

Immunological resistance and cellular reactivity in adolescent futsal players: effects of systematic training loads

DANIL DYCHKO^{1*}, ELENA DYCHKO², VLADISLAV DYCHKO³, ANDRIY KAZNACHEYEV⁴,
DANYLO KAZNACHEYEV⁵

¹Department of Theory and Methods of Physical Culture and Health Preservation, Faculty of Natural and Mathematical Education and Physical Culture, State Higher Educational Institution “Donbas State Pedagogical University”, Sloviansk, UKRAINE.

^{2,3}Department of Physical Therapy, Physical Education, Sports and Biology, Natural and Mathematical Education and Physical Culture, State Higher Educational Institution “Donbas State Pedagogical University”, Sloviansk, UKRAINE.

^{4,5}DRC “Invasport”, Bakhmut, UKRAINE.

Published online: February 28, 2026

Accepted for publication: February 15, 2026

DOI:10.7752/jpes.2026.02036

Abstract:

Problem Statement: During adolescence, the immune system undergoes a phase of dynamic development, which leads to increased sensitivity to external stimuli, in particular to intense physical exertion. Therefore, studying the immunological resistance of young athletes is extremely important for a better understanding of the mechanisms of the body's adaptive responses and minimizing the risk of immune depletion. **Objective:** This study aimed to examine the characteristics of immunological resistance and cellular reactivity in adolescent futsal players in relation to systematic physical training loads. **Materials and Methods:** The study involved 90 adolescents, stratified into two groups of 45 individuals each. Subjects underwent comprehensive clinical and laboratory assessments to ascertain the leukocyte differential, erythrocyte sedimentation rate, and to calculate immunological and hematological indices. The analysis was conducted utilizing methods of variational statistics, with the significance of differences evaluated through Student's t-test. **Results:** In Group I, a notable increase in the index of nonspecific resistance by 7.5% and an overall enhancement of immunological resistance by 3.81% were observed in comparison to Group II. Conversely, a significant reduction in immunological reactivity by 16.52% ($p<0.05$) and a decrease in the lymphocyte-to-monocyte ratio by 17.02% ($p<0.05$) were recorded. The most pronounced deviation was noted in the neutrophil shift index, which exhibited an increase of 66.7% ($p<0.05$). The parameters of erythrocyte sedimentation rate and fundamental blood cell components did not demonstrate significant discrepancies between the groups. **Conclusions:** Among athletes, first-degree changes predominated, which can be interpreted as adaptive responses. However, isolated indicators of third-degree alterations signify a potential risk of functional overload on the immune system. The findings may serve as a valuable resource in sports medicine for monitoring the health status of young athletes and for the optimization of training regimens.

Keywords: innate immune response; leukocyte indices; neutrophil shift index; training adaptation; immune stress; sports immunology.

Introduction

Contemporary athletic activity requires a systematic training regimen that mobilizes the body's internal reserves and activates complex adaptive mechanisms (Baskerville et al., 2024; Clemente et al., 2020). It is well established that moderate physical loads enhance immune reactivity and support immunological homeostasis. In contrast, excessive or prolonged exercise induces immune and endocrine shifts that may lead to adverse physiological consequences (Latour et al., 2021; Chen et al., 2022). Excessive training reduces immunological resistance, increases susceptibility to infections, and contributes to fatigue development (Traverse et al., 2022; Bekris et al., 2022). During extended physical exertion, elevated synthesis of stress hormones may suppress immune-competent cell functionality (Quatrini et al., 2021; Dychko et al., 2025).

High-intensity training is additionally associated with psychological stress, metabolic disturbances, and immune system dysfunction (Dychko et al., 2024; Lazorko et al., 2020). A significant relationship between metabolism and immune response has been established: glycogen depletion is accompanied by increased lipid metabolite concentrations (Nieman & Pence, 2020; Zavorodnia et al., 2022). Furthermore, microtrauma of muscle tissue activates innate immunity mechanisms involving granulocytes and macrophages (Bekris et al., 2022; Dychko et al., 2025). These findings support the concept that physical load acts as a physiological stressor capable of modulating both innate and adaptive immune components.

In team sports characterized by intermittent high-intensity actions, such as futsal, the stress impact may be particularly pronounced. Bekris et al. (2022) demonstrated that even a single futsal match provokes metabolic and hormonal alterations. Clemente et al. (2020) identified psychobiological changes during national team training camps and confirmed the relationship between adaptation processes and training load magnitude. Chen et al. (2022) further established associations between perceived internal load and recovery status. However, these investigations were conducted primarily in adult athletes, limiting extrapolation to adolescent populations. Additionally, while subjective and physiological load indicators were evaluated, cellular immunity markers were not comprehensively analyzed.

The literature also highlights the dual role of regular exercise. Baskerville et al. (2024) emphasized that physical activity may simultaneously strengthen and compromise immunity depending on intensity and duration. Silva et al. (2022) and Borges et al. (2022) demonstrated relationships between training intensity and immune biomarkers in professional athletes. Latour et al. (2021) reported that strenuous exercise diminishes immune resistance, although certain restorative interventions may mitigate this effect. Similar observations were presented by Traverse et al. (2022), who associated psycho-emotional stress with decreased immune functionality. Nevertheless, quantitative integrative immunological indices remain insufficiently represented in these studies.

Adolescence represents a critical developmental period characterized by immune system maturation and functional instability. Particularly between 13 and 16 years of age, phases of relative immune immaturity may increase susceptibility to infectious complications (Radziejowska et al., 2021; Didenko et al., 2022). Immune cells demonstrate heightened sensitivity to sex hormones, which can significantly modulate cytokine secretion profiles (Miles et al., 2021; Steidten et al., 2021). Quatrini et al. (2021) further emphasized the regulatory role of glucocorticoids and sex hormones in immune development, suggesting that pubertal hormonal fluctuations may influence individual immune variability. However, the specific interaction between systematic training loads and immune adaptation during puberty remains insufficiently investigated.

