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ASSESSMENT OF THE RELATIONSHIP BETWEEN MORPHOFUNCTIONAL INDICATORS AND PHYSICAL FITNESS OF GENERAL SECONDARY SCHOOL STUDENTS BASED ON CANONICAL CORRELATION ANALYSIS

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Annotation. The article examines the multivariate relationship between morphofunctional indicators and the level of physical fitness of 12–13-year-old school students using canonical correlation analysis. It was found that morphological growth indicators, particularly body length and the proportion of muscle tissue, are closely associated with speed-strength qualities. At the same time, an increase in subcutaneous fat percentage was noted to have a negative effect on movement performance. The obtained results demonstrate that the method of canonical analysis enables a comprehensive and scientifically grounded assessment of physical fitness, and the scientific-theoretical as well as practical aspects of this approach are analyzed.

Keywords: morphofunctional indicators, physical fitness, canonical correlation analysis, school students, anthropometry, motor abilities, multivariate analysis, physical development

In our country, the systematic development of physical education and mass sports is currently considered one of the priority directions at the level of state policy. In recent years, adopted regulatory and legal documents have been aimed at modernizing the field of physical education and sports, strengthening its organizational, methodological, and scientific foundations, as well as increasing the physical activity of the younger generation [1]. In this context, the scientific assessment and monitoring of the physical development level of general secondary school students are of great importance.

The introduction of unified criteria for assessing physical fitness has expanded the possibilities for an in-depth study of the relationship between morphofunctional indicators and physical fitness of school students. This, in turn, has significant scientific and practical

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importance in improving the physical education process in educational institutions, conducting systematic analysis of students' morphofunctional status, and promoting a healthy lifestyle [3,5].

From a scientific perspective, physical development reflects the processes of growth, morphological formation, and functional improvement of the organism during ontogenesis [4,7,8,10,12]. At the general school age, morphofunctional indicators such as body length, body weight, and the ratio of muscle and fat tissues are closely related to the level of physical fitness and motor abilities [9,13]. However, since these indicators have a multifactorial and interrelated nature, their assessment using only pairwise correlation methods does not always provide comprehensive scientific results [12].

Therefore, there is a need for a comprehensive evaluation of the relationships between two interrelated multivariate sets, such as morphofunctional indicators and physical fitness test results. Canonical correlation analysis is an effective multivariate statistical method used for this purpose, as it allows determining the maximum integrated relationship between sets of variables. This method evaluates not individual indicators, but the relationships between their linear combinations, thereby identifying the leading morphofunctional factors that determine physical fitness [11,12].

In this regard, assessing the relationship between morphofunctional indicators and physical fitness of general secondary school students based on canonical analysis represents a relevant scientific and practical task.

Materials and Research Methods:

This study was conducted among 12–13-year-old students studying in general secondary schools in the city of Fergana during the 2024–2025 academic year. A total of 162 students participated in the research, including 82 students aged 12 (41 boys and 41 girls) and 80 students aged 13 (40 boys and 40 girls).

Aim of the Study and Research Methods:

The aim of the study was to assess the relationship between morphofunctional indicators and physical fitness of general secondary school students based on canonical correlation analysis. For this purpose, the multivariate relationships between morphofunctional parameters (anthropometric indicators) and physical fitness tests were examined using canonical correlation analysis.

The results of the canonical analysis were mainly presented using the example of a group of 13-year-old boys (n = 40). In this group, the highest canonical correlation coefficient between morphofunctional indicators and physical fitness results was observed, which ensured the reliability of the analysis.

During the research process, international bioethical standards, as well as sanitary and hygienic requirements related to working with children, were strictly observed.

The study was conducted in the following stages:

– pedagogical observation;

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- anthropometric measurements;

– physical fitness testing;

- mathematical and statistical analysis.

Anthropometric measurements were carried out based on generally accepted classical anthropometry methods. The procedures developed by R. Martin were applied during the measurements. Body height was measured using a stadiometer, and body weight was determined using an electronic scale. In addition, shoulder and lower limb segment lengths, chest diameter, and shoulder circumference were measured using standard anthropometric instruments. All measurements were conducted under uniform conditions, in the morning, and with participants wearing light sportswear.

