PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Intra- and intergroup relationships between parameters of functional fitness and special physical work capacity in highly skilled wrestlers

Oleksandr Pryimakov[1ABCDE], Marek Sawczuk[2CDE], Georgy Korobeinikov[3ADE], Nataliya Mazurok[1CDE]

[1] *Faculty of Physical Culture and Health Promotion, Szczecin University, Poland*
[2] *Department of Physical Education, Gdansk University of Physical Education and Sport, Poland*
[3] *Department of Theory and Methodology of International Wrestling, Uzbek State University of Physical Education and Sports, Uzbekistan*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim: Functional fitness and special physical work capacity are components of performance in highly skilled wrestlers. These characteristics reflect the physiological potential of athletes and determine the effectiveness of performing specific wrestling actions under conditions of high physical load. Despite the application of various approaches to assessing functional fitness and special physical work capacity, their interrelationships in highly skilled wrestlers remain a subject of practical interest. The aim of this study was to investigate the intra- and intergroup relationships between the key parameters of functional fitness (FF) structure and special physical work capacity (SPWC) in highly skilled wrestlers.

Material and Methods: The study was conducted on 31 combat athletes from two qualification groups: the group of international class masters of sports (ICMS) and honored masters of sports (HMS), and the group of masters of sports (MS). They were members of the Ukrainian national teams in Greco-Roman and freestyle wrestling, as well as judo, aged 18–31 years. The assessment of wrestlers' FF was made according to parameters characterizing their functional potential. The assessment of their SPWC level was based on the results of performing 45 throws of a partner of equal weight at maximum speed. The research materials were processed using correlation, regression, and canonical analysis methods.

Results: Analysis of the general variability of canonical variables revealed a strong interdependence between FF and SPWC parameters in both qualification groups of subjects. An increase in anaerobic and aerobic capacities, mobility, and the efficiency of physiological processes, as well as the overall level of functional potential, contributes to an enhancement in the SPWC of combat athletes. Conversely, an increase in the SPWC of combat athletes in both groups is accompanied by an increase in their functional capabilities. The most variable indicators of SPWC, when changing the integral indicators of FF in both groups of combat athletes, are the work capacity indicators in three series of throwing tests. The most variable indicators of FF, when changing the parameters of SPWC in the group of ICMS and HMS, are the indicators of anaerobic power, general aerobic potential realization, and the general level of FF. In the MS group, the most variable indicators are general aerobic potential realization, anaerobic power, and mobility of physiological processes. The group of elite wrestlers (HMS and ICMS) is characterized by a higher level of anaerobic power, mobility of physiological processes, general FF level, resting HR, standard work watt-pulse, and SPWC level compared to less skilled combat athletes (MS). ICMS and HMS demonstrate a more pronounced effect of economy at high levels of FF and SPWC. The MS group shows a pronounced mixed influence of aerobic, ventilatory, and anaerobic factors. However, the highest contribution to SPWC belongs to anaerobic power and mobility of physiological processes.

Conclusions: The level of development and interrelationship of individual and integral parameters of FF and SPWC in combat athletes indicate higher functional reserves in elite wrestlers compared to less skilled athletes. The high level of physical work capacity of skilled wrestlers can be achieved through different sets of physiological variables. The multivariable functional provision of SPWC in highly skilled wrestlers is one of the main criteria of their functional reserves. It reflects the reliability of interchangeable mechanisms providing SPWC in combat athletes, which are formed during long-term adaptation to physical loads.

Keywords: wrestlers, qualification, functional fitness, work capacity, interrelationships.

Introduction

The fitness structure (FS) of athletes is an integral, hierarchically organized formation, the components of which are parameters of physical development, physical fitness, technico-tactical fitness, psychological fitness, functional fitness, and physical work capacity. The success of competitive activity

doi:10.15561/20755279.2026.0104

depends on all components of athletes' FS. However, the level of development, ratio, and interrelationship of FS components in achieving a level of special physical work capacity (SPWC) and ensuring athletic results can vary significantly depending on the sports event, fitness level, gender, qualification, weight category, and other factors [1, 2, 3]. Among the FS components determining the SPWC level and athletic results in various sports events, one of the major roles belongs to functional fitness (FF). Participation in competitive activities often causes extreme shifts in the activity of the body's physiological systems [2, 3, 4, 5]. Relatively few studies have been devoted to the formation of a multi-component and hierarchically organized FS of combat athletes ensuring a high level of SPWC and athletic results.

Functional fitness (FF) of wrestlers plays one of the major roles in the sports training system [6, 7, 8]. It is the basis for the development of physical fitness in combat athletes and the manifestation of such important aspects as explosive power, special endurance (strength and speed-strength), and anaerobic power. The level of SPWC and athletic results depends on the development of these qualities [5, 9, 10, 11]. At the same time, a high level of FF in combat athletes is not the only factor determining the achievement of high sports results. FF serves as the foundation for ensuring athletes' SPWC under competitive conditions and is fully manifested in close interconnection with the level of physical development, technical-tactical, physical, and psychological fitness. These characteristics constitute integral components of wrestlers' FS [12, 13, 14, 15]. As one of the components of combat athletes' FS, FF combines physiological parameters such as anaerobic (AnP) and aerobic (AeP) power, aerobic capacity, mobility of physiological processes (MPP), and other parameters of vegetative systems [6, 16, 17].

A research group under the leadership of Professor Mishchenko developed a complex of methods for recording and assessing individual and integral parameters of FF structure that ensure a high level of SPWC in various sports events: cycling [3], rowing [4], wrestling [6, 16, 17], and judo [18]. However, published works do not fully highlight the mechanisms of integration and interaction among different components of combat athletes' FS in the process of improving athletic form, ensuring SPWC, and achieving athletic results [6, 16, 17, 19, 20].

These and other studies insufficiently address the mechanisms underlying the formation of morphofunctional, metabolic, psychological, and technical-tactical profiles of combat athletes during the process of FS improvement and sports preparation [13, 21, 22]. In most publications analyzing the role of different components of combat athletes' FF structure in ensuring high physical work capacity, attention is mainly given to isolated parameters of physical condition without analyzing their interrelationships [23, 24, 25]. A few studies present a set of heterogeneous indicators demonstrating the multifactorial nature of physical work capacity provision [5, 6, 26] and characterizing the profile of highly skilled athletes [12, 15].

Some publications have analyzed the interrelations of morphological and functional indicators in the process of forming the morphofunctional profile and ensuring special work capacity in Greco-Roman wrestlers [7, 15, 21, 22], as well as in athletes specializing in taekwondo [13, 23, 24] and judo [13, 18]. In certain works, a complex of heterogeneous indicators forming the profile of highly skilled athletes is presented [22, 27, 28, 29]. However, the mechanisms of integration and interaction among such diverse indicators of physical condition in the process of ensuring combat athletes' SPWC level have not been addressed in these studies. Only a limited number of studies have investigated the interrelations of numerous individual and integral parameters of FF structure conditioning a high level of SPWC in combat athletes. These parameters include aerobic and anaerobic power, efficiency, stability, and mobility of functional manifestations of the respiratory and circulatory systems [6, 16, 26].

Based on the analysis of the state of research in the literature, it can be stated that one of the poorly studied aspects of forming combat athletes' FS is the dependence of physical work capacity and athletic form not only on the level of development and ratio of individual and integral functional parameters but also on their interactions [11, 17]. Published works do not reflect intergroup interactions of correlated indicators belonging to different sets of physical condition structure in highly skilled combat athletes of different sexes and weight categories. These sets include indicators of physical development, physical fitness, FF, SPWC, technical-tactical fitness, and psychological fitness. Only in some works [11] has material been presented reflecting intergroup interactions of physical development and physical fitness parameters in highly skilled combat athletes, as well as regression models of the dependence of wrestlers' SPWC level on a set of main parameters from the studied groups of physical condition.