Among the limited studies focusing on adolescent athletes, Dychko et al. (2025) demonstrated that systematic futsal training activates adaptive mechanisms but may simultaneously induce immune stress. Comparable findings were observed in female futsal players, indicating increased adaptive tension under regular physical load (Dychko et al., 2024). These results support the concept of training-induced immune adaptation but remain fragmented and do not encompass a comprehensive system of integrative immune indices.

Beyond physiological factors, the psychological component must also be considered. Lazorko et al. (2020) indicated that psychocorrective interventions reduce stress and indirectly enhance immune status. Moreover, futsal is characterized by elevated cognitive and psychological demands (Albalad-Aiguabella et al., 2025; Aizava et al., 2023; Spyrou et al., 2020). Terminological ambiguities in describing immunomorphological alterations further complicate inter-study comparisons (Hryn et al., 2022). These methodological challenges underscore the necessity for standardized, index-based approaches in sports immunology.

Systematic reviews confirm the multifactorial nature of exercise-immune interactions. Nieman and Pence (2020) emphasized the need for research on immunometabolic markers. Zavorodnia et al. (2022) highlighted the role of microbiota and metabolism in modulating immune reactivity in children, supporting interdisciplinary perspectives relevant to sports medicine. Recent analyses further stress the importance of validated cellular immune markers for monitoring athletic workload (Walzik et al., 2021; Kurowski et al., 2022; Zacher et al., 2023; Haller et al., 2023; Markov et al., 2023; Shi et al., 2025; Agustiningsih & Wibawa, 2024; Kostrzewa-Nowak et al., 2021; Muller Reis Weber et al., 2024; Morcel et al., 2024; Tornero-Aguilera et al., 2022).

Some studies emphasize the beneficial adaptive effects of systematic training, others warn of potential immunosuppression under excessive load. A notable deficiency is the lack of comprehensive investigations specifically addressing adolescent futsal players using integrative immunological indices.

Consequently, the innate and acquired immunological resistance of 15–16-year-old futsal players was evaluated using an index-based system. The originality of this study lies in its comprehensive characterization of immune alterations during a critical period of immune maturation. Unlike previous research, this investigation examines the relationship between systematic futsal training and the balance between immunological resistance and cellular reactivity, enabling identification of both adaptive mechanisms and potential risks of functional immune overload.

The above discussion facilitates the formulation of the hypotheses underpinning this study:

- consistent engagement in futsal among adolescents enhances nonspecific and overall immunological resistance;
- rigorous physical exertion may diminish immunological reactivity and incite the onset of inflammatory alterations within immune system's cellular constituents.

The current study was conducted in accordance with the Helsinki Declaration and received approval from the local ethics committee.

The aim of the study was to determine the features of immunological resistance and cellular reactivity in adolescent futsal players depending on systematic physical load.

Research tasks:

1. To investigate the level of general immunological resistance in adolescent futsal players compared to peers who do not engage in sports.
2. To analyze changes in nonspecific resistance and immunological reactivity after systematic physical load.
3. To identify adaptive and negative manifestations in the functioning of the immune system among adolescent athletes.

Material & methods

Research Procedure

The study was conducted through a thorough analysis of contemporary scientific literature, systematic observation, and the application of empirical research, which were gathered during the evaluation of the immunological resistance of futsal athletes. This empirical study took place during the years 2024–2025 at the Futsal Academy in Uzhhorod. The research group comprised educators from the Department of Physical Education and Sports Medicine, who oversaw the training regimen and data compilation. Observations and biological sample collection were executed in the morning following a period of rest, thereby mitigating the influence of diurnal variations. The research stages encompassed: preparatory stage, empirical stage, and final stage (Figure 1).

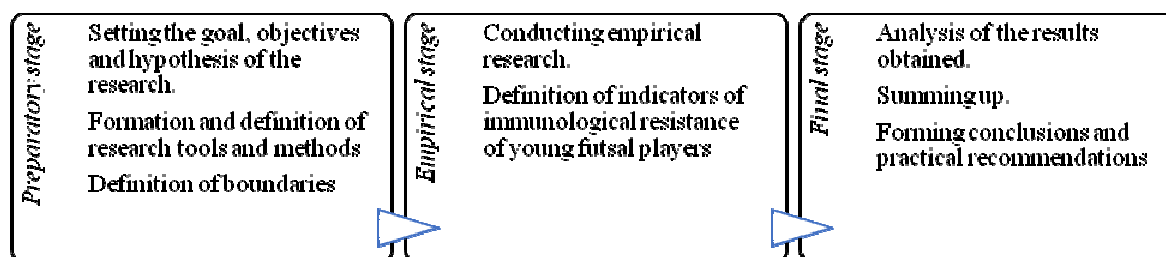


Figure 1. Research design

Source: Consolidated by the author

Sample formation

The study encompassed 90 adolescent futsal players aged 15 to 16 years who consistently trained at the Futsal Academy in Uzhhorod. The experimental group (Group I) comprised 45 athletes with a mean age of 15.38 ± 0.07 years, who not only attended training sessions systematically but also participated in competitions. Conversely, the control group (Group II) consisted of 45 physically active teenagers engaged in non-specialized sports activities, with an average age of 15.53 ± 0.08 years. The sample was randomly selected and is representative of this age group.

Inclusion criteria encompassed male adolescents aged 15 to 16 years who regularly engaged in futsal at least three times per week; those who were deemed relatively healthy according to medical examination results, devoid of chronic somatic or infectious ailments; and individuals who provided written informed consent from their parents for participation in the study.

Exclusion criteria comprised female participants; adolescents suffering from acute or chronic illnesses, immunodeficiencies, or autoimmune conditions; individuals who had taken medications that could potentially influence the immune system within the preceding 30 days; those experiencing exacerbated allergic reactions; and participants who declined to take part or lacked written parental consent.

All procedures adhered to the Ethical Principles of Medical Research Involving Human Subjects and the Universal Declaration on Bioethics and Human Rights. Written informed consent was obtained from the parents of all participants.