To assess the level of physical fitness, the following tests were used: a 30-meter sprint (speed), 3×10 m shuttle run (speed and agility), 500-meter run (endurance), ball throwing (strength), push-ups (muscular strength), and flexibility tests. These tests allowed for a comprehensive evaluation of the main physical qualities of the students.

The obtained data were processed using the SPSS 26.0 statistical software package. Canonical correlation analysis was applied to determine the relationships between morphofunctional indicators and physical fitness tests. During the analysis, Wilks' Lambda (Λ), χ^2, and p-values were calculated. The level of statistical significance was set at $p < 0.05$. The results of the study are presented in Table 1.

Table 1

Experimental Results

No.	Age	Gender	Sample Size	Height (cm)	Weight (kg)	Muscle Tissue (%)
				$\bar{x}\pm\sigma$	$\bar{x}\pm\sigma$	$\bar{x}\pm\sigma$
1.	12	Ўғил болалар	41	142,4±7,7	31,5±3,8	45,7 ± 2,5
		Қиз болалар	41	138,7±5,3	29,8±4,6	42,9 ± 2,2
2.	13	Ўғил болалар	40	145,4±5,1	32,5±3,8	44,6 ± 2,6
		Қиз болалар	40	142,5±5,4	28,2±6,3	42,3 ± 2,1

Table 2

Results of Canonical Analysis for 13-Year-Old Boys

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Canonical Function	P	P^2	Wilks' Lambda (Λ)	χ^2	df	п
1.	0,852	0,726	0,214	48,63	28	< 0,001
2.	0,412	0,169	0,681	12,84	18	0,78

Table 2 presents the results of the canonical correlation analysis assessing the relationship between morphofunctional indicators and physical fitness of general secondary school students (13-year-old boys).

According to the analysis results, the first canonical function demonstrated a high level of relationship (R = 0.852), indicating a strong integrated association between morphofunctional parameters and physical fitness indicators.

The canonical coefficient of determination (R^2 = 0.726) shows that 72.6% of the total variance is explained by the first canonical function.

In addition, the results of the statistical criteria (Λ = 0.214; χ^2 = 48.63; $p < 0.001$) confirm that this canonical function is statistically significant.

The second canonical function was not interpreted, as it was not statistically significant (p = 0.78).

Table 3

Standardized Coefficients of the First Canonical Function for 13-Year-Old Boys (n = 40)

№	Кўрсаткичлар	β
	Morphofunctional Parameters	
1.	Body height	0,68
2.	Leg length	0,54
3.	Shoulder circumference	-0,61
4.	Muscle tissue (%)	0,49
5.	Subcutaneous fat (%)	-0,44
6.	Skinfold thickness	-0,34
	Physical Fitness Tests	
7.	30 m sprint	-0,71

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8.	3×10 m shuttle run	-0,64
9.	Ball throwing	0,69
10.	500 m run	-0,42
11.	Push-ups	0,57
12.	Flexibility	0,36

Table 3 presents the standardized coefficients (β) of the first canonical function, describing the relationship between morphofunctional indicators and physical fitness tests in general secondary school students (13-year-old boys, n = 40). These coefficients reflect the integrated multivariate relationship between the two sets of variables under study.

The analysis of morphofunctional indicators showed that body height (β = 0.68), leg length (β = 0.54), and muscle tissue percentage (β = 0.49) made the greatest contribution to the first canonical function. These results indicate that during adolescence, segmental growth and the development of the muscular system are closely associated with the formation of motor abilities.

At the same time, shoulder circumference (β = –0.61) and subcutaneous fat percentage (β = –0.44) had negative loadings, indicating that excess body mass and fat components negatively affect speed and endurance performance. Skinfold thickness (β = –0.34) showed a relatively lower coefficient, suggesting that this variable is not a leading factor within the first canonical function.

Among the physical fitness tests, the highest loadings were observed in the 30 m sprint (β = –0.71), 3×10 m shuttle run (β = –0.64), and ball throwing (β = 0.69). This confirms that speed and strength qualities at this age are closely related to the level of morphological development. The relatively high loading in the push-up test (β = 0.57) can be explained by the functional state of the muscular system.

