Cellular and General Resistance of Young Futsal Players Aged 13-16 Years Depending on Blood Group according to the ABO System

Danil Dychko[1,*], Elena Dychko[2], Vladislav Dychko[2], Vadym Zhuk[3] and Natalya Shayda[4]

[1]*Department 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", Dnipro, Ukraine*

[2]*Department of Physical Therapy, Physical Education, Sports and Biology, Natural and Mathematical Education and Physical Culture, State Higher Educational Institution "Donbas State Pedagogical University", Dnipro, Ukraine*

[3]*Department of Obstetrics and Gynecology, Medical Faculty No. 1., Donetsk National Medical University, Lyman, Ukraine*

[4]*Department of General and Differential Psychology, Faculty of Natural Sciences, Mathematics and Physical Education, State Higher Educational Institution "Donbas State Pedagogical University", Dnipro, Ukraine*

Abstract: *Relevance*: Regular physical activity during adolescence affects immune adaptation, but the possible contribution of genetically determined ABO blood group phenotypes to interindividual variability in immune resistance remains insufficiently substantiated.

Purpose: This study aimed to determine the features of cellular, innate (general) and acquired immune resistance in young futsal players aged 13–16 years, taking into account ABO blood group phenotype.

Materials and Methods: A total of 75 boys aged 13–16 years were examined: 45 futsal players and 30 practically healthy peers who did not engage in organized sports. Peripheral blood parameters were analyzed, including leukocytes, granulocytes, agranulocytes, neutrophil subpopulations, lymphocytes, monocytes, erythrocytes, hemoglobin and erythrocyte sedimentation rate (ESR). The adaptation index (AI) was calculated as the lymphocyte-to-segmented neutrophil ratio. Statistical analysis included assumption checking, pairwise comparisons with correction for multiple subgroup testing, and additional reporting of 95% confidence intervals, Cohen's d effect sizes and observed power for AI comparisons.

Results: Most young futsal players demonstrated cellular and general immune resistance indicators corresponding to physiological adaptation. In athletes with O(I), A(II) and B(III) blood groups, AI corresponded to calm activation. In the AB(IV) subgroup, AI was lower than in controls and reached nominal statistical significance; however, this finding should be interpreted cautiously because of the very small subgroup size and loss of confirmatory strength after correction for multiple comparisons.

Conclusions: The study suggests that systematic futsal training in adolescents is generally associated with physiological immune adaptation. The possible relationship between ABO phenotype and immune adaptation requires verification in larger, longitudinal and statistically powered samples.

Keywords: Futsal, young athletes, immune resistance, adaptation index, ABO blood group system.

INTRODUCTION

Contemporary sport places substantial functional demands on the adolescent body. Therefore, mechanisms of adaptation involving the immune system require particular attention in young athletes. International research shows that physical activity can modify cellular and humoral immune responses, but the direction and magnitude of these changes depend on exercise intensity, training status, recovery time and biological maturity [1, 2, 5]. Along with beneficial adaptive responses, intensive or insufficiently recovered physical load may activate inflammatory pathways and alter leukocyte distribution [3, 4, 7].

The immune system plays a central role in maintaining homeostasis during muscular activity. The prior research has established that immunological responses depend not solely on the presence of physical loads but also on their intensity, duration and frequency. Generally, moderate exercise is associated with enhanced nonspecific resistance, while excessive or longer exercise may lead to temporary immunosuppression and reduced protective capacity [8]. What is more, physical activity causes complex shifts in peripheral blood composition, including changes in leukocyte, neutrophil and lymphocyte counts, which are considered markers of the body's adaptive response to stress [4, 7]. From our perspective, it is expedient to consider these changes in relation to athlete's individual characteristics and the specific features of their training regimens.

In sports medicine, peripheral blood parameters are widely used as accessible markers of functional state

*Address correspondence to this author at the Department 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", Dnipro, Ukraine;
E-mail: dychko.dv@gmail.com

and workload tolerance. Leukocyte, neutrophil and lymphocyte indices may reflect both acute redistribution of immune cells and more stable patterns of adaptation to repeated exercise exposure [4, 5, 7]. Their interpretation is most reliable when training load, recovery interval, age and individual biological factors are considered simultaneously.