Among the intergroup interactions of combat athletes' FS parameters, the intergroup interrelations and mutual influence of indicators from different sets of physical condition, including physical development, physical fitness, functional fitness, special physical work capacity, and other parameters, remain insufficiently studied. The main determinants of SPWC and competitive activity efficiency in athletes from various sports events are the integral FF components: aerobic (AeP) and anaerobic (AnP) power, economy (EC), stability, and mobility of functional manifestations of the respiratory and circulatory systems [2, 3, 10, 11].

Among the intergroup interactions of indicators from different sets of combat athletes' FS, the interrelations of integral FF and SPWC parameters in combat athletes of different skill levels, fitness levels, weight categories, and sexes remain insufficiently studied. The incomplete coverage of this issue from a systemic perspective served as the basis for selecting the aim of the present study. The aim of the present study was to investigate intra- and intergroup interrelations of major parameters of the structure of functional fitness and special physical work capacity in highly skilled wrestlers.

Material and Methods

Participants

The study was conducted on members of the Ukrainian national teams in Greco-Roman and freestyle wrestling and judo. Thirty-one combat athletes aged 18–31 years were examined. They were divided into two qualification groups: the first group consisted of 14 masters of sport (MS), while the second group included 17 international class masters of sport (ICMS) and honored masters of sport (HMS). Most of them were students at 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 [30].

Research Design

he assessment of wrestlers' physical condition was carried out according to individual and integral functional parameters characterizing their functional potential, as well as according to the level of physical work capacity.

Physiological indicators characterizing the functional potential of wrestlers were determined during standard loads on a cycle ergometer: 1) an aerobic 20-minute standard load of moderate intensity; 2) an anaerobic (alactate) 30-second load of maximal intensity; 3) a 1-minute anaerobic (glycolytic) load of maximal intensity.

The evaluation of the general level of functional fitness (FF) in wrestlers was based on the responses of respiratory and cardiovascular functions to the applied test loads and on the achieved work capacity indicators. It included the determination of the degree of development of such leading factors in the FF structure as anaerobic (AnP) and aerobic power (AeP), mobility of physiological processes (MPP), and EC, according to the method developed by V.S. Mishchenko and co-authors [3, 31]. Based on a formalized point-based assessment of the indicators, the overall level of FF (OLFF) and the degree of development of the studied structural properties were determined.

Performing a series of test loads on a cycle ergometer allowed the determination of the involvement and ratio of different energy systems in ensuring the physical work capacity of highly skilled wrestlers.

To assess wrestlers' FF, the following initial and calculated indicators were used: minute ventilation (MVmax, $L \cdot min^{-1}$), heart rate (HR, $beats \cdot min^{-1}$), oxygen consumption (VO_2, $ml \cdot min^{-1}$ and $ml \cdot min^{-1} \cdot kg^{-1}$); ventilatory equivalent for oxygen (VE, rel. units); oxygen pulse (OP, $ml \cdot beat^{-1}$); respiratory quotient (RQ, rel. units); training load (W); oxygen debt (O_2 debt, $ml \cdot kg^{-1}$); rate of O_2 consumption increase (O_2C, times); recovery time of HR to 120 $beats \cdot min^{-1}$ (s); watt-pulse of standard work ($W \cdot beat^{-1}$); mechanical efficiency of work (%), etc.

Based on each obtained indicator, the degree of development of each leading structural factor and the overall FF level of the athletes were quantified using the formalized point-based assessment system.

AeP and AnP, stability of functional manifestations, MPP, EC, and the degree of aerobic functional potential realization, as well as the overall FF level, were determined as the percentage ratio of the actually achieved level during testing to the maximum possible level of their development recorded in the most highly trained athletes.

Since the study involved highly skilled wrestlers, the obtained data served as normative values for evaluating their FF level and the degree of development of its leading structural properties.

The level of special physical work capacity (SPWC) and endurance of wrestlers was assessed during a specialized test in which wrestlers performed throws of a partner of equal weight at maximum pace. Greco-Roman wrestlers and judokas performed forward one-arm bending throws, while freestyle wrestlers performed throws with a grip on the shoulder and thigh. The tests were performed at maximal pace: each athlete executed 3 series of throws, 15 throws in each series, with a 1-minute rest interval between series [32]. The structure and intensity of throws in the test corresponded to the structure and intensity of movements in a wrestling bout.

SPWC and endurance were assessed by the total time to perform 45 throws in three series (TTPT1–3), by the total time to perform 15 throws in the first (TPT1), second (TPT2), and third (TPT3) series of testing, and by the average time to perform a single throw. The work capacity coefficient (WCC) was also calculated as the ratio of the total time to perform 45 throws in the test to the best ("reference") time shown in one of the series, multiplied by 3 [32].

The maximal intensity and the time required to perform 15 throws in each series (ranging from 24.94±0.69 s in the first series to 24.48±0.78 s in the third series), as well as the total time required

to perform 45 throws (changing from 60 to 110 s during the experiment), indicate the dominant role of the anaerobic alactate and anaerobic glycolytic systems in the energy supply of throws. This is explained by the fact that during a bout, wrestlers usually show 12 to 16 phases of "explosive" work lasting 5–6 seconds. This reflects the leading role of the alactic creatine-phosphate energy mechanism in performing 15 throws at maximum pace in each series. In addition, on average, 1–2 attacking spurts of 10–20 s duration per minute are observed during a bout. The energy supply of such work involves activation of the lactate (glycolytic) mechanism of energy production [16].

For the quantitative determination of the degree of development of the anaerobic alactate and anaerobic lactate systems and their interrelations with the aerobic system in combat athletes, a block of test loads on a cycle ergometer was performed. The development level of each energy system and their interrelations during the block of test loads were determined. Their interrelations with SPWC parameters of combat athletes during the throwing test were also determined.

Statistical Analysis

The experimental material was processed using the statistical software package STATISTICA 13.5 [33]. To determine the level of development, ratio, and interrelations of the leading indicators of the physical condition structure of combat athletes, correlation, regression, and canonical analysis methods were applied. Stepwise regression analysis was used to determine the degree of influence of the leading indicators of wrestlers' FF structure on the level of SPWC. Canonical analysis was applied to study intergroup relationships between multiple FF and SPWC variables in combat athletes. This method is effective for detecting hidden dependencies between two sets of variables [34, 35]. The canonical correlation method made it possible to determine the relationship between linear combinations of variables (canonical variables) from one set and those from another set. The method was used to identify hidden dependencies between two groups of variables, maximum correlation links, and the total mutual influence of indicators belonging to different groups of random variables. The canonical analysis method allowed the revelation of the leading factors and indicators that determine the overall variability of indicators in each of the interacting groups, FF and SPWC.

Results

The canonical analysis parameters presented in Table 1 reflect the different mutual variability of the integral indicators of FF and the indicators of SPWC in two qualification groups of combat athletes:

1. elite (ICMS and HMS) combat athletes;
2. masters of sport (MS).

The analysis of the eigenvalues of the integral indicators of FF and the indicators of SPWC resulted in the identification of five canonical roots explaining 100% of the extracted variance in each group of the studied indicators. Among them, statistically significant interrelations between the two sets of physical condition indicators were observed in each group of subjects only for two canonical roots. Therefore, the subsequent canonical analysis of the relationships between FF and SPWC indicators in combat athletes was carried out mainly for the two statistically significant roots.

The values of canonical correlations and the chi-square criterion indicate a strong positive interdependence between the weighted sums of the first pair of canonical variables (root 1) both in the MS group and in the HMS and ICMS group.

The values of total variability (redundancy) show (Table 1) that in the MS group, 57.9% of the variance

Table 1. Results of canonical correlation analysis of the mutual influence of special physical work capacity parameters and integral functional parameters of the physical condition of highly skilled combat athletes.

