The relationship between body composition before a sports fight and the technical and tactical performance of kickboxing athletes

Marta Niewczas [1ABCDE], **Wojciech Wąsacz** [2ABCDE], **Tadeusz Ambroży** [2ABC], **Katarzyna Kucia** [2BC], **Łukasz Rydzik** [2ABCDE]

[1] Institute of Physical Culture Studies, College of Medical Sciences, University of Rzeszow, Rzeszow, Poland
[2] Institute of Sports Sciences, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Krakow, Poland

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Abstract

Background & Study Aim: Combat sports determined by weight categories require specialized analysis of the body composition of athletes. The purpose of this study is both to broaden knowledge about the overall and segmental body components of kickboxing athletes immediately before a sport fight, and that relationship of this indicators with technical-tactical performance.

Material & Methods: The body composition of 30 athletes of kickboxing at a high sport level was studied by bioelectrical impedance analysis (BIA), using the InBody 770 analyser. Simulated sparring sessions were carried out by recording with a specialized camera. On the basis of retrospective analysis, technical-tactical indices were calculated, then evaluating their relationship with body composition. The Statistica 13.3 package was used to process the results of the study.

Results: The body composition of the subjects, both globally and segmentally, was characterized by the correct value of individual components. In relation to individual cases, it is recommended to strive for fat reduction ($n = 8$; $\tilde{x} = -4.56$). There were statistically significant negative correlations between indicators of technical-tactical training and traits describing body fat (BFM, PBF) and body mass indicators (BM, BMI) at the level of near-complete, very high and high correlation ($r = -0.57$ to -0.96; $p<0.001$).

Conclusions: The obtained normal results in the body composition of the subjects are evidence of proper diet and implementation of the training process. Lower values of indicators characterizing body fat (BFM, PBF) and height and weight characteristics (BM and BMI) of kickboxers' body composition are conducive to optimizing technical-tactical performance. The results of the study provide insightful diagnosis and interpretation of kickboxers' body composition profile. Individual assessment and analysis of body components, their relationship to technical-tactical training, along with the distribution of research protocols with recommendations can individualize the training process and reduce the risk of abnormalities in the body composition of kickboxing athletes. This indicates the usefulness of these methods in combat sports, promoting a broadly understood optimization of the quality of the training process.

Keywords: attack activity • attack effectiveness • combat sports • simulated sparring

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Author's address: Łukasz Rydzik, University of Physical Education, Aleja Jana Pawła II 78 St., 31-571 Krakow, Poland; e-mail: lukasz.rydzik@awf.krakow.pl

Body composition – contribution of particular tissues (i.e., fat and muscle called body components) in body mass, often shows in kilograms or percentages [9].

Bioelectrical impedance analysis (BIA) – method of bioelectrical impedance analysis for body composition measurements; the body weight is shown as sum of fat and fat free components (extracellular mass, intracellular mass) [8].

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [50].

Kickboxing – combat sport where the form of combat are strikes, performed by hands and legs [14].

Technical-tactical indicators – calculated on the basis of specialized formulas, characterize the technical-tactical performance of players [13].

INTRODUCTION

Nowadays, one can observe a growing interest and thus a trend towards a healthy lifestyle in both recreation and competitive sports [1-4].

Taking this direction for effective action, more and more people from various spheres, including the sports community, are using advanced methods of body composition analysis to monitor the level of somatic physique components and the progress of the training process [5-7]. Currently, the most popular methods for indirect estimation of body composition include dual-energy X-ray absorptiometry (DXA) and electrical bioimpedance [8]. Body composition analysis is an important activity that allows precise characterization of the proportions of individual components in the body (including muscle mass, fat mass, water content, bone mineralization) [9]. This is particularly important in disciplines determined by weight categories, which include combat sports [10, 11]. With regard to these professions, the right proportions of body composition modules can determine a greater chance of success in a sports confrontation [12, 13].

A discipline that expresses one of the directions of martial arts development is kickboxing [14]. Athletes are required to develop above-average muscular fitness in order to perform fast, coordinated, and powerful kicks and hand strikes. The athlete should also be characterized by well-developed strength-endurance and exercise endurance in order to be able to maintain a high level of intensity for the regulation time of the duel [15, 16]. Due to such high demands of the discipline, a very important aspect is the body composition of the kickboxer, which can vary depending on the weight category, level and fighting style [17]. In this profession, a low body fat content and a high level of muscle mass development are desirable, which creates optimal conditions for the formation and improvement of fitness, coordination, and technical skills. Such indicators also increase the chances of success in the ring [17, 18]. Before competing, athletes are motivated by the motive of qualifying for a lower weight category, often aiming for a lower body mass than their natural one [19]. The strategy of this approach is based on balancing in the upper limit of the lower category, with the goal of presenting fitness abilities (especially strength abilities) from their natural body weight. Often for this purpose, athletes use a strategy of dehydration with the wake-up call of rapid weight loss during pre-competition weigh-ins. This creates the risk of structural profile abnormalities, resulting in a deterioration of exercise capacity [20]. Competition determined by weight categories requires combat sports athletes, including kickboxers, to systematically shape and control body weight and body composition. Based on properly diagnosed body composition indicators, it is possible to precisely plan a broadly understood training process (including the development of the range of techniques used and the tactical approach to combat) and a nutritional strategy (i.e., optimization of weight and body composition) for athletes of these professions [21].

