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Morphometric correlates of the physical development structure of combat athletes in the process of ensuring special work capacity

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Abstract

Background and Study Aim Despite extensive training, combat athletes often face challenges in optimizing their physical development to enhance performance and work capacity. This study aims to examine the interrelations of key parameters within the physical development (PD) structure of highly skilled combat athletes in the process of ensuring special work capacity.

Material and Methods Between 30 and 83 wrestlers of different weight categories and skill levels, all members of the national teams of Ukraine in freestyle and Greco-Roman wrestling, and judo, participated in various studies. The age of the subjects ranged from 18 to 31 years. The combat athletes aged 18-24 years old were students of Ukrainian universities. A total of 56 indices of PD, speed-strength fitness, and special work capacity of the combat athletes were registered. The special work capacity of wrestlers was estimated based on the intensity of performing 15 specialized throws of a partner of equal weight in 3 series. Each series of throws was performed 3 times, with a rest interval of 1 minute between the series.

Results The studies revealed that in the morphometric component of combat athlete PD structure, the circumference dimensions of the body are more integrated compared to the longitudinal, transverse, anteroposterior dimensions, and other parameters. The most highly interconnected circumferences are those of the neck, thorax, relaxed and tensed shoulder, forearm, hip, and shin. These parameters show the highest correlation with both the athletes' skill level and the integral parameters of PD, such as body weight, surface area, weight category, and Quetelet index. An increase in wrestlers' skill level is associated with an increase in the neck, chest, shoulder, and hip circumferences. It also correlates with the enhancement of anaerobic work capacity and the formation of the morphofunctional profile of highly skilled combat athletes. Multiple regression models reflecting these dependencies were developed.

Conclusions The thorax, thigh, shoulder, and neck circumferences are key parameters of the morphometric component of combat athlete PD structure. They are the most integrated into the general structure of physical fitness and determine the integral parameters of PD, the level of anaerobic work capacity, and the strength endurance of wrestlers with a high degree of accuracy. The specificity of improving PD structure and special fitness of combat athletes is manifested in the fact that, as the athlete's skill level increases, the volumes of the thorax, neck, shoulder, and thigh increase to the greatest extent. Their interrelations among themselves, with the integral parameters of PD, and with the level of anaerobic work capacity, speed, and speed-strength endurance tend to enhance. The developed models can be used for predicting the PD structure of combat athletes of different skill levels and weight categories. They can also be utilized for assessing special work capacity and designing appropriate normative evaluation scales.

Keywords: physical development, wrestlers, skill level, category, interrelations, models.

Introduction

Combat athletes often struggle to optimize their physical development (PD) to enhance performance, despite extensive training. Additionally, the interaction between different fitness components can lead to inconsistencies in achieving peak physical condition.

PD is one of the key components of the general fitness structure (FS) of combat athletes [1, 2, 3, 4]. The PD improvement of combat athletes in the dynamics of the years-long training process occurs in interaction with the enhancement of technical, psychological, and functional fitness, which are components of athletes' general FS. The development and improvement of each component of athletes' FS in the process of long-term adaptation to physical loads occur interdependently [5]. As a result, the structure of special fitness of combat athletes is formed [2, 3], which differs from the FS of athletes in other sports.

Despite numerous publications devoted to

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the study of the specificity of morphofunctional reorganizations in the bodies of combat athletes, most of them reflect only some aspects of their FS: the level of physical development [6, 7], special physical [8, 9, 10], technical [11, 12], psychological [13], or functional [14, 15, 16] fitness. Some works analyzing the morphometric parameters of athletes' PD did not account for their interrelation with other components of combat athletes' FS during sports improvement [4, 10, 17]. This omission reduced the value of such studies.

It should be noted that there are few publications in public sources that highlight the ratios and interrelations of different morphometric parameters of PD in the process of forming and improving the general FS of combat athletes. These aspects include the formation of athletic form, improvement of sports skills, and enhancement of special work capacity from complex and systemic standpoints [1, 18, 19]. However, even these works fail to fully analyze the structure of physical fitness (PF) of combat athletes in the dynamics of improving their sportsmanship, special work capacity (SWC), skill level, and weight categories. Accordingly, algorithms for monitoring its structure in the process of sports perfection are insufficiently developed [3, 5, 20, 19]. The model characteristics of combat athletes' PF structure are either lacking or insufficiently differentiated. No studies on models have been conducted [5, 21].