Groups	Parameters	Integral functional indicators (realization of general aerobic potential, anaerobic power, mobility, economy, general level of functional fitness)	Special physical work capacity indicators (result in 1-3 series of specialized throws, work capacity coefficient)
MS	Canonical correlation (R), χ^2	0.983, χ^2 (25) =49.15, p=0.002	
	Extracted variance	100.0%	100.0%
	Total variability (redundancy)	57.91%	64.8%
HMS, ICMS	Canonical correlation (R), χ^2	0.947, χ^2 (25) =55.5, p=0.0004	
	Extracted variance	100.0%	100.0%
	Total variability (redundancy)	71.07%	66.52%

of FF indicators is explained by the impact of the group of correlated SPWC indicators, while 64.8% of the variability of SPWC indicators is due to the influence of the canonical integral FF variables of combat athletes. In the HMS and ICMS group, 71.07% of the variance of the integral FF indicators is explained by the influence of the group of correlated SPWC indicators, whereas 66.5% of the variability of the SPWC indicators is due to the impact of the canonical FF variables of combat athletes.

The cumulative contribution of the indicators of the two statistically significant roots to the overall variability of FF indicators in the MS group constituted 53.57%, and in the ICMS and HMS group 62.42%. The cumulative contribution of the indicators of the two statistically significant roots to the overall variability of SPWC parameters was 62.01% in the MS group and 50.96% in the ICMS and HMS group.

These results indicate a strong mutual influence of the integral variables of FF and SPWC in both groups of highly qualified combat athletes: an increase in the integral FF variables contributes to an increase in SPWC, and vice versa, an increase in SPWC indicators contributes to the growth of FF integral variables.

It is characteristic that in the elite group of combat athletes (ICMS and HMS), a stronger influence of SPWC indicators on FF variables is manifested, whereas in the group of less skilled athletes (MS), a stronger influence of FF variables on SPWC indicators is noted. However, the predominance of the impact of one set of indicators over the other remains relatively low in both groups of combat athletes.

Further analysis allowed the determination of the partial weight of individual indicators in the total variability of the parameters of each set.

It was revealed that for the two statistically significant canonical roots in the ICMS and HMS group, the highest partial weight in the total variability of FF indicators belongs to the parameters of anaerobic power (AnP), the overall level of functional fitness (OLFF), and the realization of the general aerobic potential (RGAeP). Their combined contribution to the total variability of the functional parameters of the two statistically significant roots constitutes 47.5%. The contribution of these three indicators amounts to 76.0% of the total contribution of all studied functional variables to the total variability of the integral indicators of the FF group.

The greatest partial weight in the total variability of SPWC variables in the ICMS and HMS group belongs to the indicators of the time of performing throws in three series of the specialized work capacity test: TPT1, TPT2, and TPT3. Their combined contribution to the total variability of SPWC parameters for the two statistically significant roots constitutes 33.87%. This represents 66.5% of the total contribution of all SPWC variables to the overall variability of the parameters of this group.

In the MS group, the greatest partial weight in the total variability of the integral FF indicators belongs to the parameters of anaerobic power (AnP), RGAeP, and MPP. Their combined contribution to the total variability of the integral FF indicators for the two statistically significant roots constitutes 37.4%. This accounts for 69.9% of the total contribution of all functional indicators to the total variability of the integral FF indicators.

The greatest partial weight in the total variability of the group of SPWC variables in the MS group belongs to the three indicators of physical work capacity: TPT1, TPT2, and TPT3. Their combined contribution to the total variability of SPWC parameters for the two statistically significant roots is 43.53%. This accounts for 70.2% of the total contribution of all SPWC indicators to the overall variability of the parameters of this group.

The obtained results can be interpreted as follows: the most variable SPWC indicators under the influence of the integral FF indicators in both groups of combat athletes are the indicators of the time of performing throws in each of the three series (TPT1, TPT2, TPT3). The most variable functional indicators under changes in SPWC parameters in the ICMS and HMS group are RGAeP, AnP, and OLFF, while in the MS group RGAeP, AnP, and MPP.

The analysis of the factor structure allowed the determination of the value and direction of intra- and intergroup pairwise correlations of the integral FF indicators and SPWC indicators.

The average value of intragroup correlations of indicators in the ICMS and HMS group is 0.557±0.08 ($p<0.001$), and intergroup correlations are 0.475±0.04 ($p<0.01$). The average value of intragroup correlations of the studied sets of indicators in the MS group is 0.457±0.08 ($p<0.01$), and intergroup correlations are 0.452±0.04 ($p<0.01$).

In the ICMS and HMS group, a closer integration of intragroup indicators is observed compared to intergroup ones, while in the MS group an equal average level of pairwise intra- and intergroup relationships is found.

The analysis of the average values of the correlation coefficients shows that in the ICMS and HMS group, the highest intergroup relationships were identified between the level of SPWC in the three throw series (TTPT1–3) and the values of AnP ($r=0.746$, $p<0.05$), mobility ($r=0.589$, $p<0.05$), and OLFF ($r=0.610$, $p<0.05$). In the MS group, the highest intergroup relationships were noted between the level of SPWC in the three throw series (TTPT1–3) and the values of AnP ($r=0.596$, $p<0.05$) and economy ($r=0.598$, $p<0.05$).

The calculations of pairwise intergroup correlations made it possible to determine the

degree of relationships only for individual pairs of indicators of functional condition and SPWC in combat athletes, as well as their average group values.

To identify the dependence of individual SPWC indicators on the combined influence of the leading physiological indicators in the two qualification groups of combat athletes, stepwise multiple regression analysis was carried out.

Before analyzing the interrelationships of the studied indicators, their average group values were calculated for each qualification group (Table 2).

The data presented in Table 2 indicate that statistically significant intergroup differences were manifested in HR in the supine position, AnP, MPP, OLFF, and in the integral indicator of special work capacity, TTPT1.

For the remaining indicators (VO_2, MV, LaM, EC, RGAeP, etc.), no significant differences between the two groups were found.

It was assumed that the level of SPWC in athletes of each group is determined not only by the values of the indicators in which statistically significant intergroup differences were observed (anaerobic power, mobility of physiological processes, general level of functional fitness), but also by the ratio and interrelations of physiological variables for which intergroup differences were insignificant.

The calculations of the coefficients of stepwise multiple regression, multiple correlation, and determination presented in Table 3 reflect strong linear dependencies of certain SPWC indicators in wrestlers on the influence of several individual and integral functional indicators in each group of subjects.

Table 3 presents regression models reflecting various options (combinations) of physiological parameters exerting the greatest influence on the dependent result in two groups of subjects:

1. ICMS and HMS;
2. MS.

All models are characterized by high values of correlation and determination coefficients, which indicate their adequacy and informativeness. These equations show high predictive accuracy of the dependent result (the level of special work capacity and mechanical efficiency of standard work) based on the functional parameters of the model. The models Y1 and Y2 have the highest predictive accuracy. They explain 97–98% of the variance of the total time to perform 45 throws (15 throws in each of the 1st–3rd series). The model for wrestlers in the MS group (Y2) has a greater number of predictors, which may indicate a broader physiological basis of work capacity in this group of athletes.

The coefficients of the three functional indicators

Table 2. Average group values of physiological indicators during standard moderate-power work and results of the specialized test in two qualification groups of wrestlers: 1) ICMS and HMS; 2) MS.

Indicators	ICMS and HMS			MS			t Student	p
	Means	Std. Dev.	N	Means	Std. Dev.	N		
VO_2, l·min^{-1}·kg^{-1}	42.79	6.95	17	43.18	4.96	14	-0.18	>0.05
MV, l·min^{-1}	114.9	15.13	17	114.2	16.76	14	0.12	>0.05
Resting HR, beats·min^{-1}	46.05	5.64	17	55.3	8.4	14	3.6	<0.001
Average HR of standard work, beats·min^{-1}	115.9	8.26	17	123.2	13.7	14	0.67	>0.05
Watt-pulse of standard work, W·beat^{-1}	1.29	0.35	17	1.14	0.23	14	1.61	>0.05
Lactate power, W	614.2	110.05	17	572.6	110.23	14	1.05	>0.05
Lactate power, W·kg^{-1}	7.66	1.37	17	7.37	0.87	14	0.72	>0.05
O_2 debt, ml·kg^{-1}	67.58	13.50	17	67.37	11.52	14	0.05	>0.05
Ventilatory equivalent (rel. units)	25.05	1.68	17	25.33	5.56	14	-0.18	>0.05
Anaerobic power, %	76.33	23.87	17	42.96	10.59	14	5.18	<0.0001
Mobility of physiological processes, %	91.24	14.61	17	67.17	16.89	14	4.19	<0.0003
Economy, %	34.18	13.07	17	32.99	8.67	14	0.30	>0.05
Overall level of functional fitness, %	70.42	16.85	17	46.32	13.42	14	4.43	<0.0001
MV, l·min^{-1}·kg^{-1}	1.44	0.28	17	1.50	0.30	14	-0.57	>0.05
Realization of general aerobic potential, %	63.05	9.06	17	58.48	7.27	14	1.56	>0.05
Mechanical efficiency of standard work, %	28.77	3.59	17	30.32	5.92	14	0.224	>0.05
Total time of throws, s	68.65	10.46	17	82.07	8.19	14	-4.01	<0.0004
Predicted result based on models Y1 and Y2 (Table 2)	68.57			82.51				

Table 3. Model characteristics of the dependence of indicators of special physical work capacity, mechanical efficiency of standard work (6-min load, 2 W·kg^{-1} of body weight), and general functional potential on individual and integral parameters of combat athletes' physical condition (Y1–Y6).