Methods

Immunological, hematological, and statistical methodologies were employed in this study. The immunological techniques facilitated the evaluation of indicators related to nonspecific and overall immunological resistance, as well as cellular reactivity. This enabled identifying both adaptive and stress-induced alterations in the immune system as a consequence of physical exertion. Hematological methods yielded computations of leukocyte indices and ratio coefficients (such as neutrophil-lymphocyte and lymphocyte-granulocyte ratios) that elucidate the interplay between innate and adaptive immunity mechanisms. Furthermore, biochemical indicators, including the reactive response index of neutrophilic granulocytes and the allergization index, permitted an assessment of the presence of inflammatory processes and the predisposition to hypersensitivity. Statistical analyses (utilizing SPSS 26.0, Student's t-test, and Mann-Whitney U-test) enabled discerning significant intergroup disparities and evaluating the significance of observed changes, thereby enhancing the obtained results reliability.

Tools

Laboratory investigations were conducted employing standard clinical hematology methodologies. The computation of immunological and hematological indices was executed utilizing standard formulas.

$$\begin{aligned} \text{Neutrophil – lymphocyte coefficient (NLC)} &= \frac{\% \text{ neutrophils}}{\% \text{ lymphocytes}} \\ \text{Lymphocyte – granulocyte index (LGI)} &= \frac{\% \text{ lymphocytes}}{\% \text{ granulocytes}} \\ \text{Leukocyte index (LI)} &= \frac{(\% \text{ lymphocytes} + \% \text{ monocytes})}{\% \text{ granulocytes}} \\ \text{Neutrophil shift index (NSI)} &= \frac{\text{banded neutrophils}}{\text{segmented neutrophils}} \\ \text{Lymphocytes to monocytes ratio index (LMI)} &= \frac{\% \text{ lymphocytes}}{\% \text{ monocytes}} \\ \text{Lymphocytes to eosinophils ration index (LEI)} &= \frac{\% \text{ lymphocytes}}{\% \text{ eosinophils}} \\ \text{Allergization index (AI)} &= \frac{(\% \text{ eosinophiles} + \% \text{ basophiles})}{\% \text{ lymphocytes}} \\ \text{Immunological resistance (IR)} &= \frac{(\% \text{ neutrophils} + \% \text{ monocytes})}{(\% \text{ lymphocytes} + \% \text{ eosinophils})} \\ \text{Immunological reactivity index (RI)} &= \frac{(\% \text{ lymphocytes} \times \% \text{ monocytes})}{(\% \text{ neutrophils})} \\ \text{Nonspecific resistance index (NRL)} &= \frac{\% \text{ eosinophils}}{\% \text{ neutrophils}} \\ \text{Level of increase in nonspecific reactivity (I.NR)} &= \frac{\% \text{ neutrophils}}{\% \text{ monocytes}} \\ \text{Level of increase in immunological reactivity (LIR)} &= \frac{\% \text{ lymphocytes}}{\% \text{ eosinophils}} \\ &+ (\% \text{ segmented neutrophils}) \\ \text{Reactive neutrofile granulocytes (RNG)} &= \frac{\% \text{ banded neutrophils}}{\% \text{ lymphocytes}} \end{aligned}$$

The degree of disturbances was ascertained by evaluating the deviation of indices from age reference limits and/or the mean value of the control group. The symbol “+” denotes an increase in the indicator (hyperactivation), “–” signifies a reduction (deficit), while “=” indicates the absence of clinically significant alterations. Categories were delineated based on the extent of deviation from the control mean in standard deviations, namely: I degree (mild changes): 0–1 SD; II degree (moderate changes): >1–2 SD; III degree (severe changes): >2 SD.

Statistical analysis of the data was conducted utilizing the Statistical Package for the Social Sciences for Windows (SPSS) version 26.0. The conformity of the distribution of traits to the normal distribution was evaluated using the Shapiro-Wilk method. In alternative scenarios, a non-parametric method (Mann-Whitney U-test) was employed. To ascertain the statistical significance of intergroup differences, the Student’s t-test was administered. The difference in indicator values was considered significant at $p < 0.05$. To assess the effect size in intergroup comparisons, Cohen’s d was utilized, interpreted as small (0.2–0.49), medium (0.5–0.79), and large (≥ 0.8) effect. In instances of variance analysis, η^2 (eta-squared) was computed to determine the proportion of variation elucidated by the group factor. For the principal indicators, 95% confidence intervals (95% CI) were provided, facilitating the accuracy and stability evaluation of the obtained results. Consequently, the statistical analysis integrated hypothesis testing (p -values) and effect size estimation, yielding a more comprehensive presentation of the results.

Results

Analyzing the levels of primary blood cells in Groups I and II, it was revealed that the total leukocyte count and lymphocyte levels did not exhibit significant differences between the two groups ($p > 0.05$) (Figure 2). This finding underscores the stability of the hematological profile in both groups. Conversely, Group I demonstrated markedly elevated neutrophil levels, surpassing those of Group II by 2.2% ($p < 0.05$), as well as a

10.1% increase in monocyte counts ($p < 0.05$). Such alterations may be interpreted as an activation of the granulocytic and phagocytic components of the immune response, indicative of a characteristic adaptive reaction to sustained physical load.