In our previous studies on the PF structure of combat athletes, we determined the key morphometric parameters of PD. Additionally, we investigated their interrelations with speed-strength indices and SWC of combat athletes [2, 3]. At the same time, mathematical models reflecting the impact of individual components of wrestlers' FS on the level of SWC were also developed. These models revealed the dependences of PD level, speed-strength fitness, and SWC on the weight category and skill level of athletes [2, 3, 5].

However, the mathematical models presented in these works were insufficiently differentiated by the level of PD, speed-strength fitness, the nature of SWC energy supply, strength, or speed-strength endurance. This was particularly evident in wrestlers of different weight categories, skill levels, and considering criteria such as age, sex, and type of combat sport. Naturally, these limitations restricted their evaluative, prognostic, and practical significance.

Our earlier developed mathematical models [3] were static and did not allow for precise modeling of the variations in the ratios and interrelations of key morphological, speed-strength, or functional components of FS in the process of providing the level of SWC for wrestlers of individual weight categories, types of combat sports, and skill levels.

The limitation of an analytical approach to the coverage of athletes' FS [6, 8, 21] prevented researchers from analyzing the influence of integral parameters of PD, speed-strength fitness, and skill level on the key morphometric parameters of PD, level of SWC, and speed-strength endurance of wrestlers from a systemic standpoint.

Given that most authors covered the PD structure of combat athletes unilaterally, without analyzing the integration of its components to provide SWC, the interrelations of PD parameters in athletes of different skill levels and weight categories were determined as the object of the present study.

This study aims to examine the interrelations of key parameters within the physical development (PD) structure of highly skilled combat athletes in the process of ensuring special work capacity.

Material and Methods

Participants

From 30 to 83 wrestlers of seven weight categories (55, 60, 66, 75, 84, 96, and 130 kg) participated in various studies. Highly skilled wrestlers, as well as members of the national teams of Ukraine in freestyle and Greco-Roman wrestling and judo, were examined. The age of the subjects ranged from 18 to 31 years. Combat athletes aged 18-24 years old were students of Ukrainian universities.

The study protocol was approved by the Ethics Committee of the University. The research was conducted in compliance with the WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects [22].

Study Design

To assess the PD structure of combat athletes, 56 morphometric indices of girth, transverse, anteroposterior, and longitudinal body dimensions were recorded along with body composition determination. Anthropometric methods were used to register the PD indices, and body composition was determined by the caliperometry method.

The tasks of the present study were addressed by processing and analyzing the key parameters of body circumference dimensions (BCD), which are most closely correlated with each other, body mass, skill level, and work capacity of athletes [3].

The level of special work capacity (SWC) and endurance of wrestlers was evaluated using a specialized test. An athlete performed 3 series of throws of a partner of equal weight, with 15 throws in each series at maximum speed. The rest interval between the series was 1 minute. The time of performance of throws in each series and the total time of performance of 45 throws were recorded.

Statistical analysis

Correlation, regression, and analysis of variance methods were used for processing the experimental material. The statistical software package

STATISTICA 14.01.25 [23] and Excel were utilized for the analysis. Appropriate mathematical models were developed.

Results

Table 1 presents the average values of correlation coefficients reflecting the interrelations between the indices of each of the analyzed groups of PD: circumference, longitudinal, transverse, and anteroposterior dimensions, fat and skin folds, and body composition. The mean values of the correlation coefficients were determined in each group (Table 1). The mean values of the correlation coefficients (Table 1) indicate that the body circumference dimensions (BCD) are more integrated compared to the longitudinal, transverse, anteroposterior dimensions, fat and skin folds, and body composition components ($r = 0.803$, $p < 0.001$).

