Complex assessment of athletes' operative status and its correction during competitions, based on the body impedance analysis

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

Abstract

Purpose:	The aim of this research was assessment and correction of highly skilled swimmers' operative status during competitions.
Material:	The authors carried out complex assessment of 46 high-skilled swimmers during competition period. The body impedance analysis and functional status express diagnosis were conducted before and after competitions.
Results:	The components limiting the operational state of swimmers were determined: "component composition of the body" (44.83% of the total load), "functional" (19.97%). Correlation relationships were established between the main indicators that determine the level of the operational state of athletes. The multiple regression equation was calculated, which made it possible to determine the influence of individual significant parameters on the level of the operational state of athletes and the confidence interval. A group of athletes with operational status indicators below the confidence interval received sport supplementation.
Conclusions:	The main characteristics of the athletes' operative status are cellular biomarker phase, fat free mass, extracellular water, intracellular water, strength index. These characteristics should be used in assessment of both operative status and complex functional diagnosis of highly-skilled swimmers during competitions.
Keywords:	operative status, correction, body impedance analysis, highly skilled swimmers.

Introduction

The duration of competitions and number of competition days directly depends on the kind of sport. Swimming is the second after track and field athletics sport kind by the number of award medals. In the XXXI Olympiad of 2016 athletes participated in 32 kinds of swimming competitions. So, duration of swimming competitions ranges from 7 to 9 days. The winner results differ in centiseconds. Many athletes participate in several swimming distance types, which predisposes for increased requirements to their training, physical working performance and rehabilitation. This is why control and assessment of their operative status during all competitions is important for both timely correction and achieving best sport results. The method of body impedance analysis has recently been widely used in complex examination of athletes, which aids in evaluation of the athlete body composition changes, hydration and energy level during various stages of training. This provides for perfection of the competition trainings, loading intensity, i.e. effectively and timely improve athlete condition before the competitions [1-4]. There have been carried out sufficient number of the body impedance analyses of athlete during training [5-8]. The relation between body impedance characteristics and physical ability to work as well as preparation level have been revealed. Some studies have been held in cyclic sport types [9-11]. However, none of the studies revealed practice application of the body impedance analysis during competitions. There are still no data on the effect of certain characteristics onto the person's sport performance as well as necessity of timely correction of the athletes' operative status at the start in swimming. *The aim of this research* was assessment and correction of highly skilled swimmers' operative status during competitions.

Materials and methods

Participants

46 athletes of the National swimming team of Ukraine have participated in the study, aged from 17 to 23 years (20+3.2). All participants agreed on their data processing and publication of the study results. In order to assess the operation status of highly-skilled swimmers several tests have been held within the study:

➢ Multi-factorial express-diagnosis according to Dushanin [17], aimed at estimating functional condition due to the anaerobic metabolism threshold heart rate (ANMT HR), maximum oxygen consumption (MOC), total metabolic capacity (TMC), creatine phosphate (CP).

➢ Variation pulsometry according to Baievskiy [17], detecting the tension index (TI).

- Body impedance analysis (Bioscan Touch8) of the following characteristics: cellular biomarker phase (CBP), fat free mass (FFM), fat mass (FM), body density (BD), extracellular water (ECW), intracellular water (ICW), Muscle mass (MM), extracellular mass (ECM), intracellular mass (ICM), strength index (SI), health index (HI), fitness score (FS).

Study design

The studies were held during the Licensing Winter Championship of Ukraine in Swimming. The athletes' operative status was assessed during all competition days. The first study was held in the day of athlete arrival, in order to detect the significant characteristics for calculating the multiple linear regression as well as confidence interval (critical data for assessment of the operation status dynamic pattern). The subsequent assessment of operation status was carried out in the morning and evening, before and after preliminary and final races on chosen distance during a day. According to the results of the survey, all athletes were divided into 2 groups. The athletes, whose characteristics exceeded confidence interval (R.L. Neuman [17]) (second group), underwent correction procedures. In order to improve the characteristics, the 2nd group athletes took sport supplementation - Micellar Casein by company Nutrent (45 g Micellar Casein mixed with 300 ml of water) before bedtime. The Micellar Casein basis is represented with milk protein isolate high in micellar casein, enriched with milk serum protein. The milk serum protein provides for enhanced rehabilitation (quick aminoacid balancing), and the level is supported during night by prolonged breakdown of micellar casein. Micellar Casein is also enriched with the probiotic and prebiotic complex LactoWise™. The probiotics (bacterium strain Bacillus coagulans) and prebiotics (bacterium strain Galactomannans) composing the LactoWise™ positively affect gastrointestinal functions.