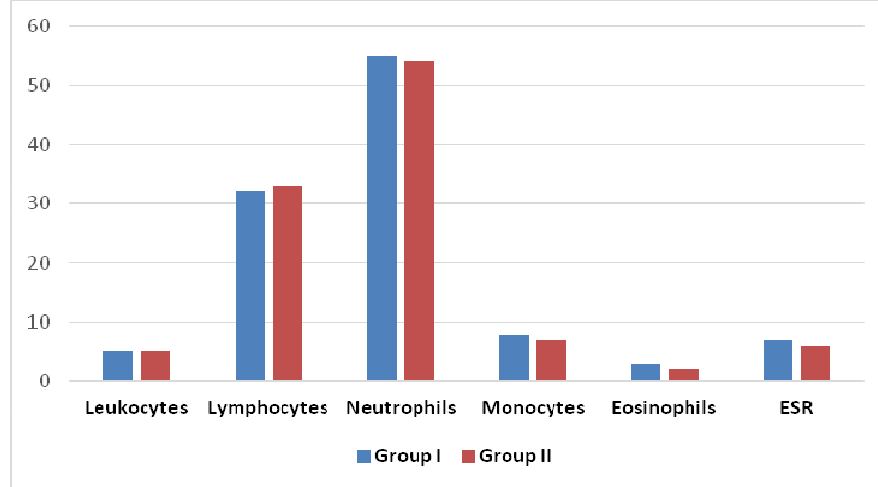


Figure 2. Level of main blood cells and erythrocyte sedimentation rate, M±m

Note: ESR – erythrocyte sedimentation rate

Source: consolidated by the author

The eosinophil levels in Group I were elevated by 7.4%; however, this disparity lacked statistical significance ($p > 0.05$). Similarly, the erythrocyte sedimentation rate (ESR) metrics revealed no discernible differences between the groups. These findings suggest that Group I exhibits a stable overall composition of blood cellular elements. Still, the notable increase in neutrophil and monocyte counts signifies the activation of innate immune response mechanisms. An analysis of the immunological indicators reflecting the body's resistance and reactivity, as delineated in Table 1, reveals significant distinctions between Groups I and II. In Group I, compared to Group II, there was a 7.5% increase in the nonspecific resistance index (0.43 ± 0.04 vs 0.40 ± 0.04 conventional units; $p > 0.05$) and a 3.81% increase in immunological resistance (2.18 ± 0.21 vs 2.10 ± 0.19 conventional units; $p > 0.05$). Although these differences do not achieve statistical significance, they nonetheless indicate the activation of innate immune defense mechanisms as a result of systematic training.

Table 1. Immunological indicators of the body's resistance and reactivity in futsal athletes, M±m

Immunological indicators	Units of measurement	Group I (n=45)	Group II (n=45)	Degree of disturbances	of P
Index of body's nonspecific (innate) reactivity	c.u.	55.28 ± 4.17	55.07 ± 4.22	+ I	> 0.05
Index of body's nonspecific resistance	c.u.	0.43 ± 0.04	0.40 ± 0.04	+ I	> 0.05
Level of body's increase in nonspecific reactivity	times	128.56 ± 11.18	137.68 ± 11.77	- I	> 0.05
Index of body's immunological reactivity	c.u.	5.57 ± 0.27	6.49 ± 0.31	- I	< 0.05
Index of body's immunological resistance	c.u.	2.18 ± 0.21	2.10 ± 0.19	+ I	> 0.05
Level of body's increase in immunological reactivity	times	2.56 ± 0.24	3.09 ± 0.27	- I	> 0.05
Reactive response of neutrophilic granulocytes	c.u.	1.57 ± 0.16	1.90 ± 0.17	- I	> 0.05

Source: Consolidated by the author

Such changes are consistent with current data on training-induced immune adaptation (Borges et al., 2022; Silva et al., 2022). Nevertheless, the indicators of cellular reactivity showed the opposite dynamics. The index of immunological reactivity in Group I was significantly lower by 16.52% compared to Group II (5.57 ± 0.27 vs 6.49 ± 0.31 c.u.; $p < 0.05$). In addition, athletes showed a decrease in the level of increase in immunological reactivity by 17.15% (2.56 ± 0.24 vs 3.09 ± 0.27 c.u.; $p > 0.05$).

The results obtained elucidate the functional stress within the immune system's cellular component, thereby substantiating the hypothesis regarding the negative effects of intense physical loads on immunological reactivity. The data pertaining to the reactive response of neutrophilic granulocytes is particularly noteworthy. In Group I, this indicator exhibited a reduction of 17.36% in comparison to Group II (1.57 ± 0.16 vs 1.90 ± 0.17 units; $p > 0.05$).

These findings corroborate the dual effect of regular futsal training. In Group I, there is an observable enhancement in indicators of nonspecific and overall immunological resistance. However, concurrently, a marked decline in cellular reactivity was recorded relative to Group II. This partially affirms the research hypotheses and underscores the necessity for careful monitoring of the immune system status in young athletes.

The data illustrated in Table 2 delineate the characteristics of leukocyte indices and cellular ratios in adolescents from both groups. In Group I, a trend towards an increase of the leukocyte index by 10% was noted (0.11 ± 0.01 vs 0.10 ± 0.01 units; $p > 0.05$), which may suggest a more active homeostatic regulation of the blood cell composition. The lymphocyte index (0.53 ± 0.05 vs 0.53 ± 0.04 units; $p > 0.05$), the lymphocyte-granulocyte index (0.51 ± 0.03 vs 0.51 ± 0.04 units; $p > 0.05$), and the neutrophil index (1.87 ± 0.18 units; $p > 0.05$) remained virtually unchanged across both groups. This indicates the preservation of the fundamental structure of the leukocyte formula, irrespective of physical load's intensity.

Table 2. Indicators of blood cell composition and their indices/ratios in futsal athletes, $M \pm m$

Hematological indicators	Units of measurement	Group I (n=45)	Group II (n=45)	Degree of disturbances	P
Leukocyte index	c.u.	0.11 ± 0.01	0.10 ± 0.01	+ I	>0.05
Lymphocyte index	c.u.	0.53 ± 0.05	0.53 ± 0.04	=	>0.05
Lymphocyte-granulocyte index	c.u.	0.51 ± 0.03	0.51 ± 0.04	=	>0.05
Neutrophil-lymphocyte ratio	c.u.	1.87 ± 0.19	1.87 ± 0.18	=	>0.05
Neutrophil shift index	c.u.	0.05 ± 0.01	0.03 ± 0.01	+ III	<0.05
Leukocyte shift index	c.u.	1.95 ± 0.17	1.67 ± 0.16	+ I	>0.05
Lymphocyte to monocyte ratio index	c.u.	5.17 ± 0.21	6.05 ± 0.22	- I	< 0.05
Lymphocyte to eosinophil ratio index	c.u.	12.71 ± 0.87	14.03 ± 0.91	- I	> 0.05
Leukocyte to ESR ratio index	c.u.	0.89 ± 0.10	0.73 ± 0.07	+ I	>0.05
Lymphocyte to ESR ratio index	c.u.	4.53 ± 0.21	3.87 ± 0.17	+ I	<0.05
Body allergization index	c.u.	5.38 ± 0.22	5.31 ± 0.23	+ I	>0.05