Statistical analysis of 56 parameters of the FS morphometric component of combat athletes showed that the circumference dimensions of the neck, thorax at rest and during inhalation, relaxed and tensed shoulder, forearm, hip, and shin were most strongly interconnected with each other. BCD also demonstrate the highest interrelation with the athletes' skill level and the integral parameters of PD - body mass, weight category, body surface, and Quetelet index (Table 2).

The mean group correlation coefficient of BCD shows strong interrelations with several integral parameters of physical development (Table 2). The highest correlation is observed with body mass and Quetelet index, indicating that as body mass increases, so do the body circumference dimensions. There is also a significant correlation with surface area and weight category, suggesting that larger surface areas and higher weight categories are associated with greater body circumferences. Additionally, a moderate correlation with skill level indicates that more skilled athletes tend to have larger body circumferences.

Table 3 presents paired correlation coefficients between individual BCD indices with integral PD indices, skill level and the level of special PF. Different values of correlation coefficients imply that the special training of wrestlers, expressed by skill level and the level of special work capacity, is differently related to individual morphological parameters.

Linear regression models were calculated for each pair correlation, in which individual indices of body circumference dimensions (y) were considered as dependent parameters, whereas integral indices of PD and skill level - as determining (Table 4). Most of the equations (Table 4) reflect the linear dependence of the key BCD on individual integral indices of PD and combat athletes' skill levels.

On the other hand, individual BCD parameters depend differently on the simultaneous impact of integral parameters, such as body mass and surface area, weight category, and athletes' skill level. For instance, the dependencies presented in models 1-2 indicate that circumferences of the thigh and tensed shoulder depend differently on the athletes' skill level and weight category (Y_1 and Y_2).

$$Y_1=43.82+2.\ 92x_1+2.34\ x_2 \pm 1.78.\ p<0.000001 \quad (1)$$

where: Y_1 – thigh circumference, cm; x_1 – skill level, c.u.; x_2 – weight category, c.u.

$$Y_2=17.44+1.09\ x_1+0.189\ x_2 \pm 1.78.\ p<.000001 \quad (2)$$

where: Y_2 – tensed shoulder circumference, cm; x_1 – skill level, №; x_2 – weight category, c.u.

Table 1. Average values of intragroup interrelations of physical development parameters in combat athletes (combined group by skill levels and weight categories)

Body dimensions	Body circumference dimensions	Body longitudinal dimensions	Transverse and anteroposterior dimensions	Fat and skin folds	Body composition
$\bar{x}$	0.803	0.472	0.529	0.367	0.325
±m	0.034	0.014	0.045	0.031	0.097
±s	0.213	0.197	0.169	0.23	0.422
n	41	210	15	55	20
P	<0.001	<0.05	<0.01	<0.05	<0.05

Table 2. Mean values of the interrelations of different physical development groups in highly skilled wrestlers.

PD indices	Body mass	Surface area	Quetelet index	Category	Skill level
Body circumference dimensions	0.824±0.08	0.798±0.1	0.829±0.08	0.636±0.09	0.521±0.08
Body longitudinal dimensions	0.614±0.06	0.654±0.06	0.567±0.05	0.587±0.05	0.246±0.04
Transverse and anteroposterior dimensions	0.703±0.05	0.713±0.05	0.683±0.05	0.604±0.06	0.442±0.07
Fat and skin folds	0.372±0.08	0.319±0.08	0.400±0.08	0.281±0.09	0.201±0.07
Body composition	0.211±0.06	0.198±0.04	0.225±0.06	0.193±0.08	0.198±0.08

Table 3. Correlation coefficients between individual circumference dimensions and indices of physical development, skill level, and the level of special physical fitness