In the literature, little attention has been paid to detailed analyses of kickboxers' body composition. There is a perceived paucity of studies showing a wider range of variables describing this plane. Based on the studies conducted to date, it has been established that, in general, high-level kickboxers present low body fat [22, 23] and above-average levels of muscle mass [24, 25]. In addition, a number of significant relationships have been established between weight category and levels of muscle mass and body fat, as well as technical-tactical training [13]. Delving deeper into the subject area, Ambroży et al. [16] showed that the COVID-19 pandemic and its associated restrictions resulted in, among other things, an unfavourable increase in the body weight and BMI indices of kickboxers.

It is noteworthy that previous studies have been predominantly based on the measurement of a few basic body composition variables. We believe that the results of the present study will add to the knowledge of methods for controlling the level of body composition and its relationship to technical-tactical performance, which will enable sports theorists and practitioners to optimize the training process in the broadest sense and ultimately contribute to the further development of the sport.

The purpose of this study is both to broaden knowledge about the overall and segmental body components of kickboxing athletes immediately before a sport fight, and that relationship of this indicators with technical-tactical performance.

MATERIAL AND METHODS

Participants

The study was conducted on a group of 30 kickboxing athletes presenting a high level of sportsmanship who regularly compete in competitions. The sample size was calculated using the G*Power 3.1.9.7 software (G*Power Team, Düsseldorf, Germany). The subjects' metric age, calculated from the difference between the date of the study and the date of birth, was between 18 and 32 years. Body height was measured using an A213 anthropometer in accordance with anthropometric recommendations [26]. Inclusion criteria for the study were a minimum of 5 years of sports experience, active competition, a positive recommendation from a coach and good health. Information on calendar age, activity and competition seniority was obtained on the basis of a diagnostic survey method, carried out by direct interview technique among athletes and coaching staff. General characteristics are presented in Table 1.

Survey design

The surveys were conducted in the morning according to the scheme presented in Figure 1.

Test procedures

Body composition analysis

Kickboxers' body composition was diagnosed using the segmental bioelectrical impedance (SBIA) method using the InBody 770 body composition analyser from InBody Co., Ltd (Seoul, Korea). The SBIA method measures electrical resistance in the body, which depends on tissue hydration and electrolyte concentration. The analyser uses 6 frequencies for the test. Based on the assessment of the amount of water in the body, in individual tissues, it calculates and operationalizes specialized indicators describing body composition. The advantage of this method is the safety, speed, accuracy and non-invasiveness of the measurement. Operation does not require high qualification of the person performing the measurement. The device is adapted to any body type, age or gender. Very important, especially for the competitive sports community, is that the results of the analysis are not based on empirical data (e.g., gender, age, body type) [27-29].

In accordance with the established procedure, the study was performed in the morning, the athletes were in just underwear, without shoes or socks. The measurement process included diagnosis of body composition immediately before the tournament bout. The athletes were hydrated in full readiness for the sports confrontation. The official weigh-in to meet the category's weight limit was performed the day before.

Table 1. General characteristics of the kickboxing athletes (n = 30) studied.

Variable	$\tilde{X}$	SD	Min	Max	Q1	Q3
Age [years]	24.12	4.33	17.8	32.00	21.00	28.5
Body height [cm]	179.02	4.91	170.1	188.4	176.25	182.08

$\tilde{X}$ arithmetic mean, **SD** standard deviation, **Min** minimum, **Max** maximum, **Q1** bottom quartile, **Q3** upper quartile

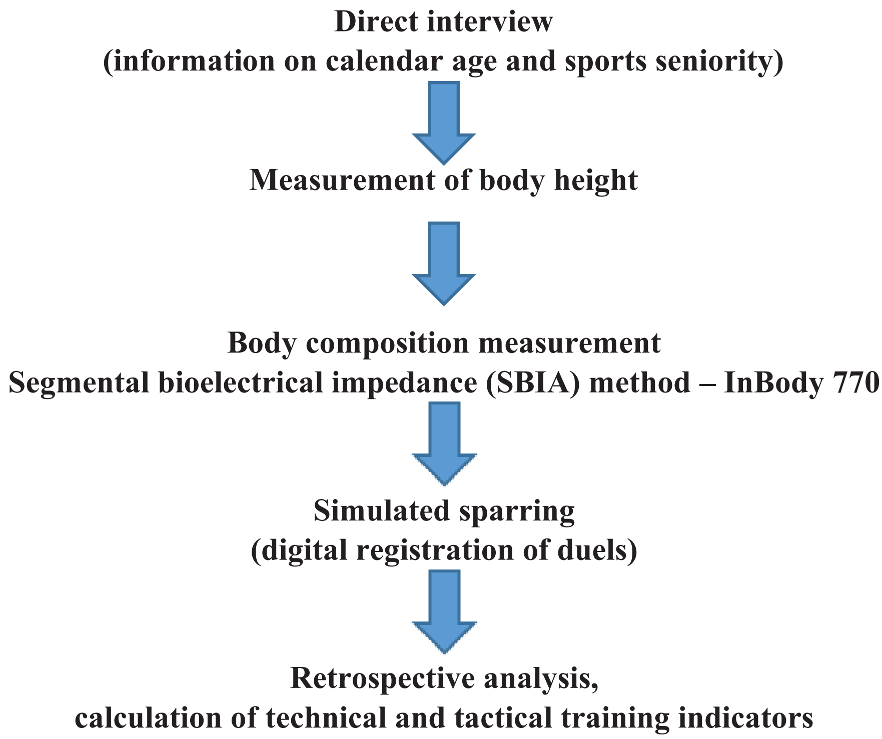


Figure 1. The course of the study.

