. Philadelphia: Elsevier; 2007. p. 521–33. https://doi.org/10.1016/B978-0-323-03961-1.50047-7
18. Voors AW, Webber LS, Berenson GS. A choice of diastolic Korotkoff phases in mercury sphygmomanometry of children. Prev Med. 1979;8(4):492–9. https://doi.org/10.1016/0091-7435(79)90323-2
19. Wuestenfeld JC, Baersch F, Ruedrich P, Paech C, Wolfarth B. Blood pressure response to dynamic exercise testing in adolescent elite athletes: what is normal? Front Pediatr. 2022;10:974926. https://doi.org/10.3389/fped.2022.974926
20. De Mey C. Method specificity of the auscultatory estimates of the inodilatory reduction of diastolic blood pressure based on Korotkoff IV and V criteria. Br J Clin Pharmacol. 1995;39(5):485–90. https://doi.org/10.1111/j.1365-2125.1995.tb04484.x
21. Glenning J, Lam K, Clarke M, Bourne H, Smolich J, Cheung M, et al. Assessment of diastolic blood pressure with the auscultatory method in children and adolescents under exercise conditions. Hypertens Res. 2021;44(11):1504–12. https://doi.org/10.1038/s41440-021-00657-7
22. Beevers G, Lip GY, O'Brien E. ABC of hypertension: blood pressure measurement. Part II — conventional sphygmomanometry: technique of auscultatory blood pressure measurement. BMJ. 2001; 322(7293):1043–7. https://doi.org/10.1136/bmj.322.7293.1043
23. Duff DK, De Souza AM, Human DG, Potts JE, Harris KC. A novel treadmill protocol for exercise testing in children: the British Columbia Children's Hospital protocol. BMJ Open Sport Exerc Med. 2017;3(1): e000197. https://doi.org/10.1136/bmjsem-2016-000197
24. Goodman CTD, Kitchen GB. Measuring arterial blood pressure. Anaesth Intensive Care Med. 2023; 24(12):785–9. https://doi.org/10.1016/j.mpaic.2023.09.015
25. O'Sullivan J, Allen J, Murray A. A clinical study of the Korotkoff phases of blood pressure in children. J Hum Hypertens. 2001;15(3):197–201. https://doi.org/10.1038/sj.jhh.1001140
26. Alpert BS, Marks L, Cohen M. K5=diastolic pressure. Pediatrics. 1996;98(5):1002. https://doi.org/10.1542/peds.98.5.1002
27. Freedman DS, Foltz JL, Berenson GS. Differences between the fourth and fifth Korotkoff phases among children and adolescents. Am J Hypertens. 2014;27(12):1495–502. https://doi.org/10.1093/ajh/hpu064
28. Viru E. Lõpmatu tooni auskultatoorse fenomeni küsimusest [On the question of the auscultatory phenomenon of the infinite tone]. Tartu Riikliku Ülikooli Toimetised. 1985; 723:63–7.
29. Girsh E, editor. Reproductive puberty. In: A Textbook of Clinical Embryology. Cambridge: Cambridge University Press; 2021. p. 8–12. https://doi.org/10.1017/9781108881760.003
30. Mykhaliuk YL. Sposib vyboru potuzhnosti druhoho fizychnoho navantazhennia na veloerhometri pid chas provedennia submaksymalnoho testu PWC170 u sportsmeniv [Method for selecting the power of the second physical load on a bicycle ergometer during the submaximal PWC170 test in athletes]. Kyiv: Ukrmedpatentinform; 2018. 4 p. (Informatsiinyi lyst; No. 295-2018, iss. 1, seriia “Likuvalna fizkultura ta sportyvna medytsyna”).
31. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Circulation. 2005;111(5):697-716. https://doi.org/10.1161/01.CIR.0000154900.76284.F6
32. Mykhaliuk YL, Horokhovskyi YY, Tsyganok VI. Perspectives of Ukrainian and international researchers on the “infinite tone” phenomenon following physical exercise in children, adolescents, and young athletes. Rehabil Recreat. 2025;19(1):147–58. https://doi.org/10.32782/2522-1795.2025.19.1.14
33. Alvarez-Pitti J, Herceg-Čavrak V, Wójcik M, Radovanović D, Brzeziński M, Grabitz C, et al. Blood pressure response to exercise in children and adolescents. Front Cardiovasc Med. 2022;9:1004508. https://doi.org/10.3389/fcvm.2022.1004508.
34. Mykhaliuk Y, Horokhovskyi Y, Bosenko A, Bazylchuk O, Orlyk N. Occurrence of dystonic-type response to physical stress in soccer players. Phys Rehabil Recreat Health Technol. 2024;9(1):3–11. https://doi.org/10.15391/prrht.2024-9(1).01
35. Ostchega Y, Fryar CD, Nwankwo T, Nguyen DT. Hypertension prevalence among adults aged 18 and over: United States, 2017–2018. NCHS Data Brief. 2020;(364):1–8.
36. Fryar CD, Kit B, Carroll MD, Afful J. Hypertension prevalence, awareness, treatment, and control among adults age 18 and older: United States, August 2021–August 2023. NCHS Data Brief. 2024;(511):1–8.
37. Hinton TC, Adams ZH, Baker RP, Hope KA, Paton JFR, Hart EC, et al. Investigation and treatment of high blood pressure in young people: too much medicine or appropriate risk reduction? Hypertension. 2020;75(1):16–22. https://doi.org/10.1161/HYPERTENSIONAHA.119.13820
38. Jansari KR, Rathva JN, Rawal K. Prevalence and risk factors of hypertension among young adults in urban settings: a cross-sectional study. Eur J Cardiovasc Med. 2025;15(4):951–4. https://doi.org/10.61336/ejcm/25-04-155