Morphometric indices		Skill level	Weight category	Body mass	Quetelet index	Surface area	Time of throws	Pull-ups
		n=30	n=30	n=30	n=30	n=30	n=30	n=30
Circumference dimensions	Neck	0.575*	0.770*	0.911*	0.910*	0.910*	-0.475*	-0.401*
	Thorax at rest	0.651*	0.778*	0.951*	0.963*	0.930*	-0.580*	-0.464*
	Thorax during inhalation	0.613*	0.768*	0.931*	0.920	0.928	-0.567	-0.379
	Thorax during expiration	0.627*	0.776*	0.954*	0.960*	0.929*	-0.575*	-0.487*
	Abdomen	0.133	0.172	0.259	0.306	0.194	-0.015	-0.429*
	Relaxed shoulder	0.569*	0.674*	0.891*	0.916*	0.841*	-0.468*	-0.392*
	Tensed shoulder	0.588*	0.786*	0.923*	0.933*	0.889*	-0.485*	-0.394*
	Forearm	0.538*	0.793*	0.952*	0.951*	0.930*	-0.427*	-0.462*
	Shin	0.372*	0.266	0.496*	0.491*	0.479*	-0.167	-0.099
	Thigh	0.547*	0.848*	0.970*	0.968*	0.947*	-0.368*	-0.522*
	$\bar{x}$	0.521*	0.663*	0.824*	0.829*	0.798*	-0.413*	-0.403*
	±m	0.052	0.080	0.081	0.077	0.085	0.062	0.039

*- statistically significant correlation coefficients

Table 4. Regression models of dependence of individual circumference indices of athletes on integral indices of physical development and skill level

Morphometric indices		Skill level and PD integral indices (x)				
		Skill level	Category	Body mass	Surface area	Quetelet index
Circumference dimensions (y)	Neck	35.6+2.2x*	35.4+1.29x*	27.9+0.15x*	19.3+11.0x*	23.3+0.04x*
	Thorax at rest	85.7+6.3x*	86.4+3.38x*	67.7+0.39x*	43.9+29.0x*	52.6+0.11x*
	Relaxed shoulder	26.7+2.5x*	26.9+1.34x*	19.0+0.16x*	9.2+12.0x*	11.8+0.05x*
	Tensed shoulder	28.5+2.7x*	28.2+1.63x*	18.7+0.2x*	8.98+13.3x*	12.4+0.05x*
	Forearm	25.7+1.48x*	25.3+0.97x*	19.7+0.12x*	13.3+8.2x*	15.9+0.03x*
	Shin	33.6+1.9x*	35.1+0.59x	30.4+0.09x	22.5+7.9x*	25.0+0.03x*
	Thigh	48.1+4.3x*	46.3+2.97x*	28.7+0.36x*	11.8+24.0x*	19.05+0.09x*

*- statistically significant dependences.

The analysis of variance of two-factor complexes showed that tensed shoulder circumference was 65.4% due to weight category and 6.3% to skill level, whereas that of the thigh was 84.4% (p<0.00001) due to weight category and 5.7% to skill level (p<0.001). The results of the analysis of variance indicate that the weight category of athletes exerts the dominant influence on the circumference of the shoulder and thigh. The degree of its impact on the circumference of the shoulder and thigh constitutes 65.4% (p<0.00001) and 84.4% (p<0.00001), respectively. The impact of skill level on these parameters is less and ranges from 6.3% (p<0.00001) for the shoulder to 5.7% (p<0.00001) for the thigh.

At the same time, the wrestlers' skill level demonstrates a high interrelation with the time of performing 15 throws in the first series of speed-strength test: the values of correlation (r = -0,776, p<0.00001) and determination coefficients (d = 0.602. p<0.00001) indicate that 60.2% of the result variability in the anaerobic test is due to skill level (t = 6.4, p<0001). The higher the skill level, the shorter the time of 15 throws, the higher their intensity, anaerobic power and SWC (Fig. 1). Total testing time shows less dependence on wrestler skill level (r