Particular attention should be devoted to immune reactivity during adolescence, which is a period characterized by an active development of functional systems, including immune defense mechanisms [10]. During this stage, the body demonstrates higher sensitivity to physical exercise, which can entail not only beneficial adaptive changes but also functional strain in case the loads are excessive [11]. Studies involving young athletes prove that regular training contributes to specific shifts in immune parameters, changes in leukocyte and lymphocyte levels included, as well as other components of cellular resistance [12]. Rather than relying solely on generalized models of sports immunology, the said findings underscore the need of a more detailed and individualized approach to assessing adaptation in adolescent athletes.

Of particular interest are the team sports which deserve special consideration in view of their dynamic and high-intensity nature. For example, futsal is characterized by a mixed anaerobic–aerobic pattern of muscular activity, thus being associated with salient metabolic demands [13, 14]. International studies emphasize that both training and competition in futsal involve many physiological systems, including the immune system. The latter plays a key role in maintaining homeostasis and supporting recovery processes [15, 16]. Moreover, regular participation in futsal has been linked to measurable changes in immune markers, such as leukocyte subpopulations and indicators of inflammation [17, 18]. Therefore, when taken together, these observations suggest that futsal provides an adequate model for delving into immune adaptation under conditions of repeated, high-intensity loads.

In the last decade, increasing attention has been paid to genetically determined factors that may influence individual adaptation to physical load. The ABO phenotype is a stable genetic characteristic based on carbohydrate antigen expression. These antigens are not restricted to erythrocytes; ABO-related glycosylation patterns are also connected with endothelial function, circulating adhesion molecules, von Willebrand factor regulation and inflammatory mediator profiles [34-38]. Therefore, the ABO system may plausibly contribute to differences in leukocyte-endothelial interactions, cytokine signaling and immune cell redistribution under physiological stress, although direct evidence in adolescent athletes remains limited.

Despite a substantial number of studies on exercise immunology, the relationship between ABO blood group and cellular or general resistance indicators in young athletes remains insufficiently examined. Existing evidence mainly addresses adult athletes, acute post-exercise responses or broad performance characteristics, whereas data on adolescent team-sport athletes are scarce [5, 7, 17, 18]. This study addresses this gap by analyzing peripheral blood parameters and AI in young futsal players with different ABO phenotypes.

It is worth noting that most contemporary research focuses on acute or post-exercise changes in immune indicators, inflammation markers and recovery, primarily in adult or highly qualified athletes, oftentimes without examining genetically determined individual differences [5, 7]. Yet, other studies tend to analyze responses to specific training sessions or competitions rather than examine typological factors that may determine adaptive processes [6, 17]. However, available data suggest that ABO system blood group may be linked to endurance, physical fitness, performance results and certain morpho-functional features [21, 22]. Furthermore, review studies also highlight a potential association between blood group and athletic performance, though its role in shaping cellular and general resistance in young athletes remains insufficiently explored [23].

The research hypothesis was that young futsal players with different ABO blood groups may demonstrate different profiles of cellular and general resistance, particularly in leukocyte distribution and AI. Given the exploratory design and unequal subgroup sizes, this hypothesis was tested as a preliminary association rather than as evidence of causality.

Scientific novelty. This study provides preliminary data on cellular and general resistance in young futsal players in relation to ABO blood group phenotype. The main novelty lies in combining routine hematological parameters, AI and ABO stratification in adolescent futsal players; however, the findings, especially those concerning the AB(IV) subgroup, should be treated as exploratory.