Statistical Analysis

All obtained data were statistically processed using the STATISTIKA 10.0 software. The data are represented as the mean average ± standard deviation (SD). The Fisher test was used to check standard distribution of the variables. In case of non-standard distribution, logarithmic transformation was used. The bilateral repeated estimation by STATISTIKA 10.0 was used for comparison of the obtained characteristics before the onset and in the end of the study. The relation between basic characteristics of function status was estimated using the Brave-Pearson correlation coefficient. To make a model of optimum operation status multiple linear regression equation was used, which aided in detecting the most significant parameters, providing for the best sport performance.

Results

To calculate the multiple linear regression in order to detect the most significant characteristics which show the swimmer's condition, factor analysis of the athletes' operation status structure was conducted. The study revealed 4 factors which completely reflect the highly-skilled swimmers operation status, with the first factor reflecting 44.83% of overall load, the second factor – 19.97%, the third factor– 13.7% and the fourth factor 112% (table 1).The first and second factors are the main in the dispersion, being the leading ones in detecting operation status of athlete.

The first factor, «body composition», consisted of 9 components - CBP, FFM, ECW, ICW, MM, ECM, ICM,

Table 1. Factor structure of operation status of highly skilled swimmers

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Anaerobic metabolism threshold heart rate	-0.269523	-0.943685	0.081395	-0.018397
Maximum oxygen consumption	-0.204162	-0.952172	0.128614	-0.041784
Detecting the tension index	0.109558	-0.043541	0.944119	-0.072216
Total metabolic capacity	-0.119290	0.217078	0.108833	0.848637
Creatine phosphate	-0.054539	-0.655495	0.742335	-0.079314
Cellular biomarker phase	-0.979173	0.026677	-0.016626	-0.230020
Fat free mass	-0.974103	0.173664	0.125126	-0.212133
Fat mass	0.934969	-0.173232	-0.125654	0.208733
Extracellular water	-0.953013	-0.076487	-0.187605	-0.041514
Intracellular water	0.834177	-0.393846	-0.224038	-0.060263
Muscle mass	-0.840674	0.375749	0.272208	0.055290
Extracellular mass	-0.961170	-0.019385	-0.135626	0.025915
Intracellular mass	-0.845954	-0.219844	-0.341937	0.087828
Strength index	-0.893531	-0.305576	0.027535	0.544199
Operative status	0.047627	0.556781	0.423843	-0.495383
Total %	44.8369	19.9718	13.7490	11.2782

SI. The maximum factor loading (0.97) observed with the FFM and CBP characteristics, which reflect functional condition of active muscular and fat tissue as well as the metabolism rate. The second factor, the «functional» one, joined two components of MOC and ANMT HR, which characterize special working performance of the swimmers. Maximum loading of the factor is observed with ANMT HR (0.95). The third factor joined two components: CP and TI. The maximum factor loading observed with the CP characteristics (0.94). The fourth factor is represented with a single parameter of TMC of 0.84.To choose the most significant characteristic changes, which define the operation status level, the authors detected reliable relation between the obtained parameters (fig.1).

According to the received correlations, multiple linear regression equation was calculated, which provided for detection of certain significant characteristics reflecting the sport performance of the athlete:

$$OS=1{,}78X_{10}+1{,}49X_7+0{,}932X_{11}+0{,}866X_6+0{,}466X_{15}-178{,}29 \quad (1)$$

where:

OS – operative status; X_{10} – ECW – extracellular water; X_7 – FFM – fat free mass; X_{11} – ICW - intracellular water; X_6 – CBP – cellular biomarker phase; X_{15} – SI – strength index.