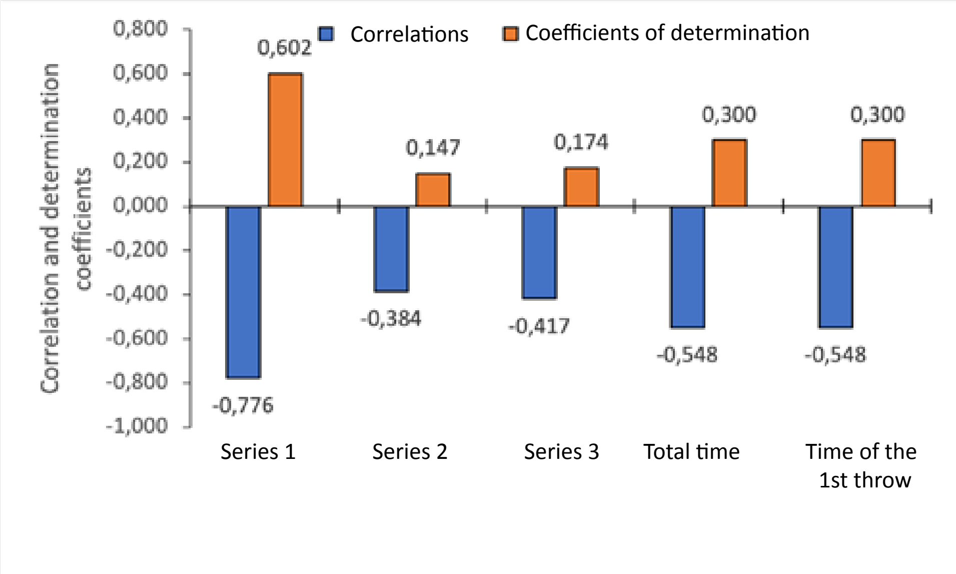

Figure 1. Correlation and determination coefficients between time of performing throws in 3 series of a specialized test and skill level of combat athletes

= -0.548, p<0.002). The coefficient of determination (d = 0.300, p<0.002) indicates that 30.0% of the variation in speed endurance indices is due to skill level (t=3.4, p<0001) and 70% to other factors.

The stepwise regression analysis allowed determining the key indices of BCD that influence the integral indices of PD and PF of combat athletes. Table 5 presents regression models of body mass, Quetelet index, weight category, special physical fitness (according to the number of pull-ups and time of performing 15 throws at the maximal rate in three series) dependence on some indices of BCD. Models 1-3 (Y_1-Y_3) reflect the dependencies of the athlete's mass, weight category, and Quetelet index on the circumference of the thorax, thigh, shin, neck, and forearm. According to models 1-3, the PD structure of wrestlers is determined above all by the circumference of the thorax, thigh, shin, neck, shoulder, and forearm. The structure of each model reflects not only the partial influence of individual indices on the integral parameters of PD, but their total impact and that of their ratios.

Body mass, weight category, and Quetelet index are interdependent integral parameters. They exhibit the highest interrelations with the key BCD parameters. BCD are most closely integrated in the structure of athletes' PD (r=0.824, p<0,0001), in contrast to the longitudinal, transverse, anteroposterior dimensions and body composition parameters of wrestlers (Table 1). This is also confirmed by the multiple correlation and determination coefficients in the first three models (Y_1-Y_3) presented in Table 5. The relationships manifested in models Y_1-Y_3 reflect the linear dependence of body mass (and weight category, respectively) and Quetelete index of athletes on the circumference of the neck, forearm, shoulder, thorax, and thigh.

The dependences of wrestlers' skill level (Y_4), anaerobic alactate work capacity (when performing throws at the maximum pace - Y_5), and strength endurance (during the performance of the maximum number of pull-ups - Y_6) on the key BCD are reflected in models 4-6 (Y_4-Y_6) (Table 5). The correlation and determination coefficients are somewhat lower in comparison with the coefficients between the generalized parameters of PD and BCD.

Table 6 presents mathematical models reflecting the dependence of individual BCD parameters on generalized parameters of PD and wrestler skill level. The dependencies of the thorax (Y_1), neck (Y_2), and thigh (Y_3) circumference on the Quetelet index (x_1), weight category (x_2), skill level (x_3), surface area (x_4), and mass (x_5) of the athlete are reflected in models 1-3 (Y_1-Y_3). Multiple correlation and determination coefficients indicate that each of the 4 BCD indices (Y_1 - Y_4) shows a high dependence on the influence of several model parameters: total PD level, weight category, athlete mass, and skill level.