Source: Consolidated by the author

The most pronounced differences concern the indices of blood cell shift. In Group I, a significant increase in the neutrophil shift index was recorded at 66.7% compared to Group II (0.05 ± 0.01 vs 0.03 ± 0.01 units; $p < 0.05$) respectively. Such changes indicate activation of the granulocyte line and a probable presence of a subclinical inflammatory process. The leukocyte shift index was higher by 16.77% in Group I compared to Group II (1.95 ± 0.17 vs 1.67 ± 0.16 units; $p > 0.05$) respectively.

Significant changes were also observed in the ratios of cell populations. The lymphocyte to monocyte ratio index in Group I was lower by 17.02% compared to individuals in Group II (5.17 ± 0.21 vs 6.05 ± 0.22 units; $p < 0.05$) respectively, indicating an imbalance between the effector and effector links of the immune response. At the same time, the lymphocyte to ESR ratio index was higher by 17.05% in Group I compared to Group II (4.53 ± 0.21 vs 3.87 ± 0.17 units; $p < 0.05$), which may reflect enhanced activation of adaptive immunity in athletes.

The lymphocyte to eosinophil ratio index did not differ significantly between both groups – 12.71 ± 0.87 (Group I) vs 14.03 ± 0.91 units (Group II), $p > 0.05$ and the body allergization index – 5.38 ± 0.22 vs 5.31 ± 0.23 units; $p > 0.05$ respectively. This indicates the absence of significant changes in the mechanisms of allergic response under the influence of physical loads.

According to the findings presented in Table 3, it can be stated that Group I exhibits moderate indications of activation within the granulocyte line. Furthermore, there exists an established imbalance in cellular ratios, albeit the fundamental structure of the leukocyte formula remains intact. This observation is substantiated by the notable disparities in the proportions of lymphocytes and monocytes, alongside the displacement of neutrophils. This suggests that regular physical loads may induce functional stress within the cellular immune response.

In futsal athletes, disorders of degree I predominate (54.5%), reflecting the adaptive nature of immunological alterations. A solitary instance of degree III (9.1%) signifies the most pronounced functional stress, as indicated by the neutrophil shift index. Conversely, in Group II, most indicators (81.8%) remained stable, illustrating the immune system's resistance in the absence of systematic athletic training.

The analysis of the data consolidated in Table 3 reveals that the most pronounced differences between athletes and the control group pertain to immunological reactivity and the ratio of lymphocytes to monocytes. Immunological reactivity in athletes was significantly diminished (-0.92 ; 95% CI $[-1.73; -0.11]$), accompanied by a medium effect size (Cohen's $d = -0.47$), indicating a reduction in the functional activity of the cellular component of the immune system. A similar trend was observed concerning the ratio of lymphocytes to monocytes (-0.88 ; 95% CI $[-1.48; -0.28]$), with a medium effect size ($d = -0.61$), reflecting an imbalance between effector and effector cell populations.

Table 3. Comparison of key immunological indicators between groups I and II considering the difference of means (Δ), 95% confidence intervals (95% CI), and effect size (Cohen's d)

Indicator	Difference (Δ)	95% CI of the difference	Cohen's d (effect size)
Immunological reactivity index	-0.92	[-1.73; -0.11]	-0.47 (medium)
Neutrophil shift index	+0.02	[-0.008; +0.048]	+0.30 (small)
Ratio of lymphocytes to monocytes	-0.88	[-1.48; -0.28]	-0.61 (medium)
Index of nonspecific resistance	+0.03	[-0.081; +0.141]	+0.11 (very small)
Reactive response of neutrophilic granulocytes	-0.33	[-0.79; +0.13]	-0.30 (small)

Source: Consolidated by the author

Note: $d = 0.20-0.49$ – small effect; $d = 0.50-0.79$ – medium effect; $d \geq 0.80$ – large effect

The index of neutrophil shift demonstrated a tendency to increase in athletes (+0.02; 95% CI [-0.008; +0.048]) with a modest effect size ($d = +0.30$). This may signify the activation of the granulocyte lineage and the manifestation of subclinical indicators of inflammatory stress. Conversely, the index of nonspecific resistance did not exhibit significant disparities (+0.03; 95% CI [-0.081; +0.141]) and was characterized by a very small effect size ($d = +0.11$), suggesting the maintenance of fundamental innate immune defense mechanisms across both groups. A comparable scenario is evident in the reactive response of neutrophilic granulocytes (-0.33; 95% CI [-0.79; +0.13]), where the difference was likewise minimal ($d = -0.30$).

The findings corroborate that systematic training in adolescent futsal players exerts a dual impact on the immune system: an activation of innate immune defense mechanisms is observed alongside a reduction in cellular reactivity, indicative of functional strain. This aligns with the hypothesis regarding the adaptive nature of immune alterations, which may pose a potential risk of overburdening immunity's cellular component during periods of intense exertion.

Dicussion

In our study, a moderate increase in nonspecific and general immunological resistance was observed, simultaneous with a decline in immunological reactivity and an elevation in the neutrophil shift index. This suggests an adaptive restructuring of innate immune defense mechanisms and a potential functional strain on the cellular component among young futsal players (15–16 years old).

Further comparative analysis reveals both consistency and notable discrepancies with the findings of other researchers. The divergences between our results and those of other scholars may be attributable to the age characteristics of the sample (adolescents versus adult athletes), varying intensities of training loads, and the incorporation of a broader spectrum of integrative immunological indices in our study.