Aim of the study is to determine the features of body's cellular, general (innate) and acquired resistance in young futsal athletes depending on the blood group according to the AB0 system. To achieve the purpose of the study, the following tasks were addressed:

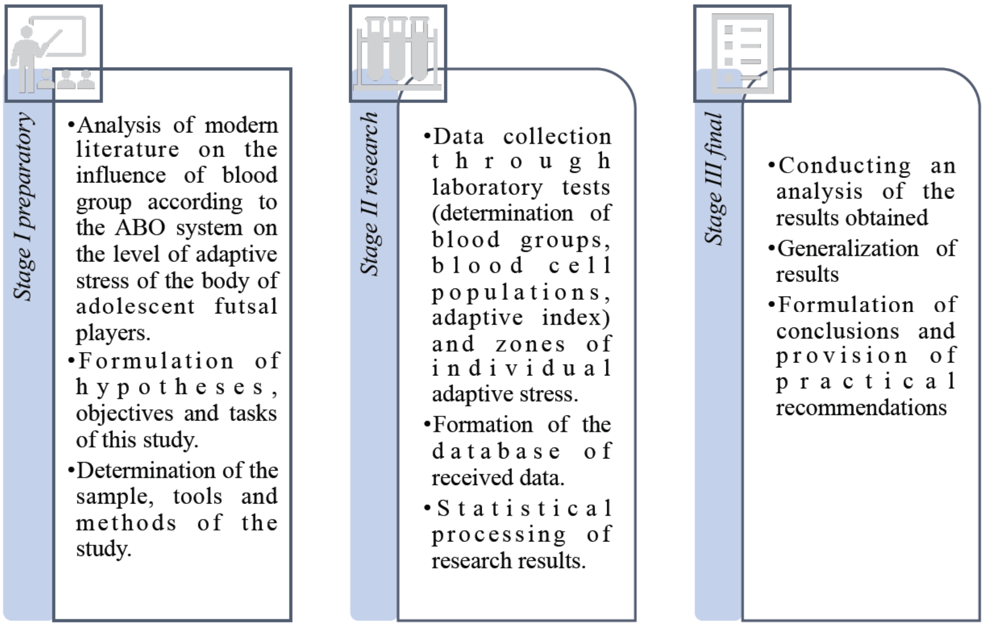

Figure 1: Stages of the study.

Source: Consolidated by the authors.

1. To identify intergroup differences in terms of cellular and general resistance indicators among futsal players aged 13–16 according to the AB0 system.

2. To evaluate the relationship between blood group affiliation and the body's adaptive capacity in young athletes.

3. To compare peripheral blood parameters in futsal players and control participants, with due regard to ABO blood group differences.

MATERIALS AND METHODS

Research Design

The study had a comparative cross-sectional design. The survey of young futsal players and control participants was carried out between September and November 2025. Because of this design, the study can identify associations between futsal training status, ABO phenotype and immune resistance indicators, but it cannot establish causal relationships. The study was executed in three consecutive stages (Figure **1**).

Participants

The study was carried out at the Uzhhorod Futsal Academy and involved 75 boys aged 13–16 years. The experimental group consisted of 45 futsal players, while the control group included 30 peers who did not participate in sports clubs. Athletes in the experimental group trained systematically and participated in competitions. Control participants attended only regular school physical education classes and did not report additional organized sports training during the study period. This criterion was used to reduce the confounding effect of non-futsal physical activity, although daily activity was not objectively measured by accelerometry.

Inclusion criteria were age between 13 and 16 years, regular futsal training and competition participation for the experimental group, absence of chronic diseases, and written informed consent from parents or legal guardians. Exclusion criteria were age outside the specified range, chronic health conditions, irregular training attendance, acute infectious disease during the preceding two weeks, and absence of informed consent. For the research purposes, all participants were subdivided according to ABO blood group (Table **1**).

Table 1: Distribution of Participants by Blood Group according to the ABO System

Blood group	Experimental group (n=45)	Control group (n=30)
O(I)	12	8
A(II)	15	10
B(III)	12	8
AB(IV)	6	4

Source: Consolidated by the authors.

The study was conducted in accordance with the ethical standards outlined in the "Ethical Principles for Medical Research Involving Human Subjects" and the "Universal Declaration on Bioethics and Human Rights". Importantly, the research protocol was reviewed and approved by academy's ethics committee. Before participating in the study, written informed consent was received from the parents or legal guardians of all participants. Those were to a full extent instructed about the study's purpose, objectives and procedures, as well as the further reflection of the results in scientific publications. Also, all participants and their guardians were informed of their right of being able to withdraw from the study at any stage.