Regression equations*	Coefficients**			
	r	d	F	p
$Y_1 = 82.49 + 2.2x_1 + 0.553x_2 - 0.261x_3 - 0.638x_4 - 0.321x_5 \pm 2.17$	0.985	0.971	72.4	<0.00000
$Y_2 = 6.88 + 7.72x_6 + 1.36x_1 + 0.576x_7 + 0.479x_2 - 0.835x_8 - 10.02x_9 - 0.218x_3 \pm 1.46$	0.993	0.985	57.4	<0.00000
$Y_3 = 32.94 + 0.473x_1 - 0.168x_4 - 0.063x_3 - 1.137x_6 \pm 0.9$	0.969	0.940	46.8	<0.00001
$Y_4 = 18.31 + 0.171x_2 + 3.012x_6 - 5.88x_9 - 0.234x_8 \pm 1.44$	0.913	0.834	11.3	<0.001
$Y_5 = 66.2 + 0.106x_5 + 0.048x_{11} - 2.04x_1 - 0.232x_8 - 0.283x_2 \pm 1.45$	0.942	0.887	17.3	<0.00007
$Y_6 = 14.94 + 0.44x_8 + 0.61x_2 - 0.04x_{11} \pm 3.3$	0.872	0.761	10.6	<0.002

Note. Y1 – total time of performing the specialized test in the ICMS and HMS group, s; Y2 – total time of performing the specialized test in the MS group, s; Y3 – time of performing the first series of the specialized test in the ICMS and HMS group, s; Y4 – time of performing the first series of the specialized test in the MS group, s; Y5 – mechanical efficiency of the standard work in the ICMS and HMS group, %; Y6 – mechanical efficiency of the standard work in the MS group, %; x1 – ventilatory equivalent (rel. units); x2 – economy, %; x3 – mobility, %; x4 – VO_2, l·min^{-1}·kg^{-1}; x5 – MV, l·min^{-1}; x6 – lactate power, W·kg^{-1}; x7 – realization of general aerobic potential, %; x8 – anaerobic (alactate) power, %; x9 – MV, l·kg^{-1}; x10 – O_2 debt, ml·kg^{-1}; x11 – lactate power, W; r – correlation coefficient; d – determination coefficient; F – Fisher coefficient.

in the regression model Y1 indicate that with increasing physiological reactivity (mobility) and aerobic reserves (VO_2, l·min^{-1}·kg^{-1} (x4); MV, l·min^{-1} (x5)) in wrestlers of the ICMS and HMS group, the time of performing the throwing test decreases (i.e., work capacity increases). Conversely, a decrease in these parameters leads to an increase in the time of performing the specialized test (i.e., a reduction in the level of SPWC). At the same time, the impact of VE and EC indicators on the final testing result in the ICMS and HMS group is relatively low. Positive coefficients, as well as the degree of change of the predicted result under their influence, reflect the auxiliary (compensatory) role of VE and EC indicators in ensuring the special work capacity of elite wrestlers.

In the MS group, the regression model Y_2, according to stepwise analysis, included with negative coefficients AnP (x_8), MV (l·min^{-1}·kg^{-1} – x_9), and mobility (x_3), and with positive coefficients LaM (W/kg – x_6), VE (x_1), RGAeP (x_7), and EC (x_2). These indicate that with a decrease in anaerobic (glycolytic) power, MV/kg, and mobility (reactivity) of physiological systems, while increasing LaM, VE, and economy, the time of performing the specialized test increases (i.e., the level of SPWC decreases). Conversely, with an increase in AnP (glycolytic), MV/kg, and mobility (reactivity) of physiological systems, and a reduction in LaM, VE, and EC, the time of performing the specialized test decreases (i.e., the level of SPWC increases). The dominant role in reducing the throwing time in the MS group belongs to anaerobic capacities and high mobility of physiological processes, as in more qualified athletes.

The presented models reflect the contribution of each physiological parameter to the final throwing time: in athletes of the ICMS and HMS group, the greatest contribution to reducing the test time is made by VO_2, MV, and MPP, while in the MS group the influence of AnP, VE, and EC is more pronounced. Despite the similar group mean values of VO_2 and MV (Table 2), their quality of utilization (including regulatory aspects) is higher in highly qualified athletes (Table 3).

It should also be noted that the parameter of economy is an integral one, expressed in %. It was calculated using a special algorithm [1, 3] based on the Watt-pulse of standard work (W·beat^{-1}), the degree of VO_2 increase depending on the degree of increase in HR (ml·beat^{-1}·kg^{-1}), lactate threshold power (W·kg^{-1}), the ratio of O_2 consumption at the lactate threshold to VO_2max (%), mechanical efficiency of standard work (%), and the mean values of VE and VO_2 during standard work (rel. units). The positive sign of the economy coefficient in models Y_1–Y_4 and Y_6 indicates additional activation of systems and energy expenditure for effective execution of the throwing test. The increase in these parameters requires additional energy costs for performing throws, which reflects a reduction in economy.

The structure of the regression models Y_1 and Y_2 and the high correlation and determination coefficients indicate that the final result may be determined by different compositions, magnitudes, and ratios of physiological components.

The use of the Backward Stepwise algorithm in regression analysis made it possible to determine the parameters that exert the greatest partial and combined influence on the level of SPWC in the first series of throws (TPT_1), where the key role in energy supply belongs to the anaerobic alactate system (Table 3, models Y_3 and Y_4).

Thus, the regression model Y_3 included with negative coefficients mobility (% – x_3), VO_2 (ml·kg^{-1} – x_4), and LaM (W/kg – x_6), and with a positive coefficient VE (x_1). The determination coefficient of the Y_3 model (r^2 = 0.940) reflects its high predictive accuracy: 94.0% of the variance of the result when performing the first series of throws in the ICMS and HMS group is due to the influence of these three indicators. The higher the anaerobic (lactate) power, VO_2 (ml·kg^{-1}), and functional mobility (%), the shorter the total throwing time and the higher the SPWC level. On the other hand, the higher the VE, the longer the total throwing time and the lower the SPWC level.

The regression model Y_4 included four indicators: AnP (alactate) (x_8), MV (l·kg^{-1} – x_9), EC (x_2), and LaM (W·kg^{-1} – x_6). The determination coefficient of the Y_4 model (r^2 = 0.834, p<0.0001) indicates high prediction accuracy: 83.4% of the variance of the result when performing the first series of throws in the MS group is explained by the influence of these four parameters. The higher the anaerobic (alactate) power and MV per kg of body mass, the greater the reduction of total throwing time; the higher LaM (W·kg^{-1}) and EC (%), the longer the total time in the first series of throws (TPT_1).