Increased nonspecific resistance in athletes aligns with findings from studies examining the interplay between physical activity and the immune system (Borges et al., 2022; Silva et al., 2022). Researchers have demonstrated that the intensity of training correlates with biomarkers indicative of immune status in professional football players. Comparable outcomes were observed in high-intensity loads beyond competitive sports, where lymphocyte activation was recorded (Borges et al., 2020; Tormero-Aguilera, et al. 2022). Thus, our findings corroborate the notion of training-induced immune adaptation.

At the same time, the reduction in immunological reactivity alongside the elevation in the neutrophil shift index partially resonates with the results of investigations into acute immune responses to increase exercise (Markov et al., 2023; Kostrzewa-Nowak et al., 2021). The application of integrative indices, particularly the neutrophil-lymphocyte ratio, is advocated in the realm of sports physiology for monitoring training loads (Walzik et al., 2021; Kurowski et al., 2022). In our sample, no statistically significant variations in this index were observed, distinguishing our findings from those reported by other scholars (Shi et al., 2025; Agustiniingsih & Wibawa, 2024). This discrepancy may be elucidated by the specificities of sample selection during a state of relative rest, as well as adolescents' developmental characteristics (Steidten, 2021; Muller Reis Weber et al., 2024).

The observed reduction in the lymphocyte-to-monocyte ratio among our participants corroborates a potential imbalance between the effector and effector components of immunity. These findings align with existing literature regarding the viability of employing panel indicators (Zacher et al., 2023; Haller et al., 2023). Consequently, the results may serve as a compelling rationale for the integration of multifaceted immune markers within the realm of sports medicine (Steidten, 2021; Morcel et al., 2024).

The review elucidates that a sport such as futsal is distinguished by its elevated intensity and cognitive-psychological demands (Borges et al., 2022; Albalad-Aiguabella et al., 2025). Psychological factors, including self-efficacy and mental resistance, exhibit a direct correlation with athletic performance (Aizava et al., 2023; Spyrou et al., 2020). This observation partially elucidates the influence of psycho-emotional stress on the immune alterations we documented in our cohort.

Thus, our findings generally affirm contemporary research regarding the adaptive effects of systematic futsal training on innate immune defense mechanisms. They also indicate manifestations of functional stress within the cellular component, which resonates with other scholars' observations (Radziejowska, 2021; Didenko, 2022). This underscores the necessity for comprehensive monitoring of immunological parameters in young athletes, taking into consideration age, lifestyle, and the unique characteristics of the training regimen.

The results obtained partially corroborate the proposed hypotheses. In futsal players, a significant enhancement in nonspecific and general immunological resistance was observed, which aligns with our study's initial hypothesis. At the same time, a reduction in immunological reactivity and an elevation in the neutrophil shift index were documented, substantiating the second hypothesis regarding the potential functional stress imposed on the immune system due to intense training regimens. Allergy indicators remained stable, while manifestations of immediate-type hypersensitivity diminished, thereby affirming the third hypothesis posited at the beginning of the investigation.

Thus, the practical implications of these findings reside in the prospective integration of immunological monitoring within the training regimen for young futsal players. The observed decline in reactivity, coupled with an increase in resistance, underscores the necessity of maintaining a balance between adaptation and stress. Employing the neutrophil shift index alongside the lymphocyte-to-monocyte ratio can assist coaches and medical professionals in promptly adjusting training loads and implementing recovery strategies, thereby mitigating the risk of immune exhaustion.

Conclusions

For the first time, specific immune changes in adolescent futsal players, who are navigating a critical phase of immune system development, have been thoroughly examined. The findings complement existing knowledge regarding the effects of physical loads, revealing a dual effect - an enhancement in resistance while simultaneously decreasing cellular reactivity. In futsal players aged 15–16 years, an increase in nonspecific resistance (by 7.5%) and overall immunological resistance (by 3.81%) was documented compared to the control group. Conversely, a notable reduction in immunological reactivity (by 16.52%) and a decrease in the lymphocyte-to-monocyte ratio (by 17.02%) were observed, indicating a strain on the cellular component of immunity. A favorable outcome is the diminishment of immediate-type hypersensitivity manifestations (by 10.39%), signifying the stabilization of immune regulation.

The results obtained can be employed to formulate health monitoring programs for young athletes, optimize the training regimen, and avert immune depletion by integrating recovery and nutritional strategies. The prospect of further inquiry lies in including athletes from varied genders and age groups, along with a multi-center framework to enhance representativeness. Establishing immunological indicators alongside hormonal and psychophysiological markers, coupled with dynamic monitoring of changes throughout training and competitive cycles, will enable the development of a more comprehensive model for assessing the immune status of young athletes. The practical implications of these findings reside in their potential application within sports medicine for monitoring the immune system's state, facilitating timely adjustments to training loads, and implementing effective recovery strategies..

Further research should be undertaken involving athletes of both genders and diverse age groups to identify gender and age-related disparities in immune changes. A multi-center design encompassing several academies is promising, as it will enhance the representativeness of the sample. Additionally, it is advisable to broaden the array of indicators by incorporating biochemical, hormonal, and psychophysiological markers. Dynamic monitoring of these parameters will facilitate the timely risks detection associated with immune system overload in young athletes.

Limitations

The study is constrained to male adolescents aged 15–16, thereby rendering it impractical to extrapolate the findings to other age categories or to the female demographic. The sample was exclusively derived from a singular sports academy, suggesting that geographical variables may further impact the generalizability of the results. Moreover, only hematological and immunological indices were evaluated, thereby neglecting biochemical and hormonal markers, which significantly limits the interpretation of the obtained data.

Declaration of generative AI and AI-assisted technologies in the writing process:

No generative artificial intelligence technologies or technologies based on artificial intelligence were used in writing this article.

Conflicts of interest: The authors declare no conflicts of interest.

Funding source. This research received no external funding.

