

Comparative analysis of physical development and body composition of kickboxing athletes with different training experience

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Abstract

Background and Study Aim. Comparative analysis of physical development and body composition using the index method in kickboxing athletes with different training experience.

Material and Methods. Participants: 30 kickboxing athletes, group 1 – 15 people, (13.20±0.60) years old, training experience (0.71±0.13) years. Group 2 - 15 people, (15.20±1.14) years old, training experience (6.80±1.16) years. 18 anthropometric indicators were determined. 21 indices were calculated based on them. The median (Me), 1 (25%) and 3 (75%) quartiles were determined. The somatotype was determined by the bioimpedance method using the OMRON BF-511 body composition monitor (Japan). The significance of differences in the groups was assessed by the nonparametric Rosenbaum test (Q).

Results. A significant excess of indicators of the 2nd group in terms of Erisman's index (Q=10), Pignet's index (Q=7), Livi's index (Q=12), Isakson's body surface area (Q=11) and relative body surface (Q=21) was established, relative length of arm (Q=11) and leg (Q=14), index of arm circumference (Q=15) and leg (Q=6), shoulder index (Q=10), indices of massiveness of segments of the forearm (Q=11) and shoulder (Q=30), conditional moments of force of the forearm (Q=30), shoulder (Q=30), lower leg (Q=30) and thigh (Q=30). A trend towards a decrease in fat content and an increase in muscle tissue in more trained athletes has been confirmed.

Conclusions. A comparative analysis of the physical development and body composition of kickboxing athletes with different training experience confirmed certain differences. More trained kickboxers had better indicators of the shoulder index, which reflects the posture of the athletes. The Erisman index illustrated the increase in the muscles of the torso under the influence of training loads. The increase in body surface area and relative body surface reflects the greater adaptive potential of more trained kickboxers. The large relative length of the arms and legs, the indices of the ratio of the segments of the limbs, the indices of massiveness and the conditional moments of the segments' strength reflect the best technical capabilities of more trained athletes, the ability to blow at a greater distance and with greater force. The adequacy of using the method of indices as more informative than anthropometric indicators is shown. It is proposed to use these indices in monitoring the state of kickboxing athletes.

Key words: martial arts, kickboxing, physical development, indices, somatotype, bioimpedance method.

Анотація

Порівняльний аналіз фізичного розвитку та складу тіла спортсменів кікбоксингу із різним стажем тренувань
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Мета. Порівняльний аналіз фізичного розвитку і складу тіла із використанням методу індексів у спортсменів кікбоксингу з різним стажем тренувань.

Матеріал і методи. Учасники – 30 спортсменів кікбоксингу, 1 група – 15 осіб, (13.20±0.60) років, стаж тренувань (0.71±0.13) років. 2 група – 15 осіб, (15.20±1.14) років, стаж тренувань (6.80±1.16) років. визначали 18 антропометричних показників. Розраховували 21 індекс на їх підставі. Визначали медіану (Me), 1 (25%) і 3 (75%) квартилі. Соматотип визначали біоімпедансним методом за допомогою монітору складу тіла OMRON BF-511 (Японія). Вірогідність відмінностей між групами оцінювали непараметричним критерієм Розенбаума (Q).

Результати. З'ясовано суттєве перебільшення показників 2 групи за індексом Ерісмана (Q=10), індексом Пін'є (Q=7), індексом Ліві (Q=12), величині поверхні тіла за Ісаксоном (Q=11) і відносній поверхні тіла (Q=21), відносній довжині руки (Q=11) і ноги (Q=14), індексів окружності руки (Q=15) і ноги (Q=6), плечевого індексу (Q=10), індексів масивності сегментів передпліччя (Q=11) і плеча (Q=30), умовних моментів сили передпліччя (Q=30), плеча (Q=30), гомілки (Q=30) і стегна (Q=30). Стверджено наявність тенденції до зменшення вмісту жирової і збільшення м'язової тканини у більш тренуваних спортсменів.

Висновки. Проведений порівняльний аналіз фізичного розвитку і складу тіла спортсменів кікбоксингу із різним стажем тренувань ствердив наявність певних відмінностей. Більш тренувані спортсмени мали кращі показники плечевого індексу, що відбиває поставу спортсменів. Індекс ерісмана ілюстрував збільшення м'язів торса під впливом тренувальних навантажень. Збільшення площі поверхні тіла і відносної поверхні тіла відбиває більший адаптаційний потенціал більш тренуваних кікбоксерів. Більша відносна довжина рук і ніг, індекси співвідношень сегментів кінцівок, індекси масивності і умовні моменти сили сегментів кінцівок відбивають кращі технічні можливості більш тренуваних атлетів, здатність наносити удари на більшій дистанції і з більшою силою. Показана адекватність застосування методу індексів як більш інформативних порівняно із антропометричними показниками. Запропоновано використовувати вказані індекси у моніторингу стану спортсменів кікбоксингу.