Paired correlations presented in Table 3 reflect statistically significant average values of interrelations of individual BCD indices with wrestlers' skill level: skill level improvement is associated with the increase of the neck (r=0.575, p<0.05), thorax (r=0.613-0.651, p<0.01), shoulder (r=0.569-0.588, p<0.01), and thigh (r=0.547, p<0.05) circumferences.

Even lower paired correlations are manifested between individual indices of BCD and those of anaerobic alactate work capacity, as well as strength endurance. The group average coefficient of paired correlations of BCD with the time of performing 15 throws (anaerobic test) and the number of pull-ups until exhaustion (strength endurance test)

Table 5. Regression models of the dependence of physical development and skill level parameters upon individual indices of body circumferences

	Regression model	Correlation (r) and determination (d) coefficients	P
1.	$Y_1 = (0.994x_1 + 0.310x_2 + 1.083x_3 + 2.01x_5 - 0.14x_4 - 105.8) \pm 2.27$	r= 0.991. d = 0.982	<0.0000
2.	$Y_2 = (3.49x_1 + 2.702x_2 + 11.52x_5 + 0.245x_6 - 0.898x_4 - 337.2) \pm 8.6$	r= 0.992. d = 0.985	<0.0000
3.	$Y_3 = (0.04x_1 + 0.87x_5 + 0.60x_7 - 0.09x_4 - 0.78x_8 - 14.98) \pm 0.7$	r= 0.924. d = 0.854	<0.0000
4.	$Y_4 = (0.112x_2 + 0.127x_3 + 0.134x_7 - 0.19x_1 - 0.024x_4 - 6.54) \pm 0.6$	r= 0.767. d = 0.588	<0.0000
5.	$Y_5 = (0.141x_2 + 0.058x_9 - 0.331x_5 - 4.59) \pm 0.6$	r= 0.719. d = 0.518	<0.0001
6.	$Y_6 = (72.3 + 2.9x_3 + 0.63x_9 + 3.78x_7 - 0.18x_6 - 1.5x_1 - 4.7x_5 - 0.72x_2) \pm 3.4$	r= 0.867. d = 0.752	<0.0001

Y_1 – body mass, kg; Y_2 – Quetelet index; Y_3 – weight category; Y_4 – skill level, index number; Y_5 –throws at the maximal rate; Y_6 – total number of pull-ups; x_1 – thigh circumference, cm; x_2 – thorax circumference, cm; x_3 – neck circumference, cm; x_4 – head circumference, cm; x_5 – forearm circumference, cm; x_6 – abdominal circumference, cm; x_7 – tensed shoulder circumference, cm; x_8 – relaxed shoulder circumference, cm; x_9 – shin circumference.

Table 6. Regression models of the dependence of the key BCD on PD parameters and wrestlers' skill level

	Regression model	Correlation (r) and determination (d) coefficients	P
1.	$Y_1 = (56.4 + 0.07x_1 + 1.562x_2 + 1.517x_3 + 13.11x_4 - 0.266x_5) \pm 2.3$	r= 0.981 d = 0.962	<0.00001
2.	$Y_2 = (19.965 + 9.996x_4 + 0.676x_3) \pm 1.2$	r= 0.937 d = 0.877	<0.00001
3.	$Y_3 = (18.385 + 0.083x_1 + 0.058x_5 - 0.757x_3) \pm 0.8$	r= 0.993 d = 0.986	<0.00001
4.	$Y_4 = (11.525 + 0.06x_1 - 0.067x_5) \pm 1.45$	r= 0.929 d = 0.863	<0.00001

Y_1 – thorax circumference at rest, cm; Y_2 – neck circumference, cm; Y_3 – thigh circumference, cm; Y_4 – shoulder circumference, cm; x_1 – Quetelet index, kg/cm; x_2 – weight category, number; x_3 – skill level, c.u.; x_4 – surface area, cm^2; x_5 – body mass of athlete, kg.