Acknowledgments. None

References

- Agustiniingsih, D., & Wibawa, T. (2024). Demystifying roles of exercise in immune response regulation against acute respiratory infections: A narrative review. *Sports medicine and health science*, 6(2), 139–153. <https://doi.org/10.1016/j.smhs.2024.01.004>
- Aizava, P. V. S., Codonhato, R., & Fiorese, L. (2023). Association of self-efficacy and mental toughness with sport performance in Brazilian futsal athletes. *Frontiers in psychology*, 14, 1195721. <https://doi.org/10.3389/fpsyg.2023.1195721>.
- Albalad-Aiguabella, R., Navarrete-Villanueva, D., Mainer-Pardos, E., Villanueva-Guerrero, O., Muniz-Pardos, B., & Vicente-Rodríguez, G. (2025). Physical Training Considerations for Futsal Players According to Strength and Conditioning Coaches: A Qualitative Study. *Sports (Basel, Switzerland)*, 13(4), 126. <https://doi.org/10.3390/sports13040126>
- Baskerville, R., Castell, L., & Berman, S. (2024). Sports and Immunity, from the recreational to the elite athlete. *Infectious diseases now*, 54(4S), 104893. <https://doi.org/10.1016/j.idnow.2024.104893>
- Bekris, E., Gioldasis, A., Gissis, I., Katis, A., Mitrousis, I., & Mylonis, E. (2022). Effects of a Futsal Game on Metabolic, Hormonal, and Muscle Damage Indicators of Male Futsal Players. *Journal of strength and conditioning research*, 36(2), 545–550. <https://doi.org/10.1519/JSC.0000000000003466>.
- Borges, L., Gorjão, R., Gray, S. R., Martins, T. R., Santos, V. C., Momesso, C. M., Pithon-Curi, T. C., & Hatanaka, E. (2020). Lymphocyte activation after a high-intensity street dance class. *PloS one*, 15(9), e0239516. <https://doi.org/10.1371/journal.pone.0239516>.
- Borges, L., Dermargos, A., Gorjão, R., Cury-Boaventura, M. F., Hirabara, S. M., Abad, C. C., Pithon-Curi, T. C., Curi, R., Barros, M. P., & Hatanaka, E. (2022). Updating futsal physiology, immune system, and performance. *Research in sports medicine (Print)*, 30(6), 659–676. <https://doi.org/10.1080/15438627.2021.1929221>.
- Chen, Y. S., Clemente, F. M., Pagaduan, J. C., Crowley-McHattan, Z. J., Lu, Y. X., Chien, C. H., Bezerra, P., Chiu, Y. W., & Kuo, C. D. (2022). Relationships between perceived measures of internal load and wellness status during overseas futsal training camps. *PloS one*, 17(4), e0267227. <https://doi.org/10.1371/journal.pone.0267227>.
- Clemente, F. M., Silva, A. F., Sarmento, H., Ramirez-Campillo, R., Chiu, Y. W., Lu, Y. X., Bezerra, P., & Chen, Y. S. (2020). Psychobiological Changes during National Futsal Team Training Camps and Their Relationship with Training Load. *International journal of environmental research and public health*, 17(6), 1843. <https://doi.org/10.3390/ijerph17061843>.
- Didenko, V. I., Klenina, I. A., Tatarchuk, O. M., Hrabovska, O. I., & Petishko, O. P. (2022). Specificities of lipotoxicity of free fatty acids and cytokine profile in patients with chronic diffuse liver diseases. *Regulatory Mechanisms in Biosystems*, 13(1), 3–9. <https://doi.org/10.15421/022201>
- Dychko, D. V., Dychko, O., & Dychko, V. V. (2024). The influence of physical exertion on the level of adaptive stress of the body of futsal girls who are in a critical period of the formation of the immune system. *Scientific Journal of Drahomanov Ukrainian State University. Series 15*, 11(184), 54–57. [https://doi.org/10.31392/UDU-nc.series15.2024.11\(184\).11](https://doi.org/10.31392/UDU-nc.series15.2024.11(184).11)
- Dychko, D., Dychko, V., Kushakova, N., Kholodnyi, O., & Mukhina, V. (2025). The Impact of Physical Activity on the Adaptation Processes in the Body of Adolescent Futsal Athletes. *International Journal of Human Movement and Sports Sciences*, 13(2), 397–403. <https://doi.org/10.13189/saj.2025.130217>.
- Haller, N., Behringer, M., Reichel, T., Wahl, P., Simon, P., Krüger, K., Zimmer, P., & Stöggel, T. (2023). Blood-Based Biomarkers for Managing Workload in Athletes: Considerations and Recommendations for Evidence-Based Use of Established Biomarkers. *Sports medicine (Auckland, N.Z.)*, 53(7), 1315–1333. <https://doi.org/10.1007/s40279-023-01836-x>
- Hryn, V., Yudina, K., Donchenko, V., Zhamardiy, V., & Horoshko, V. (2022). Eponymous terms in the morphology of angioarchitectonics of the human head. *Wiadomosci lekarskie*, 75(6), 1583–1591. <https://doi.org/10.36740/WLek202206129>
- Kostrzewa-Nowak, D., Wityk, P., Ciechanowicz, A., & Nowak, R. (2021). Post-match recovery profile of leukocyte cell subsets among professional soccer players. *Scientific reports*, 11(1), 13352. <https://doi.org/10.1038/s41598-021-92956-9>
- Kurowski, M., Seys, S., Bonini, M., Del Giacco, S., Delgado, L., Diamant, Z., Kowalski, M. L., Moreira, A., Rukhadze, M., & Couto, M. (2022). Physical exercise, immune response, and susceptibility to infections—current knowledge and growing research areas. *Allergy*, 77(9), 2653–2664. <https://doi.org/10.1111/all.15328>
- Latour, E., Arlet, J., Latour, E. E., Juszkievicz, A., Łuczowska, K., Marcinkiewicz, A., Basta, P., Trzeciak, J., Machaliński, B., & Skarpańska-Stejnborn, A. (2021). Standardized astragalus extract for attenuation of the immunosuppression induced by strenuous physical exercise: randomized controlled trial. *Journal of the International Society of Sports Nutrition*, 18(1), 57. <https://doi.org/10.1186/s12970-021-00425-5>.
- Lazorko, O., Overchuk, V., Zhylin, M., Bereziak, K., & Savelchuk, I. (2020). Modern types of psychological correction and their practical application. *Systematic Reviews in Pharmacy*, 11(11), 1316–1322. <https://doi.org/10.31838/srp.2020.11.186>.