In the study, the following were performed on the basis of specialized indicators: overall body composition analysis, muscle-fat analysis, obesity analysis, segmental analysis of lean body mass, body fat and water content. The procedure for using the device during the study followed the manufacturer's instructions [30].

In addition, each athlete received an individualized protocol with an assessment based on his performance and recommendations for further management relative to optimal body composition (Table 2).

Specialized indicators describing the body composition profile of the athletes studied were compared with the reference values of the upper and lower limits (normal range: upper limit and lower limit) calculated by the InBody 770 analyser based on the pre-test data entered (age, height and gender).

Simulated sparring

Each athlete performed a standard set of exercises to prepare the body for the exercise (warm-up). Then, immediately after, he participated in simulated sparring in accordance with K1 rules adopted by the World Association of Kickboxing Organizations (WAKO). Thirty duels were conducted. Each subject had one three-round sparring session, 2 minutes each with a one-minute break between rounds. The fighters were matched according to their weight categories. The fights took place in the ring, which was located in a neutral environment. The duels were supervised by a qualified, licensed referee. A GoPro HERO10 (GoPro Inc, San Mateo, USA) camera on a specialized tripod was placed in a vantage point giving a full view of the ring, which recorded footage for planned, retrospective analysis of the fights.

Technical and tactical analysis

Technical and tactical analysis of simulated sparring matches was conducted by three master-class coaches and one licensed referee. The researchers recorded all offensive techniques on special measuring sheets, divided into effective (scored) and ineffective (missed, hit on block, guard). The observational data were averaged and entered into a Microsoft Excel (Microsoft Corporation, Redmond, USA) spreadsheet, where

Table 2. Statistical characteristics of the body composition recommendations of the kickboxing athletes (n = 30) studied.

Indicator	X̃	SD	Min	Max	CV
Target weight [kg]	76.28	5.51	65.80	86.40	7.22
Weight control [kg]	−4.25	7.29	4.30	−22.00	−171.57
BFM control [kg]	−4.56	7.01	3.10	−22.00	−153.79
FFM control [kg]	0.31	0.17	0.00	4.6	380.56
BMR (basal metabolic rate) [kcal]	1776.93	114.31	1479.00	1956.00	6.43
Recommended calorie intake [kcal]	2807.33	288.72	2355.00	3662.00	10.28

X̃ arithmetic mean; **SD** standard deviation; **Min** minimum; **Max** maximum; **CV** coefficient of variation

technical-tactical training indicators (attack activity, attack effectiveness, attack efficiency) were calculated using the specialized formulas listed below (equations 1-3) [13] – in the present study, each fighter fought one fight.

Attack activity (Aa):

$$Aa = \frac{number\ of\ recorded\ attacks\ by\ the\ player}{number\ of\ fights\ fought\ by\ the\ athlete\ under\ study} \quad (1)$$

Attack effectiveness (Sa):

$$Sa = \frac{n}{N} \quad (2)$$

where **n** is the number of successful attacks rated at 1 point (in K1 formula, each clean hit on an opponent gives 1 point); **N** the sum of observed fights for a given fighter (in the present study, each fighter fought one fight).

Attack effectiveness (Ea):

$$Ea = \frac{number\ of\ successful\ attacks}{number\ of\ all\ attacks} \times 100 \quad (3)$$

Assessment criteria

The following assessment criteria were adopted:

- a successful attack is defined as a technical action for which a point was awarded.
- the number of all attacks determines all offensive techniques (effective and ineffective).

Statistical analysis

In developing the results of the study, basic statistical methods were applied by determining the arithmetic mean (M), standard deviation (SD or ±), minimum value (Min), maximum value (Max), coefficient of variation (CV), lower and upper quartile (explanations under the tables). The normality of the distribution was checked and confirmed distributions deviating from normal, using the Shapiro-Wilk test. Spearman's rank correlation was used to assess the relationship between the variables studied. The analysis of the collected material was developed in the Statistica 13.3 package (TIBCO Software Inc, Santa Clara, USA).

Ethics

The research was conducted in accordance with the Helsinki Declaration. The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow, Poland (No. 287/KBL/OIL/2020).

RESULTS

In terms of evaluation, it was found that the collective of athletes presented a normal level of development of indicators describing body composition, and their value in all cases was closer to the upper limit (UP) of normal for healthy people. A slight exceeding of the upper limit of normal was noted for skeletal muscle mass (SMM) and BMI. The results of the coefficient of variation indicate that among the population under study, within group variation appeared to be relatively low. The exceptions were body mass (BM), mineral content, body fat mass (BFM), percent body fat (PBF) and BMI (above 10%) (Table 3).