The structure of regression models Y_5 and Y_6 (Table 3) reflects the dependence of the mechanical efficiency of standard work (6 min of moderate-power load on a cycle ergometer, 2 W per kg of body weight) in the HMS and ICMS group on five functional indicators (Y_5), and in the MS group on three (Y_6). In the HMS and ICMS group, the mechanical efficiency of work shows a positive dependence on the Watt-pulse of standard work and MV (l/min), and a negative one on VE, EC, and O_2 debt. In the MS group, a positive influence on mechanical efficiency is exerted by VE and EC, while a negative influence is exerted by the Watt-pulse of standard work.

The model equations demonstrate that physical work capacity in athletes can be provided by different combinations of FF variables, especially if the set of indicators has a similar influence. In stepwise analysis, the indicators selected into the regression model are those whose combination provides the best prediction and achievement of the result.

The values of the canonical weights of normalized variables in the ICMS and HMS group showed that among the integral FF parameters, the greatest contribution to the value of the first canonical variable is made by AnP (-0.808), to the second canonical variable by RGAeP (0.914), and to the third by the EC parameter (-1.45). The values of canonical factor loadings and canonical weights indicate that in the group of elite wrestlers, the variable AnP, having the strongest relationship with the canonical variable (r = -0.919), makes the greatest contribution to the formation of the canonical variable of the first root (-0.808).

Among the SPWC parameters of the elite wrestlers' group, the greatest contribution to the value of the first canonical variable is made by the variable of the total number of throws ($TTPT_{1\_3}$) (-3.756), to the second canonical variable by the variable TPT_2 (-5.262), and to the third by TPT_1 (5.139). The values of canonical factor loadings and canonical weights in the ICMS and HMS group indicate that the variable TPT_1 has the strongest relationship with the canonical variable (r = -0.805). However, the greatest contribution to the formation of the canonical variable of the first root is made by the integral parameter of physical work capacity, reflecting the work capacity expressed in three series of throws, $TTPT_{1\_3}$ (-3.756).

The values of *canonical factor* loadings in the MS group indicate that among the integral FF parameters, the strongest relationship with the canonical variable of the first root is shown by RGAeP (0.614), of the second root by AnP (0.692), and of the third by OLFF (0.763). The values of *canonical weights* indicate that in the MS group, the greatest contribution to the formation of the canonical variable of the first root is made by RGAeP (0.875), of the second canonical variable by MPP (0.594), and of the third by OLFF (1.358).

Among the SPWC parameters of the MS group, the greatest contribution to the value of the first canonical variable is made by the total throws variable ($TTPT_{1\_3}$) (-3.122), to the second canonical variable by TPT_3 (-1.038), and to the third by TPT_1 (3.192). The values of canonical factor loadings indicate that the strongest relationship with the canonical variable of the first root is shown by the work capacity coefficient (WCC) (0.496), and of the second root by TPT_3 (-0.927).

Canonical weights were used to construct multiple regression equations that reflect the contribution of each SPWC and FF indicator to the formation of the values of canonical variables.

Thus, regression equations are presented below, reflecting the contribution of individual SPWC and FF variables to the formation of the value of the canonical variable of the 1st root in wrestlers of the ICMS and HMS (Eq. 1-2) and MS (Eq. 3-4) groups.

1. Root 1_{SPWC}=2.14TPT_1+0.205TPT_2 +2.173TPT_3-3,756$TTPT_{1-3}$-0,2540WCC (1)
2. Root 1_{FF} = 0.493RGAeP-0.808AnP+0,041MPP-0,152EC-0.143OLFF (2)
3. Root 1_{SPWC}=2.966TPT_1+0.043 TPT_2 +0.1083TPT_3-3,122 $TTPT_{1-3}$+0.279WCC (3)
4. Root 1_{FF} = 0.875RGAeP-0.265AnP+0.441MPP-0.708EC+0.148OLFF (4)

Graphical and generalized regression models, as well as correlation and determination coefficients characterizing the relationships of canonical variables of root 1 in the ICMS and HMS and MS groups, are presented in Figure 1.

The plot reflects the linear relationship between

two canonical sets of variables, SPWC and FF. Each point represents the integral parameter of the weighted sums of the original FF variables (5 variables) and SPWC variables (5 variables) for each subject: the X-axis represents the scale of weighted FF sums, and the Y-axis represents the scale of weighted SPWC sums. The location of individual points on the plot reflects the relationship between the weighted sums of SPWC and FF indicators for the first canonical root (Fig. 1).

The scatterplots of canonical variables for both roots display a pattern characteristic of a linear dependence.

A strong positive linear relationship between FF and SPWC canonical variables for root 1 in MS (r=0.984, p<0.0000) and in ICMS and HMS (r=0.947,

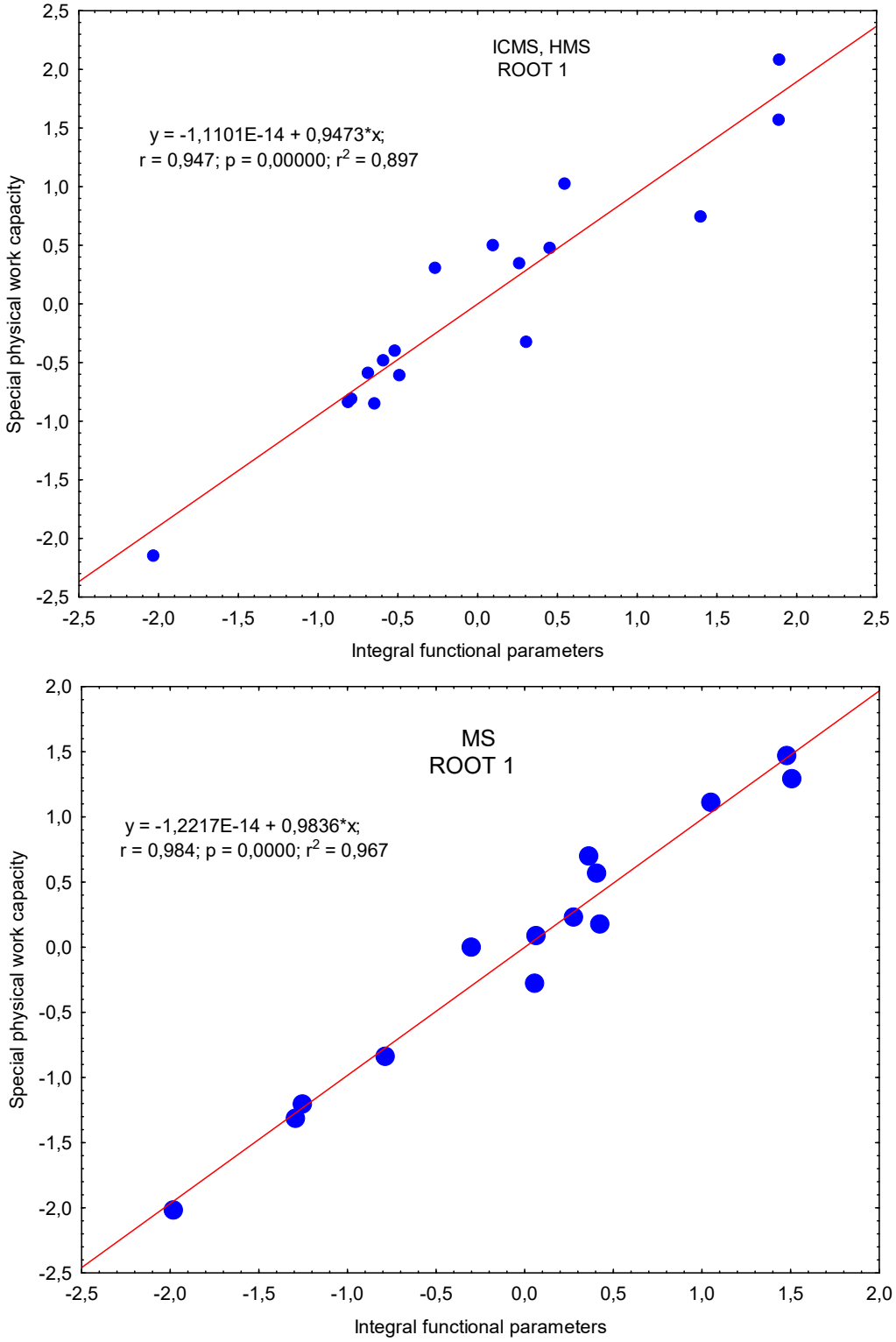

Figure 1. Graphical and regression models of the relationships between weighted SPWC variables and the integral FF indicators of the first and second canonical roots.

p<0.0000) indicates that with an increase in the FF of combat athletes, their SPWC level also increases, and vice versa. The high values of correlation and determination coefficients indicate that the variables of one group of indicators are well predicted through the variables of the other group.