Data Collection Procedures

The immune reactivity in young futsal players was assessed using the adaptation index (AI), which served as an indicator of the body's type of adaptive response and overall adaptive capacity. Blood group classification was determined using standard methods according to the ABO groups system.

All participants underwent complete blood count analysis. Venous blood samples were collected from the ulnar vein in the morning under fasting conditions and placed in tubes containing EDTA. In the experimental group, sampling was performed 36–48 hours after the last training session and not after a competitive match, in order to reduce the acute influence of exercise-induced leukocyte redistribution. Control participants were examined under the same morning fasting conditions. Laboratory analysis was performed using an automated hematological analyzer. The evaluated parameters included erythrocyte count, leukocyte count, platelet count, hemoglobin concentration and hematocrit level. Special attention was directed to the leukocyte formula, including neutrophils, band and segmented neutrophils, lymphocytes and monocytes.

AI = lymphocytes / segmented neutrophils

The type of adaptive response of each futsal player was determined based on the level of AI:

- in the range from 0.07 to 0.29 u.o. corresponds to a stress response;
- from 0.30 to 0.47 corresponds to training reactions;
- from 0.48 to 0.68 corresponds to a calm activation reaction;
- from 0.69 to 1.13 corresponds to a reaction of increased activation.

The use of this formula index is based on the assumption that the lymphocyte-to-segmented neutrophil ratio reflects the balance between adaptive immune-cell representation and the neutrophil component of nonspecific resistance. The AI categories used in this study correspond to the applied Ukrainian physiological approach to nonspecific adaptive reactions and are not presented as an internationally standardized diagnostic scale. Therefore, AI was interpreted as an auxiliary monitoring indicator rather than as an independent clinical diagnostic criterion. This clarification is particularly important for adolescents, in whom immune and endocrine maturation may influence leukocyte distribution.

Statistical analysis involved comparisons between the experimental and control groups and between subgroups stratified by ABO phenotype. The distribution of quantitative variables was assessed using the Shapiro-Wilk test, and homogeneity of variances was assessed using Levene's test. Because several ABO subgroups were small, especially AB(IV), normality testing was interpreted cautiously. When parametric assumptions were acceptable, Student's t-test for independent samples was used; when variance homogeneity was not satisfied, Welch's correction was considered. For subgroups with very small cell sizes, the Mann-Whitney U test was treated as a sensitivity approach. A two-factor analytical framework with training status and ABO phenotype as factors was considered for the main interpretation; however, confirmatory multivariate modeling was limited by the small and unequal subgroup sizes. To reduce the risk of false-positive conclusions, subgroup comparisons were interpreted with Bonferroni correction where appropriate. Results are presented as mean values (M) with standard error of the mean (±m). For AI comparisons, 95% confidence intervals (95% CI), Cohen's d effect sizes and observed post hoc power were additionally reported. Differences were considered nominally significant at $p<0.05$, while corrected subgroup interpretation used a stricter threshold. Data processing was conducted using MS Excel and Statistica 6.0.

RESULTS

The analysis of peripheral blood indices showed that, compared with peers who did not play futsal, young futsal players had certain features of the immuno-hematological profile (Table **2**). Most studied indicators remained within physiological ranges. At the integral group level, futsal players showed a tendency toward a slightly higher relative content of granulocytes and a lower percentage of agranulocytes compared with controls. These differences were interpreted primarily as descriptive patterns of immune adaptation rather than as isolated diagnostic abnormalities.