Table 3. Statistical characteristics of body composition of the kickboxing athletes (n = 30) studied.

Indicator	X̃	LL (value according to InBody 770)	UP (value according to InBody 770)	SD	Min	Max	Q1	Q3	CV
Body mass (BM) [kg]	80.53	59.97	81.16	10.41	61.5	95.4	71.6	91.75	12.93
Total body water (TBW) [l]	47.72	39.66	48.49	3.74	38.00	53.50	45.80	48.5	7.83
Intracellular water (ICW) [l]	29.94	24.60	30.05	2.43	23.30	33.30	28.80	30.9	8.12
Extracellular water (ECW) [l]	17.78	15.07	18.41	1.34	14.70	20.20	17.00	18.1	7.53
Protein [kg]	12.94	10.64	13.00	1.07	10.00	14.40	12.50	13.4	8.25
Minerals [kg]	4.50	3.67	4.49	0.49	3.42	5.48	4.24	4.7	10.97
Body fat mass (BFM) [kg]	15.37	8.48	16.94	7.84	6.40	33.00	8.68	18.95	50.99
Soft lean mass (SLM) [kg]	61.47	50.96	62.28	4.87	48.70	68.80	59.00	62.7	7.92
Fat free mass (FFM) [kg]	65.16	53.95	65.96	5.29	51.40	73.40	62.40	66.6	8.11
Skeletal muscle mass (SMM) [kg]	37.04	30.29	36.98	3.17	28.40	41.50	35.60	38.4	8.56
Body mass index (BMI) [kg/m^2]	25.19	18.41	24.96	3.73	20.50	33.00	22.90	27.9	14.81
Percent body fat (PBF) [%]	18.39	10.00	20.00	7.24	9.00	34.60	12.33	20.75	39.36

X̃ arithmetic mean; **LL** bottom reference; **UP** upper reference; **SD** standard deviation; **Min** minimum; **Max** maximum; **Q1** bottom quartile; **Q3** upper quartile, **CV** coefficient of variation

Table 4. Statistical characteristics of segmental lean body composition of the studied kickboxing athletes (n = 30).

Indicator	X̃	LL (value according to InBody 770)	UP (value according to InBody 770)	SD	Min	Max	Q1	Q3	CV
Fat free mass (FFM) of right arm [kg]	3.78	2.85	3.86	0.31	3.04	4.29	3.61	3.93	8.11
FFM of left arm [kg]	3.79	2.85	3.86	0.32	2.95	4.27	3.66	4.00	8.34
FFM of right leg [kg]	9.93	8.40	10.26	0.99	7.70	11.84	9.54	10.57	9.98
FFM of left leg [kg]	9.87	8.40	10.26	0.91	7.79	11.53	9.50	10.41	9.19
FFM of trunk [kg]	29.05	24.11	29.48	1.87	24.00	31.90	28.20	29.9	6.44

X̃ arithmetic mean; **LL** bottom reference; **UP** upper reference; **SD** standard deviation; **Min** minimum; **Max** maximum; **Q1** bottom quartile; **Q3** upper quartile, **CV** coefficient of variation

Based on the analysis of the average values, it can be seen that the studied athletes presented a correct level of development of all indicators, while their weight was close to the upper limit of the norm (UP). The results also illustrate high inter limb symmetry. The coefficient of variation values report that the kickboxers were highly heterogeneous (homogeneous) with respect to the body composition segments in question (CV<10%) (Table 4).

The same results were observed for body water content. The kickboxers group presented normal levels of all indices determining segmental analysis of body water levels with intercondylar symmetry and balance of water management. Analysing the coefficient of variation values, there was a high homogeneity of the community (CV<10%). A slight exception was the intracellular (CV = 10%) and extracellular (CV>10%) water of the right lower limb (Table 5).

In the indicators of the upper and lower extremities, a normal level was noted in comparison with the norms (BFM<160%). In the case of the trunk segment, a 27.7% excess of the norm (BFM>160%) was noted. With regard to body fat distribution, a slight asymmetry in predominance

Table 5. Statistical characteristics of segmental water levels in the body composition of the kickboxing athletes (n = 30) studied.