Discussion

In the course of long-term adaptation to physical loads, athletes in different sports events develop a structurally and functionally multilevel system of physical condition with a certain level of physical development, special work capacity, technical-tactical, functional, and psychological fitness, as well as competitive activity efficiency [3, 25, 36, 37].

The peculiarities of wrestlers' sports training, the high pace of a bout, and the opponent's resistance determine the formation of a specific FS of athletes. In the functional component of this system, an important place is occupied by speed-strength endurance, explosive muscle activity, reaction speed, reserves of vegetative systems, anaerobic and aerobic energy supply systems, and other components. Their level of development, proportion, and interrelationships determine the level of special work capacity and competitive activity efficiency, as well as the ability to resist fatigue and recover faster after loads [6, 9, 16, 21, 38].

Among the variety of physiological indicators, MPP, EC, AnP, AeP, and OLFF are integral functional parameters that determine the level of SPWC and competitive activity efficiency of athletes in different sports events: cyclists [2, 3], middle- and long-distance runners [4], rowers [4], and combat athletes [6, 16, 17, 23].

Individual publications noted that the level of SPWC and competitive activity efficiency of elite athletes is determined not only by the level of development of separate and integral functional components of FS but also by their ratios and interrelationships [3, 17].

However, relatively few studies have been devoted to the formation of the multicomponent, hierarchically organized FF structure of combat athletes that determines their SPWC level and competitive activity efficiency [6, 16, 19]. In addition, these studies did not sufficiently highlight the mechanisms of intergroup interactions of integral FF parameters, both among themselves and with sports results [11].

A number of publications analyzed the development level and proportions of a complex of separate and integral indicators of FF structure in providing sports results in cyclic sports events [2, 3, 4] and combat sports [6, 11].

However, in comprehensive studies, the main principle of the systems approach was not followed. The ratios and interrelations of functional components within the overall structure of athletes' fitness were not considered in connection with ensuring a high SPWC level [2, 4, 13, 20] or competitive activity efficiency [9].

In addition, published studies have insufficiently covered the mechanisms of integration and mutual influence of the most interrelated FS indicators of combat athletes: physical development, physical and functional fitness, and special work capacity.

While the influence of individual FS components of combat athletes on the SPWC level and sports results is reflected in numerous publications, the mechanisms of intergroup interactions in ensuring high SPWC levels in combat athletes remain among the least studied aspects of FS in the process of improving athletic mastery.

In this regard, one of the main objectives of this study was to investigate the level of development and interrelationships of separate and integral indicators of FF structure in the process of ensuring the SPWC of highly skilled combat athletes.

The application of correlation, dispersion, regression, and canonical analyses in processing and analyzing the data of this study made it possible to obtain new insights reflecting the specificity of the interrelationships and mutual influence of separate and integral functional parameters and SPWC parameters of highly skilled combat athletes in two groups: (1) Masters of Sport (MS); and (2) International Class Masters of Sport (ICMS) and Honored Masters of Sport (HMS).

The obtained results revealed the advantage of the ICMS and HMS group over the MS group in several paired and multiple intra- and intergroup relationships between functional parameters and SPWC parameters. Elite wrestlers surpassed less qualified athletes in several integral functional parameters: AnP, MPP, OLFF, and the SPWC level.

In the ICMS and HMS group, the strongest paired intergroup relationships were found between the SPWC level in three series of the specialized throw test and the values of AnP, MPP, and OLFF.

In the MS group, the strongest paired intergroup relationships were observed between the SPWC level during three throw series ($TTPT_{1\_3}$) and the values of AnP and economy.

Stepwise regression analysis made it possible to identify the dependence of certain indicators of one set on the combined and partial influence of the most informative indicators of the other set in each qualification group of combat athletes. This method allowed the calculation of regression models with different combinations of functional parameters ensuring a high SPWC level, mechanical efficiency of standard work, and the general FF level of wrestlers. The determination coefficients indicate the high accuracy of predicting the dependent result from functional parameters. This confirms the adequacy and informativeness of the regression models calculated in each experimental group.

The stepwise regression analysis method made it possible to identify: (1) the key physiological parameters determining the level of SPWC of wrestlers from two qualification groups during three series of throws performed at maximum intensity; (2) the key physiological parameters exerting the greatest impact on the SPWC level of wrestlers during the first series of throws at maximum intensity; (3) the key physiological parameters determining the mechanical efficiency of standard nonspecific work of moderate intensity on a cycle ergometer; (4) the key physiological parameters determining the overall level of functional fitness.

The components of the multiple regression models indicate that the SPWC of highly qualified wrestlers can be ensured by different sets of physiological variables, both individual and integral. The values of aerobic and anaerobic potential, mobility and economy of physiological processes, as well as the overall level of functional potential, contribute differently to the increase of SPWC in highly qualified wrestlers of the two groups. This is consistent with the principle of equifinality, which reflects the multivariance of physiological mechanisms for providing the level of special work capacity [3].

The conducted studies produced new results showing that in elite wrestlers (ICMS and HMS), the level of SPWC is mainly determined by high anaerobic power (AnP), aerobic indicators, and the ability for rapid reorganization of physiological systems. In wrestlers of the MS group, work capacity depends on a wider set of factors, including AnP, RGAeP, EC, and ventilatory characteristics, but their contribution is heterogeneous. High mobility of physiological processes is a key element both for the elite group (ICMS and HMS) and for the MS group.

The results show that the participation of the three energy systems in providing SPWC in the elite group of athletes is more balanced compared to the wrestlers of the MS group. In both groups, with the reduced role of anaerobic alactate and anaerobic glycolytic energy systems in maintaining the SPWC level, the compensatory role of the aerobic mechanism increases. It is characteristic that the role of the anaerobic energy system (alactate and glycolytic) in maintaining the SPWC level is the leading one in both groups.

Canonical correlation analysis made it possible for the first time to determine the features of the mutual influence of the most interrelated indicators of the two sets, SPWC and FF.

This method revealed strong positive interdependencies between the weighted sums of canonical variables of FF and SPWC in both groups of wrestlers: an increase in the integral FF parameters of wrestlers in both groups contributes to an increase in their SPWC, and vice versa, an increase in the SPWC level of wrestlers is associated with an increase in their FF level. In the most highly qualified group of wrestlers (ICMS and HMS), a stronger influence of SPWC indicators on FF was revealed, while in the less qualified group (MS), a stronger influence of FF indicators on SPWC indicators was revealed. However, in both groups of wrestlers, the difference in the degree of mutual influence of one group of indicators on the other is relatively small.

The methods of canonical analysis made it possible to determine both intergroup interactions and the partial contribution of individual indicators to the total variability of the parameters of each interacting group, SPWC and FF. Thus, the greatest partial contribution to the total variability of FF indicators in the ICMS and HMS group is made by the parameters of general aerobic potential realization (RGAeP), anaerobic power (AnP), and the overall level of functional fitness (OLFF). In the total variability of SPWC variables in this qualification group, the greatest partial weight belongs to the parameters of physical work capacity in the three series of throws, TPT_1, TPT_2, TPT_3.

In the MS qualification group, the greatest partial contribution to the total variability of the integral FF indicators is made by the parameters RGAeP, AnP, and MPP. The greatest partial weight in the total variability of SPWC variables in the MS group, as in the elite group, belongs to the parameters of work capacity in the three series of throws performed, TPT_1, TPT_2, TPT_3.