- Markov, A., Bussweiler, J., Helm, N., Arntz, F., Steidten, T., Krohm, L., Sacot, A., Baumert, P., Puta, C., & Chaabene, H. (2023). Acute effects of concurrent muscle power and sport-specific endurance exercises on markers of immunological stress response and measures of muscular fitness in highly trained youth male athletes. *European Journal of Applied Physiology*, 123(5), 1015–1026. <https://doi.org/10.1007/s00421-022-05126-8>
- Miles, E. A., Childs, C. E., & Calder, P. C. (2021). Long-Chain Polyunsaturated Fatty Acids (LCPUFAs) and the Developing Immune System: A Narrative Review. *Nutrients*, 13(1), 247. <https://doi.org/10.3390/nu13010247>.
- Morcel, J., Béghin, L., Michels, N., De Ruyter, T., Drumez, E., Cailliau, E., Polito, A., Le Donne, C., Barnaba, L., Azzini, E., De Henauw, S., Miguel Berges, M. L., Cacau, L. T., Moreno, L. A., & Gottrand, F. (2024). Nutritional and physical fitness parameters in adolescence impact cardiovascular health in adulthood. *Clinical nutrition (Edinburgh, Scotland)*, 43(8), 1857–1864. <https://doi.org/10.1016/j.clnu.2024.06.022>
- Muller Reis Weber, V., Bessa Dantas, D., Fernandes da Silva, D., Gustavo Cavazzotto, T., Sergio Portela, B., Aires Ferreira, S., & Roberto Queiroga, M. (2024). Trends in anthropometric and somatotype profiles of Brazilian female futsal players: a 20 year study. *European journal of translational myology*, 34(1), 11887. <https://doi.org/10.4081/ejtm.2024.11887>
- Nieman, D. C., & Pence, B. D. (2020). Exercise immunology: Future directions. *Journal of sport and health science*, 9(5), 432–445. <https://doi.org/10.1016/j.jshs.2019.12.003>
- Radziejowska, M., Radziejowski, P., Knotowicz, J., Dereka, T., Vasylyuk, D. A., & Kalabuchova, A. (2021). Lifestyle and physical condition parameters of primary school. *Zdravotnicke Listy*, 9(3), 19-26. <https://doi.org/10.32782/1339-3022/2021/3.9.4>
- Quatrini, L., Ricci, B., Ciancaglini, C., Tumino, N., & Moretta, L. (2021). Regulation of the Immune System Development by Glucocorticoids and Sex Hormones. *Frontiers in immunology*, 12, 672853. <https://doi.org/10.3389/fimmu.2021.672853>.
- Shi, X., Hu, L., Nieman, D. C., Li, F., Chen, P., Shi, H., & Shi, Y. (2025). Exercise workload: a key determinant of immune health - a narrative review. *Frontiers in immunology*, 16, 1617261. <https://doi.org/10.3389/fimmu.2025.1617261>
- Silva, A. F., González-Fernández, F. T., Ceylan, H. I., Silva, R., Younesi, S., Chen, Y. S., Badicu, G., Wolański, P., Murawska-Ciałowicz, E., & Clemente, F. M. (2022). Relationships between Fitness Status and Blood Biomarkers in Professional Soccer Players. *Journal of healthcare engineering*, 2022, 5135817. <https://doi.org/10.1155/2022/5135817>
- Spyrou, K., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review. *Frontiers in psychology*, 11, 569897. <https://doi.org/10.3389/fpsyg.2020.569897>
- Steidten, T., Baumbach, P., May, R., Gabriel, B., Herbsleb, M., Markov, A., Granacher, U., Kellmann, M., Bloch, W., Gabriel, H. H. W., & Puta, C. (2021). Overnight Immune Regulation and Subjective Measures of Sleep: A Three Night Observational Study in Adolescent Track and Field Athletes. *Frontiers in sports and active living*, 3, 689805. <https://doi.org/10.3389/fspor.2021.689805>.
- Tornero-Aguilera, J. F., Jimenez-Morcillo, J., Rubio-Zarapuz, A., & Clemente-Suárez, V. J. (2022). Central and Peripheral Fatigue in Physical Exercise Explained: A Narrative Review. *International journal of environmental research and public health*, 19(7), 3909. <https://doi.org/10.3390/ijerph19073909>
- Traverse, H. M., Horoshko, V. I., & Hordienko, O. V. (2022). The state of human immune system amid various types of psychical exceptions. *Rehabilitation and Recreation*, 12, 80–85. <https://doi.org/10.32782/2522-1795.2022.12.11>.
- Walzik, D., Joisten, N., Zacher, J., & Zimmer, P. (2021). Transferring clinically established immune inflammation markers into exercise physiology: focus on neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio and systemic immune-inflammation index. *European journal of applied physiology*, 121(7), 1803–1814. <https://doi.org/10.1007/s00421-021-04668-7>
- Zacher, J., Wesemann, F., Joisten, N., Walzik, D., Bloch, W., & Predel, G. (2023). Cellular Integrative Immune Markers in Elite Athletes. *International journal of sports medicine*, 44(4), 298–308. <https://doi.org/10.1055/a-1976-6069>
- Zavhorodnia, N. Yu., Klenina, I. A., Hrabovska, O. I., Tatarchuk, O. M., & Petishko, O. P. (2022). Insulin resistance and intestinal microbial metabolites in childhood obesity. *Gastroenterology*, 56(3), 171-178. <https://doi.org/10.22141/2308-2097.56.3.2022.506>.