Indicator	X̃	LL	UP	SD	Min	Max	Q1	Q3	CV
		value according to InBody 770							
Total body water (TBW) of right arm [l]	2.94	2.24	3.03	0.24	2.37	3.34	2.80	3.05	8.11
TBW of left arm [l]	2.95	2.24	3.03	0.25	2.30	3.32	2.85	3.11	8.34
TBW of right leg [l]	7.71	6.58	8.05	0.77	6.02	9.21	7.42	8.22	9.96
TBW of left leg [l]	7.67	6.58	8.05	0.70	6.09	8.97	7.39	8.1	9.15
TBW of trunk [l]	22.55	18.90	23.09	1.44	18.70	24.80	21.93	23.2	6.38
Intracellular water (ICW) of right arm [l]	1.84	1.39	1.87	0.15	1.46	2.08	1.76	1.91	8.14
ICW of left arm [l]	1.84	1.39	1.87	0.15	1.42	2.06	1.77	1.93	8.34
ICW of right leg [l]	4.85	4.08	4.99	0.49	3.68	5.74	4.63	5.11	10.00
ICW of left leg [l]	4.80	4.08	4.99	0.45	3.72	5.57	4.59	5.04	9.29
ICW of trunk [l]	14.16	11.72	14.31	0.95	11.50	15.60	13.7	14.6	6.72
Extracellular water (ECW) of right arm [l]	1.10	0.85	1.15	0.09	0.91	1.26	1.05	1.14	8.22
ECW of left arm [l]	1.11	0.85	1.15	0.09	0.88	1.26	1.07	1.18	8.43
ECW of right leg [l]	2.86	2.50	3.06	0.29	2.34	3.47	2.69	3.04	10.16
ECW of left leg [l]	2.87	2.50	3.06	0.26	2.37	3.40	2.74	3.06	9.19
ECW of trunk [l]	8.39	7.18	8.78	0.51	7.20	9.20	8.20	8.6	6.06
ECW/TBW ratio	0.373	0.360	0.390	0.006	0.362	0.387	0.370	0.377	1.578

X̃ arithmetic mean; **LL** bottom reference; **UP** upper reference; **SD** standard deviation; **Min** minimum; **Max** maximum; **Q1** bottom quartile; **Q3** upper quartile, **CV** coefficient of variation

Table 6. Statistical characteristics of segmental fat analysis of body composition of kickboxing athletes (n = 30) studied.

Indicator	X̃	Score range of standard* (%)	SD	Min	Max	Q1	Q2	CV
Body fat mass (BFM) of right arm [kg]	0.87	135.97	0.69	0.20	2.60	0.35	1.08	79.85
BFM of left arm [kg]	0.83	136.08	0.71	0.10	2.60	0.28	1.05	85.46
BFM of right leg [kg]	2.14	117.91	0.84	1.20	4.00	1.35	2.5	39.24
BFM of left leg [kg]	2.11	116.75	0.84	1.20	4.00	1.35	2.48	39.62
BFM of trunk [kg]	8.24	187.70	4.63	2.70	18.30	4.33	10.6	56.13

X̃ arithmetic mean; **LL** bottom reference; **UP** upper reference; **SD** standard deviation; **Min** minimum; **Max** maximum; **Q1** bottom quartile; **Q3** upper quartile, **CV** coefficient of variation

* normal range (where 80 is lower limit, 160 upper limit, 100 ideal state)

was shown for the upper right limb and lower right limb. In terms of homogeneity, the group of athletes studied showed very high intra-group variation in relation to the upper extremities, high for the trunk and moderate for the lower extremities (Table 6).

Effective blows accounted for 33.29% of the share of all offensive techniques inflicted. The greatest variation in the results of the study group at the moderate level was shown in terms of the effectiveness of the attack (Table 7).

For attack activity, a statistically significant negative correlation was shown with BFM and PBF with very high strength and for BM and BMI with high strength. For attack efficacy, associations with negative direction, statistically significant with almost full correlation were noted in juxtaposition with BFM and PBF, with very high strength with BM and BMI while with TBW, SLM, FFM, SMM and BCM with moderate strength. Associations of identical directions and significance were found between attack effectiveness and BM, BFM with very high correlation, for BMI and PBF high correlation, and for TBW, proteins, minerals, SLM, FFM, SMM and BCM moderate correlation (Table 8).

DISCUSSION

In preparations related to competition and competition activities and reaching the weight limit in combat sports, a comprehensive diagnosis is important. In addition to the measurement of body weight, the analysis of its composition also plays a significant role. Knowledge of this matter in combat sports optimizes the formation and control of the starting form, weight category and prevents the occurrence of injuries [31-33].

General body composition analysis defines body mass as the sum of total water, protein, minerals and fat mass in the body. The formation and maintenance of the aforementioned components

Table 7. Values of indicators of technical and tactical training.

Indicator	X̃	SD	Min	Max	Q1	Q3	CV
Attack activity (Aa)	118.87	29.72	80.00	196.00	104.75	121.5	25.00
Attack effectiveness (Sa)	39.57	15.99	22.00	72.00	25.75	52.00	40.42
Attack effectiveness (Ea)	32.94	9.35	20.00	50.49	26.32	36.73	28.39

X̃ arithmetic mean; **SD** standard deviation; **Min** minimum; **Max** maximum; **Q1** bottom quartile; **Q3** upper quartile, **CV** coefficient of variation

Table 8. Relationship according to Spearman's ranks between indicators of technical-tactical training and components of body composition.