Table 7. Regression models of the dependence of special (anaerobic) work capacity, strength endurance, and skill level of combat athletes on the key BCD

	Regression model	Coefficient of determination (d)	P
1.	$Y_1 = (136.2 + 2.81x_1 + 1.75x_2 + 1.34x_3 + 1.53x_4 + 0.18x_5 - 4.43x_6 - 0.78x_7 - 1.53x_8 - 3.6x_9) \pm ...$	d = 0.930	<0.00001
2.	$Y_2 = (165.8 + 1.36x_1 + 3.0x_{10} + 2.8x_8 + 3.55x_7 + 1.09x_5 + 4.5x_3 + 2.74x_4 + +0.06x_{11} - 14.5x_9 - 6.0\, x_6 - 0.2x_{12}) \pm ..$	d = 0.956	<0.00001
3.	$Y_3 = (1.04x_6 + 0.75x_{10} + 0.72x_9 + 0.14x_7 + 0.03x_{12} + 0.38x_8 - 0.02x_{11} - 0.48x_1 - 0.93x_2 - 0.21x_4 - 17.9) \pm 0.3$	d = 0.827	<0.00001

where: Y_1 – time of performing 15 throws in the anaerobic test; Y_2 – number of pull-ups in strength test; Y_3 – skill level; x_1 – thigh circumference, cm; x_2 - thorax circumference during inhalation, cm; x_3 - thorax circumference during expiration, cm; x_4 - relaxed shoulder circumference, cm; x_5 – shin circumference, cm; x_6 - thorax circumference at rest, cm; x_7 – neck circumference, cm; x_8 – tensed shoulder circumference, cm; x_9 - forearm circumference, cm; ; x_{10} – chest rise, cm. x_{11} - head circumference, cm; x_{12} - abdominal circumference, cm.

constitutes -0.413 ($p < 0.01$) and -0.403 ($p < 0.01$), respectively (Table 3).

The method of stepwise regression allowed revealing the total and interacting impact of BCD indices on these PF parameters and athletes' skill levels (Table 7). It turned out to be higher ($d = 0.827$-0.956, $p < 0.00001$) in comparison with the influence of individual indices (Table 3).

The first dependence (Y_1) is characterized by high coefficients of multiple correlation ($R=0.962$, $p<0.001$) and determination ($R=0.962$, $p<0.001$). They are indicative of the high prognostic significance of the presented model: 86.5% of variations of anaerobic alactate work capacity are due to the impact of the model morphometric parameters: thigh, thorax, relaxed and s\tensed shoulder, shin, and neck circumferences.

Most of the model parameters, with the exception of the neck and shin circumference, have a reliable influence on the intensity of the throws performed.

The second regression model (Y_2) reflects the dependence of the number of pull-ups on BCD (Table 7, Y_2). It is characterized by high multiple correlation ($r = 0.978$, $p<0.001$) and determination coefficients (R = 0.956, p<0.001). They indicate that 95.6% of the variations in the strength endurance indices of wrestlers depend on morphometric parameters.

The parameters of the third model imply that the skill level of wrestlers is determined by BCD in 82.7% of cases (r = 0.909, p<0.001, d = 0.827, p<0.001(Table 7, model Y_3).

Discussion

This study aims to examine the interrelations of key parameters within the physical development (PD) structure of highly skilled combat athletes in the process of ensuring special work capacity. The results indicate that body circumference dimensions (BCD) are highly integrated with other physical development parameters and significantly correlate with the skill level, body mass, surface area, Quetelet index, and weight category of the athletes.

Analysis of the state of the art in the literature showed that the PD structure of combat athletes has been unilaterally studied by most authors, typically without taking into account the ratios, interrelations, and degree of integration of its individual components in the general structure of combat athletes' PF. A number of studies have analyzed the interrelations of individual PD parameters during increased PF levels [5, 9, 18], the development of motor qualities [8, 24], and the improvement of athletes' SWC [5, 25].

Only a few studies have considered the formation of wrestlers' PD structure from comprehensive and systemic perspectives [1, 3, 26], i.e., taking into account the development level, ratios, and interrelations of different components of the PD structure in the process of improving competition form, SWC, and skill level.