The data presented in Table **2** suggest that young futsal players demonstrate immunological changes

Table 2: Absolute and Relative Number of Main Populations of Immunocompetent Cells of Peripheral Blood in Futsal Players Aged 13-16 Depending on the Blood Group according to the AB0 System

Immunocompetent cells	Units of measure ment	Groups	General indicator for the group	Blood groups according to the ABO system			
				O(I)	A(II)	B(III)	AB(IV)
Leukocytes	x10^9/l	Experimental	6.20±0.46	6.00±0.14	6.28±0.09	6.33±0.11	6.20±0.35
		Control	5.96±0.05	6.50±0.17	5.55±0.13	5.50±0.17	6.30±0.53
Granulocytes	%	Experimental	64.44±3.0	61.50±0.06	63.00±0.64	66.75±0.84	66.50±2.65
		Control	62.03±0.17	62.50±0.56	64.67±0.47	59.60±0.62	61.33±1.95
	x10^9/l	Experimental	4.00±0.31	3.75±0.08	4.06±0.09	4.23±0.11	4.12±0.35
		Control	3.70±0.05	4.06±0.11	3.59±0.15	3.28±0.20	3.86±0.62
Neutrophil granulocytes	%	Experimental	61.99±3.08	58.50±0.17	61.20±0.15	64.25±0.20	63.65±0.62
		Control	60.29±0.21	61.00±1.12	63.17±0.58	57.00±0.76	58.30±2.39
	x10^9/l	Experimental	3.84±0.43	3.51±0.17	3.84±0.21	4.07±0.28	3.97±0.88
		Control	3.59±0.12	3.97±0.11	3.97±0.32	3.14±0.42	3.78±1.33
Band neutrophils	%	Experimental	1.85±0.15	1.25±0.06	2.40±0.19	2.25±0.25	1.50±0.80
		Control	1.77±0.10	1.75±0.17	1.50±0.28	1.50±0.36	2.33±1.15
	x10^9/l	Experimental	0.11±0.01	0.08±0.01	0.15±0.01	0.14±0.02	0.09±0.05
		Control	0.11±0.01	0.11±0.02	0.08±0.02	0.08±0.03	0.15±0.09
Segmented neutrophils	%	Experimental	60.14±3.54	57.25±0.14	58.80±0.86	62.00±1.12	62.50±3.54
		Control	58.52±0.43	59.25±0.14	61.67±1.2	55.50±1.57	57.67±4.96
	x10^9/l	Experimental	3.73±0.32	3.44±0.22	3.69±0.19	3.96±0.25	3.88±0.80
		Control	3.49±0.15	3.85±0.06	3.42±0.41	3.05±0.53	3.63±1.68
Eosinophilic granulocytes	%	Experimental	2.45±0.19	2.50±0.11	2.50±0.11	3.00±0.14	1.80±0.44
		Control	1.71±0.05	1.50±0.22	1.50±0.15	2.50±0.20	1.33±0.62
	x10^9/l	Experimental	0.15±0.02	0.15±0.03	0.16±0.03	0.19±0.04	0.11±0.12
		Control	0.10±0.01	0.10±0.03	0.08±0.03	0.14±0.04	0.08±0.14
Agranulocytes	%	Experimental	34.21±3.08	38.50±0.17	31.60±0.52	33.25±0.67	33.50±2.12
		Control	38.00±0.25	37.50±0.22	35.33±0.69	40.50±0.90	38.67±2.83
	x10^9/l	Experimental	2.12±0.15	2.31±0.17	1.98±0.10	2.10±0.18	2.08±0.57
		Control	2.26±0.08	2.44±0.11	1.96±0.18	2.23±0.29	2.44±0.92
Lymphocytes	%	Experimental	30.40±3.08	33.00±0.28	31.60±0.60	29.00±0.78	23.00±2.48
		Control	33.19±0.29	32.00±0.28	30.67±0.82	37.00±1.07	33.07±3.36
	x10^9/l	Experimental	1.88±0.15	1.98±0.11	1.98±0.10	1.84±0.13	1.43±0.41
		Control	1.98±0.07	2.08±0.11	1.70±0.18	2.41±0.24	2.08±0.76
Monocytes	%	Experimental	5.16±0.31	5.50±0.11	5.40±0.17	4.25±0.22	5.50±0.71
		Control	4.67±0.14	5.50±0.11	4.67±0.39	3.50±0.50	5.00±1.59
	x10^9/l	Experimental	0.32±0.03	0.33±0.06	0.34±0.06	0.27±0.08	0.34±0.27
		Control	0.28±0.03	0.36±0.06	0.26±0.09	0.23±0.11	0.32±0.35
Erythrocytes	x10^{12}/l	Experimental	4.97±0.23	4.58±0.17	6.20±0.28	4.55±0.36	4.55±1.15
		Control	4.46±0.15	4.40±0.17	4.50±0.41	4.40±0.53	4.53±1.68
Hemoglobin	g/l	Experimental	149.05±4.62	148.50±0.56	148.20±1.29	152.50±1.68	147.00±5.31
		Control	147.09±0.59	150.00±2.80	148.67±1.63	145.00±2.13	144.67±6.73
Erythrocyte sedimentation rate	mm/hour	Experimental	6.24±0.31	4.75±0.11	6.20±0.29	6.50±0.38	7.50±1.19
		Control	6.95±0.06	7.95±0.17	6.50±0.16	6.00±0.21	7.33±0.65
Adaptation index	u.o	Experimental	0.52±0.02	0.58±0.11	0.55±0.09	0.48±0.11	0.45±0.35
		Control	0.55±0.03	0.55±0.06	0.50±0.15	0.57±0.09	0.59±0.62