Body component	Attack activity (Aa)	Attack effectiveness	
		(Sa)	(Ea)
Body mass (BM) [kg]	**r = –0.63; p<0.001**	**r = –0.90; p<0.001**	**r = –0.71; p<0.001**
Total body water (TBW) [l]	r = –0.20; p= 0.28	**r = –0.90; p<0.001**	**r = –0.48; p=0.01**
Protein [kg]	r = –0.17; p = 0.36	r = –0.36; p = 0.051	**r = –0.43; p=0.02**
Minerals [kg]	r = –0.17; p = 0.37	r = –0.32; p = 0.08	**r = –0.39; p = 0.03**
Body fat mass (BFM) [kg]	**r = –0.72; p<0.001**	**r = –0.96; p<0.001**	**r = –0.72; p<0.001**
Soft lean mass (SLM) [kg]	r = –0.19; p = 0.31	**r = –0.39; p = 0.03**	**r = –0.47; p = 0.01**
Fat free mass (FFM) [kg]	r = –0.19; p = 0.31	**r = –0.41; p = 0.02**	**r = –0.49; p = 0.006**
Skeletal muscle mass (SMM) [kg]	r = –0.18; p = 0.33	**r = –0.36; p = 0.048**	**r = –0.42; p = 0.02**
Body mass index (BMI) [kg/m^2]	**r = –0.68; p<0.001**	**r = –0.82; p<0.001**	**r = –0.57; p<0.001**
Percent body fat (PBF) [%]	**r = –0.74; p<0.001**	**r = –0.95; p<0.001**	**r = –0.70; p<0.001**
Body Cell Mass (BCM)	r = –0.18; p = 0.33	**r = –0.36; p = 0.048**	**r = –0.42; p = 0.02**
Bone mineral content (BMC)	r = –0.17; p = 0.37	r = –0.34; p = 0.07	**r = –0.40; p = 0.03**
InBody Score	r = 0.20; p = 0.28	r = 0.23; p = 0.23	r = 0.09; p = 0.63

statistically significant correlation (bold font): a near-complete relationship r>0.90; a very high association r = 0.70 to 0.90; high association r = 0.50 to 0.70; moderate association r = 0.30 to 0.50

within normal limits ensures balanced body composition [27, 34]. This type of desirable level was demonstrated in kickboxers' own research. The values of all indicators are in accordance with the norms for a healthy person [30]. Adequate body weight, good body hydration as well as adequate mineral and protein content can be observed in the athletes, which may be evidence of the use of a proper diet and the training process carried out in this population. This is confirmed by the high levels of soft lean body mass (SLM) and fat-free mass (FFM) located in the upper range of the norm. In addition, analysing the mean values of the standard deviation and coefficients of variation, it was observed that the formation of kickboxers was characterized by high homogeneity in terms of the results obtained (the exception were the indicators describing body fat) (Table 3). Again, the influence of targeted and specialized training on the lower dispersion of intragroup results seems highly probable. A review of scientific reports from the realm of kickboxing emphasizes that aspects of body composition not only determine competition with opponents of similar structural potential (i.e., weight class division), but also provide an optimal pillar for mastering technical knowledge and applying it in sports combat [17]. In this profession, body composition should be monitored regularly since the diagnosed body components can influence the course of a fight and the level of technical-tactical training [13].

The weight of skeletal muscle (muscles fused to the bones of the head, limbs and trunk) and adipose tissue (the sum of adipose tissue: subcutaneous, visceral and surrounding muscle) defines the assessment of the correct distribution of these components in the body. This allows for possible compensatory intervention (e.g., fat reduction vs. muscle mass expansion) [27, 34]. Available information shows that both amateur and elite male kickboxers are characterized by above-average development of muscle mass and low body fat [17, 35]. This is supported by reports on the dominance of the mesomorphy component among athletes in this profession [24, 25, 23]. Muscle-fat analysis (BM, SMM, BFM) and obesity (BMI, PBF) of the kickboxers' group from our study, situates the indicators defining it in the favourable range of balanced body composition (Table 3) [30]. The level of lean body mass ($\tilde{x}$ = 65.16) corresponds positively when compared with the study of the collective of kickboxers from 2021, where the average level was 65.12 kg [13]. Skeletal muscle mass (SMM) values in our study ($\tilde{x}$ = 37.04) exceeded the upper range of normal. Such results indicate that the training process was aimed at maximizing the development of muscle structures, which is consistent with scientific reports on this environment [17, 35]. All indicators describing the profile of fat-free mass were characterized by high homogeneity, which indicates similar results in this matter among the kickboxers studied.

Before a tournament or fight, kickboxers work to reach the weight category limit by, among other things, minimizing body fat [17]. In our study, normal levels were recorded with the exception of fighters in heavier weight categories (n = 8). The studied athletes achieved higher values of body fat percentage ($\tilde{x}$ = 18.39 ±7.24), in correspondence with high-class elite kickboxers (range from 6.1 to 12.2%) albeit these communities were characterized by smaller size (range from 4 to 16 subjects) and lower average body weight (range from 67.35 to 73.90 kg) [24, 22, 23]. The value of the indicators in question in our study is similar to boxing ($\tilde{x}$ = 18.0 ±4.6), Brazilian jiu-jitsu (BJJ); ($\tilde{x}$ = 16.9 ±4.2), karate ($\tilde{x}$ = 17.7 ±4.2), taekwondo ($\tilde{x}$ = 19.0 ±3.8) and wrestling ($\tilde{x}$ = 21.3 ±3.0) competitors, diagnosed by Stachoń et al. [36]. Subsequently, our own studies have shown similar values of body fat percentage and BMI ($\tilde{x}$ = 25.19 ±3.73) in relation to judo, ju-jitsu, thai boxing practitioners and BJJ fighters (PBF range from 15.4 to 21.3%; BMI range from 22.9% to 27.2%) [37, 10, 36, 11, 38]. Significant within-group variation was observed with respect to body weight, its relation to body height (BMI) and body fat indices. This is confirmed by the individual results of each subject (n = 8) for which intervention is required in the form of fat reduction at an average level of −4.56 kg (Table 2). Individual subject assessment showed higher PBF in athletes with higher body weight (up to 70 kg, n = 4/ $\tilde{x}$ = 13.25%; up to 80 kg, n = 10/ $\tilde{x}$ = 12.66%; up to 90 kg, n = 6/ $\tilde{x}$ = 18.98%; up to 100 kg, n = 10/ $\tilde{x}$ = 25.84%).