Our complex studies show that among the morphometric parameters of combat athletes' PD, body circumferences are the most highly integrated. They have the highest mean group coefficient of pair correlations and are closely associated with the key parameters of combat athletes' speed-strength fitness [3]. It was found that the circumferences of the shoulder, thorax, thigh, and neck are most closely interrelated with the integral indices of PD, skill level, weight category, and SWC.

The findings partially coincide with those obtained in the studies of Melki et al. [5], who revealed significant correlations between thigh circumference and strength endurance of wrestlers, and Podrigalo et al. [26], who found close interrelations between individual BCD and muscle strength of the upper extremities of combat athletes.

In addition, numerous interrelations between individual PD indices and the integral parameters of PD, skill level, weight category, and SWC were analyzed in our recent studies. This is a significant addition to our previous studies and those of other authors. The revealed regularities supplement the findings of Melki et al. [5], Podrigalo et al. [26], and other authors who have investigated the relationships of individual PD structure parameters of combat athletes with the level of special PF and work capacity of elite combat athletes [4, 5, 6, 17].

The obtained results represent a continuation of our previous observations on intra-group interrelations of the key morphometric parameters of combat athletes' PD and their interrelations with individual speed-strength indices [1, 2, 3].

In the present study, a more in-depth, clarifying, and differentiated analysis of intra- and intergroup interrelations of BCD, and their integration during the increase of skill level, weight category, and provision of SWC was carried out.

Comparison of intragroup correlations in each of the analyzed morphometric groups of PD and the developed model characteristics indicate that BCD and extremities are the most interconnected parameters in the structure of combat athletes' PD.

The level of their development, ratios, and interrelations characterizes the morphological profile of skilled combat athletes. This profile determines both the integral parameters of PD (Quetelet index, body surface area, and mass) and the level of SWC, strength endurance, as well as the athletes' skill level.

The analysis of the findings demonstrated that an increase in the shoulder, thorax, thigh, and neck circumference is associated with an increase in combat athletes' skill level. Conversely, the increase in athletes' skill level is accompanied by an increase in BCD and extremities. This highlights the specificity of PD changes in combat athletes during the increase of skill level and the formation of their morphometric profile.

The novelty of the results of the present study lies in this relationship and adds to the findings of our previous observations [2, 3] as well as studies by various authors [4, 17, 26]. The developed multiple regression models allow for modeling, estimating, and predicting integral parameters of PD, the level of special anaerobic work capacity, and strength endurance.

On the whole, the methods of statistical analysis revealed:

1. A high interrelation of separate morphometric parameters of PD with each other, as well as with the level of anaerobic work capacity and strength endurance.
2. Dependence of separate BCD on the group of integral parameters of PD - weight category, skill level, Quetelet index, surface area, and body mass.
3. Dependence of integral parameters of PD, special work capacity, and strength endurance on separate morphometric parameters as well as their complex and interacting influence.

Since the skill level integrally reflects the level of the combat athletes' special fitness in the dynamics of long-term adaptation to specific physical loads, its high interrelations with BCD characterize the specificity of combat athletes' morphometric profile in the process of sports mastery improvement.

Conclusions

1. The thorax, thigh, shoulder, and neck circumferences are key parameters of the morphometric component of combat athletes' PD structure. These parameters determine the integral parameters of PF, such as body mass, surface area, and the Quetelet index, as well as the level of anaerobic power (work capacity) and strength endurance.
2. The specifics of improving the morphological component of combat athletes' PD are evident in the fact that with the increase of athletes' skill level, the dimensions of the thorax, neck, shoulder, and thigh circumferences tend to increase to the greatest extent.
3. The skill level of wrestlers shows various interrelations with separate parameters of physical development and special work capacity. The highest interrelations are observed with the level of anaerobic power, speed, and speed-strength endurance.
4. The revealed informative indices of the physical fitness structure of highly skilled wrestlers and the constructed mathematical models are recommended for use in designing normative estimation scales, differentiated according to weight categories, classification, and level of special fitness.

Conflict of interests

The authors declare that there is no conflict of interests.

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