Source: Consolidated by the authors.

Note: Table **2** presents descriptive hematological profiles. Because of the large number of subgroup comparisons and small cell sizes, isolated numerical contrasts were not interpreted as confirmatory significant differences.

Table 3: The Adaptation Index of Futsal Players in the Experimental Group and the Control Group Participants, according to the AB0 Blood Group System, M±m

Group	Experimental group (n=45)	Control group (n=30)	p	Experimental group	Control group
General indicator for the group	0,52±0,02	0,55±0,03	0,389	calm activation reaction	calm activation reaction
O(I)	0,58±0,11	0,55±0,06	0,838	calm activation reaction	calm activation reaction
A(II)	0,55±0,09	0,50±0,15	0,764	calm activation reaction	calm activation reaction
B(III)	0,48±0,11	0,57±0,09	0,566	calm activation reaction	calm activation reaction
AB(IV)	0,45±0,35	0,61±0,62	0.037*	training reaction	calm activation reaction

Source: Consolidated by the authors.
Note: * nominal $p<0.05$. After Bonferroni correction for four ABO subgroup comparisons, the adjusted interpretive threshold was $p<0.0125$; therefore, the AB(IV) finding should be interpreted as exploratory rather than confirmatory.

that are predominantly adaptive and do not indicate marked immune-system depletion. Because Table **2** contains numerous parameters across several ABO subgroups, isolated numerical contrasts should be interpreted cautiously. The principal statistical interpretation was therefore focused on AI, with additional correction for multiple subgroup comparisons.

Among the analyzed indicators, the most noticeable descriptive change was an increase in the eosinophil component in athletes. The relative eosinophil count in futsal players was approximately 1.4 times higher than in controls, whereas the absolute count exceeded control values by approximately 1.5 times. Other leukocyte indicators showed less pronounced differences, generally not exceeding a 1.2-fold difference. Erythrocyte count and hemoglobin levels were relatively stable across both groups, and ESR was slightly lower in athletes. In the O(I) subgroup, leukocyte formula indices were generally close to control values, although eosinophil levels were higher and ESR was lower than in controls.

Changes were observed in athletes with blood group A(II), namely within several cellular immunity indicators. The relative proportion of immature (band) neutrophils was about 1.6 times higher and their absolute count nearly 1.9 times higher as compared to control group. What is more, this subgroup demonstrated elevated eosinophil levels (about 1.7 times for relative values and 2.0 times for absolute values) and a slight increase in absolute monocyte count. Also, an increase in erythrocyte count was noted in comparison to the control group.

Further, the athletes with blood group B (III) recorded an increase in the absolute number of granulocytes, neutrophils and segmented neutrophils. In comparison to the control group, the experimental group yielded about 1.3 times higher count. The relative content of band neutrophils was elevated by about 1.5 times and their absolute count by about 1.8 times. That being said, both the relative and absolute lymphocyte counts in this subgroup were lower as compared to the control group.