The 500 m run (β = –0.42) demonstrated a moderate level of association, while flexibility (β = 0.36) was found to have relatively lower importance within the first canonical function.

In general, the obtained results indicate that the first canonical function represents a комплексный morpho-motor component that integrates morphological growth, muscle development, and speed-strength qualities.

Table 4

Canonical Loadings (Structure Coefficients, $r_s > 0.40$)

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№	Body height	p_s
1.	Leg length	0,74
2.	Muscle tissue	0,71
3.	Subcutaneous fat	0,66
4.	30 m sprint	-0,59
5.	Ball throwing	-0,81
6.	Push-ups	0,78
7.	3×10 m shuttle run	0,62
8.	Body height	-0,60

The results of the conducted study showed that there is a statistically significant relationship between morphofunctional indicators and the level of physical fitness of general secondary school students . In particular, it was found that the proportion of muscle tissue and body height are strongly associated with motor abilities.

In the group of 13-year-old boys, the canonical correlation coefficient obtained for the first canonical function (R = 0.852) indicates that morphological and functional parameters jointly determine motor abilities in a complex manner. This result reflects a high level of integrated relationship and confirms the internal consistency of the studied system of indicators .

The analysis of canonical coefficients demonstrated that body height, leg length, and muscle tissue percentage are positively associated with physical fitness test results. This scientifically substantiates that, during adolescence, morphological growth processes are closely related to the development of motor qualities. In particular, the strong association of muscle tissue percentage with the 30 m sprint, ball throwing, and push-up tests indicates the morphofunctional basis of speed and strength qualities .

At the same time, indicators related to fat tissue (subcutaneous fat percentage and skinfold thickness) showed negative coefficients, suggesting that excess fat mass may reduce the efficiency of motor activity. This finding emphasizes the importance of monitoring body composition in the physical education process .

The non-significance of the second canonical function (p = 0.78) indicates that the main relationship between morphofunctional indicators and physical fitness is fully explained by the first canonical function. Therefore, at this age stage, the leading factors determining motor abilities are directly related to the level of morphological development .

The use of canonical correlation analysis made it possible to comprehensively assess multivariate relationships between sets of variables, demonstrating its advantage over traditional pairwise correlation analysis. This method allows identifying the integral effect of morphofunctional parameters on physical fitness as a unified statistical indicator .

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From a practical perspective, the obtained results indicate that comprehensive assessment of morphofunctional status can serve as a scientific basis for individualizing physical education, optimizing training loads, and improving students' motor abilities. In addition, this approach enables early identification of potential deviations in physical development and the development of preventive measures .

However, the study has certain limitations. In particular, the analysis was conducted within a limited age group (12–13 years) and a relatively small sample size (especially n = 40), which requires caution when generalizing the results. Moreover, the cross-sectional nature of the study limits the ability to assess dynamic changes. Therefore, future studies should include larger samples, longitudinal designs, and additional physiological and biomechanical indicators .

Conclusion:

The results of the study confirmed the presence of a statistically significant multivariate relationship between morphofunctional indicators and physical fitness in 12–13-year-old school students. In particular, the first canonical function identified in the group of 13-year-old boys ($R = 0.852$; $p < 0.01$) reflects a high level of integrated relationship, confirming that morphofunctional status plays a key role in determining motor abilities at this age.

The findings showed that body height, leg length, and muscle tissue percentage are leading factors positively associated with speed- and strength-related physical indicators, whereas fat-related parameters demonstrate negative relationships. This confirms that body composition and morphological development are essential determinants of physical fitness during adolescence.

The application of canonical correlation analysis proved to be an effective tool for identifying complex relationships between variable sets and provides a more comprehensive evaluation compared to traditional correlation methods. The obtained canonical index can be considered an integral indicator for assessing students' physical fitness.

From a practical standpoint, these results provide a scientific basis for individualizing the physical education process, optimizing training loads based on morphofunctional characteristics, and improving assessment systems. At the same time, they enable early detection of potential deviations in physical development among students.

Nevertheless, due to the relatively small sample size and limited age range, caution is required when generalizing the results. Future research should expand the sample size, incorporate longitudinal approaches, and include additional functional and physiological parameters.

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