According to the results of the primary study, all athletes were characterized with high and "better than average" operation status. To assess the operation status dynamic pattern the authors calculated confidence interval, which equalled 2.67 units. The examination of 46 athletes in the end of the first competition day established two athletes groups. The changes of operation status in first group, represented with 35 athletes (76.09%), didn't exceed the confidence interval limits. Decreased characteristics of FFM, ECW, ICW, SI and CBP were within tolerance, being closer to the initial ones after the morning and evening start. The operation status criteria in the second group, represented with 11 people (23.91%) were considerably under the confidence interval limits after the morning start and after the final (table 2).

Maximum decrease observed in the FFM characteristics, which evidences about decreased dry muscle mass as well as energy supply SI, which is indicative of decreased power potential of the athletes, CBP, i.e. observed working performance and metabolism intensity. The decrease in these parameters coincides with decreased operation status of the second group athletes. Repeated assessment of the 1st and 2nd group athletes was conducted the next day, before the competitions. An increase in the second group athletes' operative status was noted, being almost similar with the initial one (Fig.2).
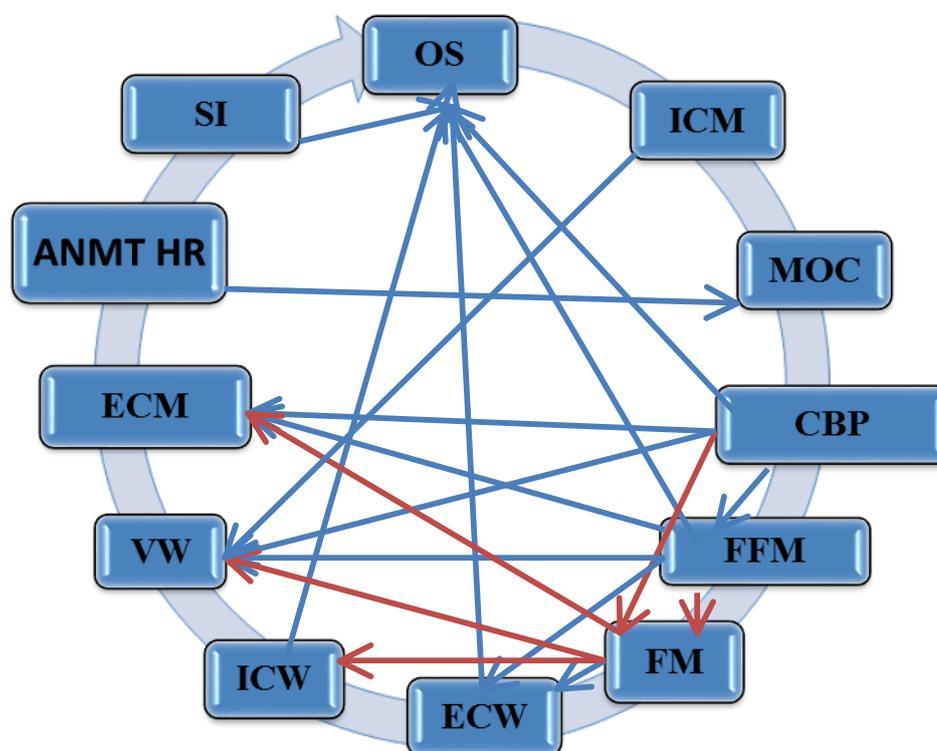
Figure 1. Correlation between the characteristics of sport performance of highly skilled swimmers during competitions.

Note: ⟶ positive correlation; ⟶ negative correlation; OS – operative status; SI – strength index; ANMT HR - anaerobic metabolism threshold heart rate; ECM - extracellular mass; VW - ; ICW - intracellular water; ECW – extracellular water; FM - fat mass; FFM – fat free mass; CBP – cellular biomarker phase; MOC - maximum oxygen consumption; ICM - intracellular mass.