The results of segmental analysis of body composition (fat-free, fat and water levels) illustrate whether the aforementioned components are correctly distributed in individual body segments (limbs, torso). Comparative analysis of individual segments makes it possible to diagnose interlimb symmetry or asymmetry. Unequal distribution of muscle mass between the right and left lower or upper limbs (asymmetry) can be a sign of unbalanced exercise, current injuries or past trauma. This type of information can be very useful for coaches as well as athletes to provide direction for correcting any disproportions [27, 34]. The results of our own study and their interpretation showed a normal, symmetrical picture of the distribution of the fat-free mass of kickboxers (Table 4). As in the global dimension, the results of the segmental analysis of fat-free mass distribution are characterized by high heterogeneity. Most likely, this phenomenon was influenced by the quality of targeted training the subjects underwent, and the aforementioned body composition components could be highly symmetrically shaped and refined, in accordance with the widely understood principle of versatility of muscle work [39]. For most of the fight, a kickboxing fighter stays in the so-called 'guard', from which he delivers a series of blows from different angles, with both upper and lower limbs. As a result, he must strongly and symmetrically engage various muscle groups of the legs and arms [40].

When it comes to hydration in combat sports determined by weight categories, one can often observe the limitations associated with achieving a given body weight. Athletes aiming to compete in a lower category limit reduce their body weight, which creates the risk of dehydration [41]. The results of our own study seem to prove the avoidance of such a phenomenon, confirming the proper preparation of the subjects to face a sports confrontation with the desired state of hydration in and out of cells both globally and segmentally (Table 3 and 5). This is confirmed by the results of the ECW/TBW ratio, reporting proper water distribution and the absence of water-electrolyte disturbances. There was a high homogeneity of the recorded community effect. TBW averaged 59.26% of body weight, while ICW averaged 62.74% of TBW.

The kickboxers studied showed lower TBW values ($\tilde{x}$ = 47.72 ±3.74) than judokas ($\tilde{x}$ = 54.97), fencers ($\tilde{x}$ = 49.61) and kickboxers ($\tilde{x}$ = 51.45), while they showed higher values than karatekas ($\tilde{x}$ = 47.59), wrestlers ($\tilde{x}$ = 44.06) and taekwondo athletes ($\tilde{x}$ = 45.82) from a study by Mala et al. [42]. Compared to the same reports, the kickboxing athletes studied showed lower values of segmental TBW scores than athletes of the six combat sports [42]. However, different methodology in the form of different diagnostic devices used to measure body composition should be noted.

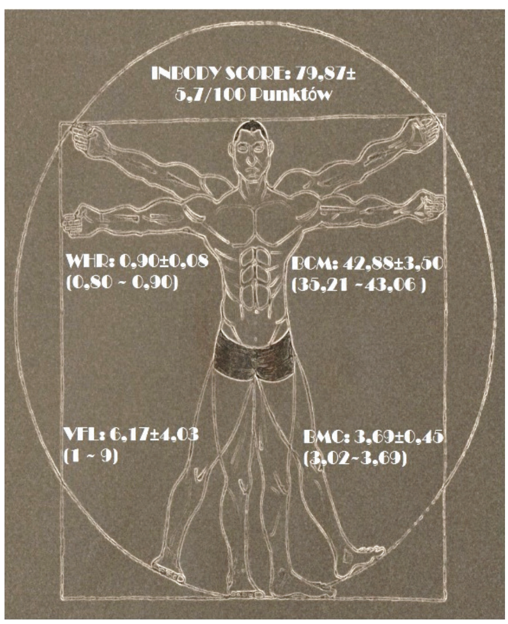
Segmental fat analysis in our study showed results close to the upper limit of normal, falling within the tolerance range outside the trunk segment. The results of the collective were also shown to be highly variable. A slight asymmetry in the distribution of body fat in the upper and lower extremities was noted (Table 6). In a study by Rydzik et al. [13] it was shown that the lower the weight category, the lower the body fat content and lower BMIs were achieved in kickboxing athletes. This type of tendency is also seen in representatives of other combat sports [43, 44] In our study, the athletes presented a wide range of weight categories (up to 70 kg, n = 4; up to 80 kg, n = 10; up to 90 kg, n = 6; up to 100 kg, n = 10). Therefore, it can be concluded that this had an impact on the large intra-group variation.