The obtained results can be interpreted as follows: the most variable and informative indicators of SPWC, which change to a greater extent under the influence of integral functional parameters, in both groups of wrestlers are the work capacity indicators in the first–third testing series, TPT_1, TPT_2, TPT_3. The most informative functional parameters changing under the impact of SPWC indicators are as follows: in the ICMS and HMS group, the indicators of RGAeP, AnP, and OLFF; in the MS group, the indicators of RGAeP, AnP, and MPP.

The findings reflect both similarities and differences in the interaction of the integral parameters of FF and SPWC in the two qualification groups, as well as indicate the multivariance of the functional support of wrestlers' SPWC and its influence on the FF of athletes of different skill levels [17, 27].

The results of regression and canonical analyses show that a high level of wrestlers' SPWC can be ensured by various combinations of leading FF parameters. The role of each factor in ensuring the SPWC of wrestlers is determined both by the degree of its development and by its ratios and interrelations with other factors. An insufficient level of development of some factors may be compensated by a high level of development of others. However, to achieve the highest level of physical work capacity, the development level of the leading factors in the FF structure should be as high as possible.

The development level and interrelations of individual and integral FF parameters, their ratios, and their partial role in determining SPWC in the presented multiple regression models complement our previous research [11] and the studies of several authors devoted to the formation of combat athletes' functional profiles [9, 12, 21, 27].

Conclusions

1. Regression and canonical analyses revealed the multivariance of functional provision of physical work capacity in highly qualified wrestlers. A high level of special physical work capacity (SPWC) and mechanical efficiency of standard work in the group of highly qualified wrestlers can be ensured by different sets of functional variables. The multivariance of SPWC functional provision in highly qualified wrestlers reflects the reliability of interchangeable mechanisms for providing SPWC and is one of the major criteria of combat athletes' functional reserves formed in the process of long-term adaptation to physical loads.
2. The influence of each functional fitness parameter on the level of physical work capacity is determined by its development level, its ratios, and interrelations with other functional parameters. An insufficient level of development of some parameters may be compensated by a high level of development of others. However, to achieve the highest level of physical work capacity, the development of the leading integral parameters of wrestlers' functional fitness (FF) structure should be maximized.
3. Indicators of the total variability of canonical FF and SPWC variables demonstrate a strong interdependence of the parameters of the two sets in each qualification group of subjects. An increase in anaerobic and aerobic capacities, mobility and economy of physiological processes, as well as the overall level of functional potential, is associated with an increase in wrestlers' SPWC, and vice versa, an increase in wrestlers' SPWC contributes to an increase in athletes' functional capacities in both groups.
4. Elite wrestlers of the highest qualification (ICMS and HMS) differ from medium-qualification wrestlers (MS) by a higher level of anaerobic power, mobility of physiological processes, overall level of functional fitness, resting HR, watt-pulse of standard work, and the integral indicator of special work capacity. At a high level of development of these parameters, ICMS and HMS demonstrate a more pronounced effect of economy. In the less qualified group of wrestlers (MS), a pronounced mixed influence of aerobic, ventilatory, and anaerobic factors is observed, but the greatest contribution to physical work capacity belongs to anaerobic power and mobility of physiological processes. High mobility of physiological processes is a key element both for medium- and elite-level wrestlers.
5. The most variable and informative indicators of SPWC, changing to a greater extent under the influence of integral functional parameters in both groups of combat athletes, are the work capacity indicators in the first–third series of throw testing. The most variable FF indicators during the change of SPWC parameters are as follows: in the ICMS and HMS group, the indicators of anaerobic power, general aerobic potential realization, and the overall level of functional fitness; in the MS group, the indicators of general aerobic potential realization, anaerobic power, and mobility of physiological processes.
6. The SPWC level of highly qualified wrestlers can be ensured by different sets of individual and integral physiological variables. Multiple correlation and determination coefficients, as well as multiple regression models, demonstrate that with various combinations of variables from one group of indicators, the variables of the other group can be predicted with high accuracy. This indicates the adequacy and informativeness of the developed models in each experimental group. This is consistent with the principle of equifinality, reflecting the multivariance of physiological mechanisms ensuring athletes' special physical work capacity.
7. The mechanical efficiency of standard work in the HMS and ICMS group demonstrates the greatest dependence on the indicators of watt-pulse of standard work, MV (l/min), ventilatory equivalent, economy, and oxygen debt; in the MS group, on the indicators of watt-pulse of standard work, ventilatory equivalent, and economy.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Mishchenko VS. *Athletes' functional capacities*. Kyiv: Health; 1990; 1990.
2. Mishchenko VS, Pavlik AI, Dyachenko VF. *Functional fitness as an integral characteristic of the prerequisites for high work capacity of athletes*. Kyiv: Scientific World; 1999.
3. Pavlyk A. Competitive activity efficiency of highly skilled cyclists depending on functional fitness level. *Science in Olympic Sport*, 2019;3:151158.
4. Lysenko E. N., Yeremenko N. P., Sokolov V. V. Functional potential realization and peculiarities of special work capacity manifestation in skilled athletes of cyclic sports events. *Sports Medicine and Physical Rehabilitation*, 2018;1:37–46.
5. Niu Z, Huang Z, Zhao G, Chen C. Impact of three weeks of integrative neuromuscular training on the athletic performance of elite female boxers. *PeerJ*, 2024;12: e18311. https://doi.org/10.7717/peerj.18311
6. Danko T.G. Characteristics of functional fitness structure of highly skilled wrestlers during precompetitive preparation stage. *Pedagogics, Psychology and Medico-Biological Issues of Physical Education and Sport*. 2008; 4: 25–32.
7. Konstantinova LI, Semenova EI, Okhlopkova ED, Efremova AV, Olesova LD, Krivoshapkina ZN, et al. Morphofunctional indicators of organism of the athletes-wrestlers of Yakutia. *Yakut Medical Journal*, 2019;(1): 24–27. https://doi.org/10.25789/YMJ.2019.65.07
8. Šimenko J, Mahnič N, Kukovica D, Sertić H, Segedi I, Milić R, et al. Exploring the Relationship between Anaerobic and Morphological Characteristics and Competition Success in Young Male Slovenian Judo Athletes. *Applied Sciences*, 2024;14(3): 1235. https://doi.org/10.3390/app14031235
9. Nikooie R, Cheraghi M, Mohamadipour F. Physiological determinants of wrestling success in elite Iranian senior and junior Greco-Roman wrestlers. *The Journal of Sports Medicine and Physical Fitness*, 2017;57(3). https://doi.org/10.23736/S0022-4707.16.06017-5
10. Ceylan B, Šimenko J, Balcı ŞS. Which Performance Tests Best Define the Special Judo Fitness Test Classification in Elite Judo Athletes? *Journal of Functional Morphology and Kinesiology*, 2022;7(4): 101. https://doi.org/10.3390/jfmk7040101
11. Pryimakov O, Sawczuk M, Korobeynikov G, Mazurok N, Omelchuk O. Intra- and intergroup interrelations of parameters of physical development structure and speed-strength fitness of highly skilled combat athletes. *Physical Education of Students*, 2025;29(1): 13–26. https://doi.org/10.15561/20755279.2025.0102
12. Rahmani-Nia F, Mirzaei B, Nuri R. Physiological profile of elite Iranian junior Greco-Roman wrestlers. *International Journal of Fitness*, 2007;3:49–54.
13. Shariat A, Shaw BS, Kargarfard M, Shaw I, Lam ETC. Kinanthropometric attributes of elite male judo, karate and taekwondo athletes. *Revista Brasileira de Medicina do Esporte*, 2017;23(4): 260–263. https://doi.org/10.1590/1517-869220172304175654
14. Podrigalo LV, Volodchenko AA, Rovnaya OA, Ruban LA, Sokol KM. Analysis of adaptation potentials of kick boxers' cardio-vascular system. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports*, 2017;21(4): 185. https://doi.org/10.15561/18189172.2017.0407
15. Alekseeva V, Guryeva A, Nikolaeva E. Morphofunctional characteristics of adolescents and young males in combat sports. *Human Sport Medicine*, 2020;20(2): 38–46. https://doi.org/10.14529/hsm200205
16. Malinsky II. Individual peculiarities of wrestlers' anaerobic lactate capacities as one of the factors of their functional fitness. *Science in the Olympic Sport*, 2000;1:79–85. (In Russian)
17. Pryimakov O, Iermakov S, Kolenkov O, Samokish I, Juchno J. Monitoring of functional fitness of combat athletes during the precompetitive preparation stage. *Journal of Physical Education and Sport*, 2016;16 (2):551–561.
18. Casals C, Huertas JR, Franchini E, Sterkowicz-Przybycień K, Sterkowicz S, Gutiérrez-García C, et al. Special Judo Fitness Test Level and Anthropometric Profile of Elite Spanish Judo Athletes. *Journal of Strength and Conditioning Research*, 2017;31(5): 1229–1235. https://doi.org/10.1519/JSC.0000000000001261
19. Kons RL, Detanico D, Ache-Dias J, Dal Pupo J. Relationship between physical fitness and match-derived performance in judo athletes according to weight category. *Sport Sciences for Health*, 2019;15(2): 361–368. https://doi.org/10.1007/s11332-018-00524-y
20. Sterkowicz-Przybycień K, Fukuda DH, Franchini E. Meta-Analysis to Determine Normative Values for the Special Judo Fitness Test in Male Athletes: 20+ Years of Sport-Specific Data and the Lasting Legacy of Stanisław Sterkowicz. *Sports*, 2019;7(8): 194. https://doi.org/10.3390/sports7080194
21. Mirzaei B, Ghahremani Moghaddam M, Alizaee Yousef Abadi H. Analysis of Energy Systems in Greco-Roman and Freestyle Wrestlers Who Participated in the 2015 and 2016 World Championships. *International Journal of Wrestling Science*, 2017;7(1–2): 35–40. https://doi.org/10.1080/21615667.2017.1394402
22. Burdukiewicz A, Pietraszewska J, Stachoń A, Andrzejewska J. Anthropometric profile of combat athletes via multivariate analysis. *The Journal of Sports Medicine and Physical Fitness*, 2018;58(11). https://doi.org/10.23736/S0022-4707.17.07999-3
23. Kirk C, Clark D, Langan-Evans C. The influence of aerobic capacity on the loads and intensities of mixed martial arts sparring bouts. *Journal of Sports Sciences*, 2024;42(22): 2093–2102. https://doi.org/10.1080/02640414.2024.2419239
24. Apollaro G, Ouergui I, Rodríguez YQ, Kons RL,