Table 2. Dynamic pattern of operative status of highly-skilled athletes of second group

Athletes	OS – operative status (conventional units)			CBP – cellular biomarker phase (conventional units)			FFM– fat free mass (%)			ECW – extracellular water (%)			ICW – intracellular water (%)			SI – strength index (conventional units)		
	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES	BC	AMS	AES
Bohdan D.	95.28	86.03*	82.89*	10.46	9.22	8.47	89.4	84.5	83.2	43.8	42.62	42.4	56.1	58.0	57.9	1.18	1.14	1.11
Victoriia P.	95.54	92.79*	90.56*	10.32	8.73	8.68	91.7	89.19	89.0	41.8	43.62	43.5	58.1	56.37	56.3	1.22	1.07	1.07
Olga M..	82.73	78.56*	75.93*	8.29	8.12	7.95	82.48	80.0	78.6	43.92	43.52	43.52	56.07	56.47	56.07	1.18	1.15	1.13
Vadim N.	99.71	96.65*	95.56*	11.21	9.19	8.94	92.79	91.53	90.94	42.79	43.65	43.6	57.2	56.34	56.39	1.22	1.12	1.11
Mukhailo R.	89.37	84.51*	76.64*	8.8	8.9	8.22	87.08	86.33	84.09	43.22	42.82	41.88	56.77	57.17	58.11	0.91	0.91	0.91
Karina S.	92.64	86.02*	82.75*	10.95	9.06	8.39	88.3	83.86	82.84	42.24	44.45	43.19	57.75	55.54	56.8	1.9	1.39	1.31
Alina T.	70.11	69.2	66.64*	8.55	7.9	7.24	71.79	71.58	70.57	47.9	47.58	47.03	52.0	52.41	52.96	1.03	1.01	1.01
Daniil T.	99.45	97.92	96.40*	11.34	10.7	9.81	92.89	92.56	91.77	42.05	41.74	42.19	57.95	58.25	57.8	1.2	1.2	1.13
Evgeniia G.	79.82	77.8	75.94*	8.86	8.14	8.11	80.37	79.66	78.66	43.57	43.23	43.37	56.42	56.76	56.2	1.13	1.13	1.13
Dariia Z.	74.72	75.24	64.68*	8.24	8.13	8.0	76.79	76.57	70.34	44.5	45.4	44.3	55.49	55.56	55.69	1.2	1.14	1.12
Margo V.	73.51	72.87	69.5*	7.65	7.38	7.23	74.46	74.46	72.22	47.85	47.73	48.04	52.14	51.95	51.26	1.03	1.02	0.98

Note:

* - operative status of athletes, exceeding the confidence interval limits;

BC – before competition; AMS – after morning session; AES – after evening session.