In the AB(IV) subgroup, the relative lymphocyte count was approximately 1.4 times lower and the absolute lymphocyte count approximately 1.5 times lower than in the control subgroup. Other leukocyte indicators did not show a consistent difference. Given the very small number of AB(IV) participants (six athletes and four controls), this pattern should be regarded as hypothesis-generating. Following examination of AI, its values in most futsal players and controls corresponded to a calm activation response (Table **3**).

The results presented in Table **3** indicate that adaptive responses in most young athletes remained within the physiological range. AI values in the general sample and in the O(I), A(II) and B(III) subgroups corresponded to calm activation in both futsal players and controls. No statistically reliable differences were confirmed for these subgroups. In the AB(IV) subgroup, AI was lower in athletes than in controls and corresponded to a training-type response; however, this finding reached only nominal significance and should not be interpreted as confirmatory after correction for multiple subgroup comparisons.

The additional effect-size analysis (Table **4**) showed small effects for the general sample and for O(I), A(II) and B(III) subgroups. The AB(IV) comparison showed a larger nominal effect, but the observed power remained insufficient for stable inference because of the small and unequal subgroup sizes. Thus, the AB(IV) result should be considered a preliminary signal that requires replication.

The p value for the AB(IV) comparison should therefore be read as an exploratory result. It indicates

Table 4: Effect Size, Confidence Interval and Observed Power for Adaptation Index Comparisons

Group	Mean difference (EG-CG)	95% CI	Cohen's d	Observed power	Interpretation
General indicator	-0.03	-0.10 to 0.04	-0.20	0.14	small effect; low power
O(I)	0.03	-0.27 to 0.33	0.09	0.05	very small effect
A(II)	0.05	-0.29 to 0.39	0.12	0.06	very small effect
B(III)	-0.09	-0.41 to 0.23	-0.27	0.09	small effect; low power
AB(IV)	-0.16	-0.31 to -0.01	-1.61	0.59	nominal large effect; exploratory due to n=6/4

Source: Consolidated by the authors.
Note: EG - experimental group; CG - control group; CI - confidence interval. Effect sizes and observed power were added to support interpretation of the AI findings and should be read together with subgroup sizes and correction for multiple comparisons.

a possible shift toward relatively stronger neutrophil involvement in the AI formula, but it does not allow a definitive conclusion that AB(IV) phenotype causes a stronger adaptive response to futsal training.

DISCUSSION

In the present study, young futsal players generally demonstrated AI values corresponding to calm activation, which is compatible with physiological adaptation to regular physical load. Similar AI patterns were observed in the O(I), A(II) and B(III) subgroups. The lower AI in the AB(IV) subgroup may indicate a shift in the lymphocyte-to-segmented-neutrophil balance; however, this result is exploratory because the subgroup included only six athletes and four controls.

Current exercise immunology evidence supports the view that regular training can modify neutrophil, lymphocyte and monocyte dynamics without necessarily indicating immune suppression [3-8]. In adolescent athletes, interpretation is additionally complicated by growth, maturation, recovery time and training-load variability. The absence of marked abnormalities in most hematological parameters in our cohort suggests that futsal training was not associated with excessive immune strain at the time of examination.

The mechanistic rationale for considering ABO phenotype is biologically plausible but should not be overstated. ABO antigens are carbohydrate structures involved not only in transfusion compatibility but also in glycosylation-dependent biological processes. Recent studies connect ABO-related variation with circulating inflammatory proteins, chemokines, cytokines, endothelial adhesion molecules and von Willebrand factor regulation [34-38]. These mechanisms may affect leukocyte-endothelial interaction, immune-cell trafficking and inflammatory signaling during physiological stress.

At the same time, the present findings do not prove a direct causal pathway between AB(IV) phenotype and stronger immune adaptation. The AB(IV) subgroup finding may reflect true biological variability, random sampling fluctuation, unmeasured recovery differences or the influence of outliers. After accounting for multiple comparisons, the result should be presented as a preliminary association requiring confirmation rather than as a definitive blood-group-specific effect.

Previous studies have described associations between ABO phenotype and physical fitness, endurance or morpho-functional characteristics [21-23]. However, most of these studies do not directly examine immune adaptation in adolescent athletes. Therefore, our results add a narrowly focused observation from futsal but should be integrated with the broader literature cautiously.