Based on the results seen in Figure 2, it can be concluded that in terms of the level of the other global indicators of the study, the athletes showed a normal level of development. The group of kickboxers scored slightly below 80 points of the total score reflecting the overall assessment of body composition. The studied collective of athletes showed normal levels of the other global indicators of the study (WHR, VFL, BCM, BMC – Figure 2). For example, the results of bone mineral content (BMC), athletes from our study ($\tilde{x}$ = 3.69 **±0.45**) were higher than those recorded in karatekas ($\tilde{x}$ = 3.27), fencers ($\tilde{x}$ = 3.45), wrestlers ($\tilde{x}$ = 3.40), taekwondo ($\tilde{x}$ = 3.14) and kickboxers ($\tilde{x}$ = 3.59) while lower than the judoka group ($\tilde{x}$ = 4.34) [42].

The results presented a high homogeneity effect with the exception of VFL. The InBody Score is a measure of health and fitness profile, calculated by the InBody 770 analyser based on measurements of body composition (including muscle mass, body fat, body water). The value of the index is expressed in points, with a range from 0 to 100. The higher the point value, the better the physical and health condition. The athletes participating in the study scored at an average of 79.87 points/100. No reports were found in the literature to which this score could be related. The manufacturer itself does not present a hierarchy for evaluating the various score ranges, detailing only that the higher the score the more favourable.

In characterizing the technical-tactical profile of the athletes studied, specialized formulas were used, which are reliable indicators of this plane [45, 16, 13, 46]. During the analysis, it was found that the indicators of activity, effectiveness and efficiency of attack in our study (Table 7) were lower than those registered in participants and medallists of the World Championships, while they exceeded those presented by participants and finalists of local ranked tournaments. Moreover, the recorded attack activity was at a similar level to that recorded in the finalists of the Polish Championships, albeit with lower efficiency and effectiveness [47].

Figure 2. Sketch with values of test indicators – in brackets reference range.



Source: own compilation based on Leonardo da Vinci's so-called 'Vitruvian Man' drawing, c. 1490.

Diagnosis of the relationships between technical-tactical training and selected components of body composition showed significant correlations with a negative direction (Table 8). Lower body mass (BM) correlated very strongly with higher efficiency and effectiveness, and strongly with attack activity. Body mass index (BMI) very strongly with efficiency, and strongly with activity and effectiveness. For indices describing body fat, i.e., body fat mass (BFM) and percent body fat (PBF), there was an almost complete relationship with effectiveness and a very strong relationship with attack activity and effectiveness. These results unequivocally show an inverse proportion, i.e. the lower the body fat and the mentioned height and weight characteristics in the subjects' bodies, the higher was the technical-tactical performance presented by them. The fighters with lower body weight and fatness were characterized by greater broadly understood dynamics in the conduct of the duel with a higher variety and frequency of application of offensive techniques, which is consistent with reports from other combat sports [48, 49]. The results illustrate differences in the offensive technical patterns used. Heavier, fattier athletes used fewer techniques, demonstrating lower technical-tactical performance. The analyses do not refer as to the quality of these techniques, in the sense of the rival's feeling of the effects of a given blow (this aspect was not studied in the present work). The conclusions shown correspond positively with the reports presented earlier as to the significant negative relationships between body composition indicators (body weight, BMI, body fat, muscle and water content) and the technical-tactical training of a collective of kickboxers against weight category [13]. Analyses of the relationships showed a negative, moderate relationship albeit statistically significant for technical-tactical indices and other indicators of kickboxers' body composition (TBW, SLM, FFM, SMM and BCM vs. Sa and Ea; protein, minerals and BMC vs. Ea – Table 7). For the other correlations, no clearer relationships were found among the athletes studied. Positive and negative correlations of a negligible co-occurrence nature were noted (ranging from r = 0.09 to 0.36 – Table 8).

When summarizing the assessment of kickboxers, it was noted that they presented a balanced body composition. Inferring qualitatively, this was most likely influenced by recruitment and systematic selection in the kickboxing section, which prefers athletes with just such structural predispositions. Another insanely important factor in the influence of the environment seems to be the specialized and targeted training process to which they were subjected.

CONCLUSIONS

The results of the study make it possible to diagnose and interpret the body composition profile along with its key components of importance in combat sports, which are determined by weight category. Optimal technical and tactical performance in kickboxing can be strongly associated with lower values of indicators describing body fat and body mass characteristics. This confirms the usefulness of these methods, for optimizing the quality of coaching control. Objective analysis of body composition, its relationship to technical-tactical training, as well as the provision of individualized testing protocols and interpretation of results can individualize the training process and reduce the risk of abnormalities in the overall and segmental body composition of kickboxing athletes. The results obtained confirm that regular kickboxing training, to which the subjects were subjected, has a beneficial effect on the formation and maintenance of normal body composition.

Practical application

The presented results of the study can be used by researchers for comparisons and interpretation of indicators based on the average values shown in this study. The identified indicators allow diagnosing and interpreting the body composition profile of combat sports athletes, taking into account the priority components and the level of symmetry of the segmental distribution of individual components. This type of activity can contribute to optimizing the quality of coaching control.

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