69
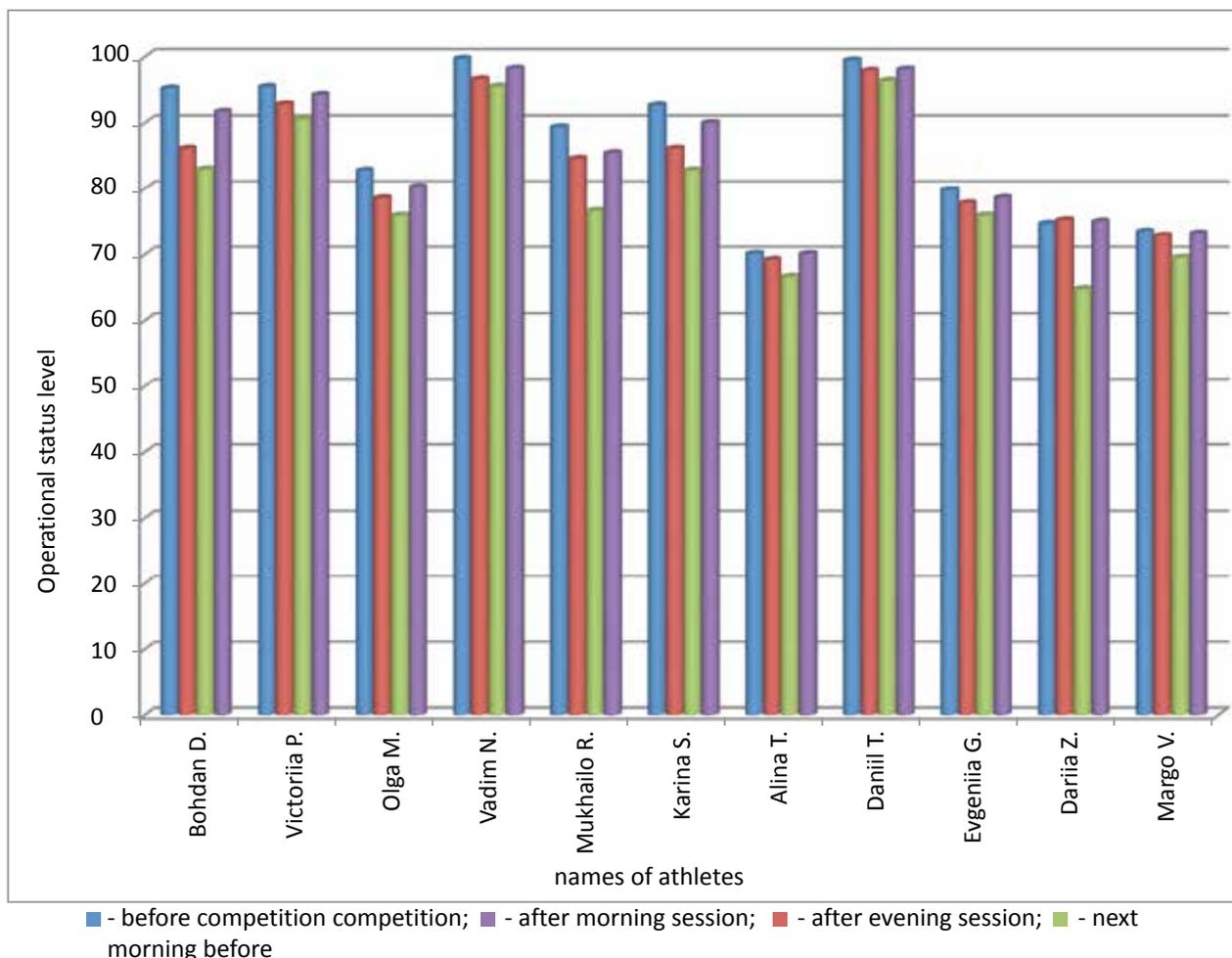
Figure 2. Dynamic pattern of the highly skilled second group swimmers' operation status changes.

Discussion

The importance of the athletes' operation status as a leading factor in high sport performance is doubtless. The offered study includes assessment and correction of the athletes' operation status during the competitions, which was based on the multi-factorial express- diagnosis of functional condition, variation pulsometry and body impedance analysis. According to the received data, the multiple linear regression equation was calculated as well as the most significant characteristics of the body impedance analysis were detected. As far as the authors know, this is the first study, based on the factor, correlation and regression analysis aimed at completing the model of highly skilled swimmers' competition operation status model. Gutiérrez et al. [18] studied the body mass indicators of athletes and determined their role in assessing the preparedness of athletes. Malá et al. [5] conducted a systematic review and identified prospects for the future in the use of bio-impedance analysis in sport and exercise. Campa et al. [19] in his studies established a specific profile of an athlete according to the characteristics of body composition: FFM, EBW, FM, which completely coincides with our studies. Esco et al. [20] determined the accuracy of bioimpedance