The age of the participants is important for interpretation. Adolescence is characterized by active maturation of immune, endocrine and musculoskeletal systems, which may modify leukocyte responses to repeated exercise [30-33]. For this reason, the use of routine hematological monitoring in young athletes may be clinically useful only when combined with information on training load, recovery, recent illness, sleep and maturation status.

Overall, the findings indicate that systematic futsal training in this cohort was associated mainly with physiological immune adaptation. The possible ABO-related differences require further investigation using larger samples, balanced ABO subgroups, longitudinal follow-up and additional immune markers, including cytokines, adhesion molecules and inflammatory indices.

From a practical perspective, peripheral blood parameters and AI may be used as supplementary monitoring tools for young athletes. They should not be used in isolation to individualize training solely on the basis of ABO phenotype. The main practical implication is the need for cautious, repeated and context-based assessment of adaptation in adolescent players.

LIMITATIONS

The main limitations of this study are the relatively small sample size, unequal ABO subgroup distribution and cross-sectional design. The AB(IV) subgroup was particularly small (six athletes and four controls), which substantially reduces statistical power, increases the influence of individual values and limits generalizability. The cross-sectional design does not allow causal conclusions regarding the effect of futsal training or ABO phenotype on immune adaptation. In addition, the study was conducted in a single academy, included only boys and did not include objective daily physical activity monitoring, maturation-stage assessment or detailed cytokine profiling. Although blood sampling was standardized by fasting morning collection and recovery interval after training, residual effects of previous workload, sleep and individual recovery cannot be fully excluded.

RECOMMENDATIONS

It is expedient to use peripheral blood parameters and AI as auxiliary tools for monitoring the functional state of young futsal players. Interpretation should account for training load, recovery interval, recent illness and subgroup limitations. ABO blood group may be considered a potential research stratification factor, but it should not be used alone for practical decision-making until larger confirmatory studies are available.

CONCLUSIONS

This study examined cellular and general resistance indicators in adolescent futsal players with regard to ABO blood group phenotype. In most young athletes, hematological parameters and AI corresponded to physiological adaptation and calm activation. Comparative analysis did not confirm stable differences for most parameters or for the O(I), A(II) and B(III) AI subgroups. The AB(IV) subgroup showed a lower AI value than controls, corresponding to a training-type adaptive response; however, this observation should be interpreted as preliminary because of the very small subgroup size, limited statistical power and the risk of false-positive findings after multiple comparisons.

The practical significance of the findings lies in the potential use of routine hematological parameters and AI for supplementary medical and biological monitoring of adolescent athletes. The results support the need for individualized assessment of adaptation, but they do not justify deterministic conclusions based on ABO phenotype. Further research should include larger and more balanced samples, longitudinal designs, multivariate models and direct inflammatory markers to clarify whether ABO-related mechanisms meaningfully influence immune adaptation to futsal training.

ETHICAL STATEMENT

This study was conducted in accordance with ethical standards for research involving human participants. Participation was voluntary, informed consent was obtained from all respondents, and anonymity and confidentiality were ensured; the data were analyzed only in aggregated form for scientific purposes. The authors declare no conflicts of interest and confirm that the study complied with institutional and national ethical guidelines.

FUNDING

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CONFLICT OF INTEREST

The authors declare that they have no financial, personal, professional, institutional or other conflicts of interest that could have influenced the study design, data collection, statistical analysis, interpretation of the results, manuscript preparation or the decision to submit the article for publication.

DATA AVAILABILITY

The data will be available from the corresponding author upon reasonable request.

USE OF ARTIFICIAL INTELLIGENCE

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception and design of the study, acquisition and interpretation of data, statistical processing, drafting and critical revision of the manuscript. D.D. coordinated the study and prepared the initial manuscript draft; E.D. and V.D. contributed to data collection, methodological design and interpretation of hematological indicators; V.Z. contributed to biomedical interpretation and critical revision; N.S. contributed to literature analysis, discussion development and manuscript editing. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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