Detanico D, Franchini E, et al. Anaerobic Sport-Specific Tests for Taekwondo: A Narrative Review with Guidelines for the Assessment. *Sports*, 2024;12(10): 278. https://doi.org/10.3390/sports12100278
25. Venckunas T, Bruzas V, Snieckus A, Stasiule L, Kniubaite A, Mickevicius M, et al. Anaerobic Performance Profiling in Elite Amateur Boxers. *Sports*, 2024;12(9): 231. https://doi.org/10.3390/sports12090231
26. Plush MG, Guppy SN, Nosaka K, Barley OR. Developing a comprehensive testing battery for Mixed Martial Arts. *International Journal of Exercise Science*, 2021;14(4); 941–961. https://doi.org/10.70252/BUHI5001
27. Melki H, Bouzid M, Fadhloun M. Correlation between Morphological and Functional Variables during a Specific Wrestling Test For Tunisian Cadet Greco-Roman Wrestlers. *Journal of Physical Education and Sport*, 2019; 19(4):1282–1287. https://doi.org/10.7752/jpes.2019.s4186
28. Roklicer R, Trivic T, Milovanovic I, Ostojic SM, Drid P. Fitness and anthropometric profiles of Serbian elite Greco-Roman wrestlers. *Science & Sports*, 2020;35(2): 115–116. https://doi.org/10.1016/j.scispo.2019.10.008
29. Gierczuk D, Sadowski J. Fitness profiles of successful and less successful Greco-Roman and freestyle wrestlers. *Journal of Physical Education and Sport,* 2021;21 (6);3541–3546. https://doi.org/10.7752/jpes.2021.06479
30. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA*, 2013;310(20): 2191. https://doi.org/10.1001/jama.2013.281053
31. Mischenko, V.S., Pavlik, A.I., Savchin, S., Dyachenko, A.Yu., Lysenko, O.M. (). Functional preparedness of qualified athletes: approaches to increasing the specialization of evaluation and directed improvement]. *Science in the Olympic* Sport, 1999;1:61–69. (In Russian)
32. Kolenkov OV, Prijmakov OO, Pristins'kij VM, Osipcov AV. *Modeling the structure of the special physical fitness skilled fighters on the stage of maximum realization of individual features.* Donetsk: Noulidzh; 2012. (In Russian).
33. Borovikov VP. *A popular introduction to modern data analysis in STATISTICA. Methodology and technology of modern data analysis*. Moscow: Goryachaya Liniya-Telecom; 2018.
34. Härdle WK, Simar L. Canonical Correlation Analysis. In: *Applied Multivariate Statistical Analysis*, Cham: Springer International Publishing; 2019. P. 431–442. https://doi.org/10.1007/978-3-030-26006-4_16
35. Jendoubi T, Strimmer K. A whitening approach to probabilistic canonical correlation analysis for omics data integration. *BMC Bioinformatics*, 2019;20(1): 15. https://doi.org/10.1186/s12859-018-2572-9
36. Meierbachtol A, Yungtum W, Paur E, Bottoms J, Chmielewski TL. Psychological and Functional Readiness for Sport Following Advanced Group Training in Patients With Anterior Cruciate Ligament Reconstruction. *Journal of Orthopaedic & Sports Physical Therapy*, 2018;48(11): 864–872. https://doi.org/10.2519/jospt.2018.8041
37. Bueno JCA, Faro H, Lenetsky S, Gonçalves AF, Dias SBCD, Ribeiro ALB, et al. Exploratory Systematic Review of Mixed Martial Arts: An Overview of Performance of Importance Factors with over 20,000 Athletes. *Sports*, 2022;10(6): 80. https://doi.org/10.3390/sports10060080
38. Tota Ł, Pilch W, Piotrowska A, Maciejczyk M. The Effects of Conditioning Training on Body Build, Aerobic and Anaerobic Performance in Elite Mixed Martial Arts Athletes. *Journal of Human Kinetics*, 2019;70(1): 223–231. https://doi.org/10.2478/hukin-2019-0033

Information about the authors:

Oleksandr Pryimakov; (Corresponding author); https://orcid.org/0000-0003-0351-486X ; sanaol7.alex@gmail.com ; Faculty of Physical Culture and Health Promotion, University of Szczecin (Szczecin, Poland); Faculty of Physical Education, Sports and Health, Mykhailo Drahomanov Ukrainian State University (Kyiv, Ukraine).

Marek Sawczuk; https://orcid.org/0000-0002-5730-5249 ; Marek.Sawczuk@usz.edu.pl ; Department of Physical Education, Gdansk University of Physical Education and Sport; Gdansk, Poland.

Georgiy Korobeynikov; https://orcid.org/0000-0002-1097-4787 ; k.george.65.w@gmail.com; Department of Theory and Methodology of International Wrestling, Uzbek State University of Physical Education and Sports (Chirchik, Tashkent, Uzbekistan); National University of Physical Education and Sport of Ukraine (Kiev, Ukraine);

Nataliya Mazurok; https://orcid.org/0000-0001-7346-1156 natprim75@gmail.com ; Institute of Physical Culture Sciences, University of Szczecin (Szczecin, Poland); Faculty of Physical Education, Sports and Health, Mykhailo Drahomanov Ukrainian State University (Kyiv, Ukraine).

Cite this article as:
Pryimakov O, Sawczuk M, Korobeinikov G, Mazurok N. Intra- and intergroup relationships between parameters of functional fitness and special physical work capacity in highly skilled wrestlers. *Physical Education of Students,* 2026;30(1):28–42.
https://doi.org/10.15561/20755279.2026.0104

Received: 10.01.2026

Accepted: 24.02.2026; Published: 28.02.2026