analysis to predict body composition in athletes. The significance of FFM was reassessed as one of the main factors in predicting body composition, which is also confirmed by our studies. Koury et al. [21, 22] used the bio-impedance analysis method to assess the functional state of young athletes in conditions of training based on the dynamics of FFM, and a conclusion was made about the need to take into account gender differences. It is proved that FFM can be a marker for determining the level of preparedness. CBP vectors were also determined, as a result of which a significant difference was found in the performance of qualified and unskilled athletes. The results of our studies have confirmed that FFM can be one of the main markers in assessing the operational state, and it was also proved that the FU index depends on the level of the athletes' operational state. Bešlija et al. [23] created a model for classifying athletes according to their level of preparedness based on bio-impedance indicators. Sesbreno et al. [24] monitored body composition and determined its relationship with performance, developed anthropometric models for assessing FFM and ACM, which allows us to determine the workability of athletes based on these indicators. In our studies, these indicators were identified as markers in assessing the performance

of swimmers. Marini et al. [25] developed an individual approach to sports training and determined the main criteria for the effectiveness of the training process of athletes using bio-impedance analysis based on the phase angle index. A high correlation (effects) of FM, FFM, TBW, ICW was obtained, which indicates more accurate indicators of bioimpedance. It was also proven that CBP shows changes in the ratio of ECW and ICW under the influence of physical activity. In our studies, a high correlation relationship between these indicators was also determined. Sukach et al. [16], Veitia et al. [26] investigated the features of the component composition of the body of young athletes in cyclic sports and its impact on the level of performance. Higher CBP values (7.2-7.5) were determined, as well as compliance with the age norm of BMI, FFM indicators. Our studies also confirm the data obtained; higher CBP indicators were noted with an increase in the qualifications of athletes. Tinsley et al. [27] in his studies examined the FFM indicator and conducted a comparative analysis of its effect on the performance of athletes with an atypical physique. In our studies, the FFM indicator was considered as an indicator of improving sportsmanship and the performance of highly qualified athletes. Khafzova et al. [4] in their studies showed the importance of bioimpedance for assessing the adequacy of the applied loads, predicting sports results and the possibility of their use as selection criteria for sports. Our studies confirm the data. Komarova [11] in her studies determined the effect of the FFM, ACM, ECW, ICW indicators on bioimpedance and also confirmed that the indicators of this analysis are markers of a sports form and testify to the effectiveness of building the training process. In our studies, it was determined that FFM, ICW, ICW, SI, CBP are the main brokers in diagnosing the level of operational status of highly qualified swimmers in the conditions of competitive activity, which partially confirms the results of Komarova research. Meleleo et al. [28] evaluated muscle and fat mass, hydration of young athletes. It was determined that the BIA provides reliable information on competitive athletes based on the progression of ECW, ICW, CBP, FFM, FM and the less significant impact of TBW. We confirmed these data in studies with highly qualified swimmers in the conditions of competitive activity. Nickerson et al. [29], the change in VIA indicators was reliably confirmed depending on the level of sportsmanship, which is confirmed by

our research. Silva [7] examined the structural and functional components of the body of athletes in the phenotype of sports health and performance based on the BIA. An integrative model has been proposed that links performance, risk of injury and athletic health. In these studies, it was determined that the performance of FM, FFM, ICW, ECW affect the level of fitness and the performance of athletes. Our results fully confirm these data, but in the conditions of competitive activity of highly qualified swimmers. Sonksen [30] used bio-impedance analysis to evaluate the performance of sports activities. The significance of these studies is confirmed by our data. Segal [6] in his studies showed the importance of the BIA on the basis of the ECW, ICW, FFM indicators in assessing the clinical status of athletes at risk of hydration disorders, indicated the need for certain correction tools. In our studies, these indicators were examined from the point of view of assessing the operational status and performance; on the basis of the identified changes, specific means of correcting these indicators were also proposed, which expands and partially confirms the research of Segal. An important factor for the study is defining significant criteria for the high skilled swimmers' operation status correction during competitions: calculating the confidence interval. Despite the obtained results, it is necessary to note that the importance of physical, technical and tactical readiness for achieving high results in swimming still stays high.

Conclusions

The basic criteria, determining the athletes' operation status, are CBP, FFM, ECW, ICW, SI. According to high reliability of the obtained results, these characteristics must be used for assessment of both operation status and complex functional diagnosis of high-skilled swimmers during competitions.

Conflicts of interest
Authors have no conflict of interest to declare.

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