Ключові слова: єдиноборства, кікбоксинг, фізичний розвиток, індекси, соматотип, біоімпедансний метод

Introduction

Indicators of the physical development of athletes are widely used in sports science. These criteria allow assessing the level of training of athletes, predicting the success and growth of sportsmanship [1,2]. Physique features and proportions of physical development of athletes are important prognostic and diagnostic indicators in martial arts [2]. Their study provides important information for the development of a forecast for the growth of sportsmanship, allows for effective selection [3].

Burdukiewicz et al [4] studied the physical characteristics of martial arts athletes involved in judo, jujitsu, karate, taekwondo and fencing. Significant differences in the circumferences of the chest, hips, arms and forearms in judo and karate, taekwondo and fencing athletes were established. It is concluded that the differences in physique are due to the specific influence of the sport. It is proposed to use anthropometric indicators as a selection tool in martial arts.

Noh et al [5] evaluated the features of the physique and somatotype in Korean martial arts athletes. Differences depending on the type of martial arts and weight category were revealed. The differences were more pronounced in the light and medium weight categories. The presence of correlation dependencies between somatotype components and body weight was confirmed.

The contribution of anthropometric indicators, physical fitness tests to the success of elite and non-elite martial arts athletes was studied in [6]. It is proposed to take these criteria into account when selecting and predicting the growth of martial arts sportsmanship. The indicators used can be used to classify athletes.

Evaluation of morphological features and differential diagnosis of anthropometric characteristics contribute to the improvement of results in martial arts. Sirazetdinov et al [7] conducted a comparative analysis of such traits. These include a well-developed chest, broad shoulders, low leg-to-body ratio, high arm-to-body ratio, and minimal body fat.

Morphological indicators are an obligatory component of monitoring the condition of athletes. The study [8] was devoted to monitoring long-term seasonal changes in anthropometry, body composition and physical preparedness of young judo athletes. The work establishes a relationship between these indicators and sports success. Significant changes in anthropometric criteria, body composition and physical preparedness in the dynamics of the training season have been confirmed.

The presence of relationships between indicators of body composition and physical performance of martial arts athletes was studied in [9]. A decrease in maximum oxygen consumption was registered with an increase in fat mass. The maximum indicators of aerobic potential were established in athletes with a minimum body fat content. It is concluded that the content of somatotype components correlates with aerobic capacity and can affect the level of biochemical adaptation. This demonstrates the importance of body composition regulation to improve training efficiency.

The index method is widely used in sports science [10, 11, 12]. This is due to the simplicity, clarity and information content of the indices. A comparative analysis of the physical development of athletes of various types of martial arts with the help of indices made it possible to highlight the features that are important for achieving success [10]. The eligibility of using special indices in monitoring the functional state of athletes has been proved. Particularly important are the indices of the ratio

of segments of the limbs.

Catikkas et al [11] used indices in a comparative analysis of anthropometric indicators in athletes of various martial arts (karate, taekwondo, judo, and kickboxing). The informativeness of the Monourier index, acromioliac index, Martin index, biacromial index and hip index was confirmed.

Alekseeva et al [13] studied the functional features of the cardiovascular system in martial arts athletes, taking into account body type. The battery of tests used included body mass index, Pignet and Rees-Eysenck indices. It is proposed to use the data in the selection and prediction of the performance of athletes.

The specificity of indexes is their important characteristic for use in this context. The index of the ratio of the lengths of the 2nd and 4th fingers of the right hand (2D: 4D) is considered promising for martial arts [14, 15]. The presence of dependencies of this index with anthropometric and psychological characteristics of athletes of mixed martial arts has been confirmed [14, 15].

Body composition is an important predictor in various sports. Reale et al [16] examined the body composition of martial arts athletes. The study was conducted during 7-21 days of the competition. It is concluded that it is necessary to monitor the components of the somatotype of athletes. The level of adipose and muscle tissue is important for assessing the quality of their training.

Similar results are given in another paper [17]. The authors evaluated the body composition of karate athletes using the method of dual-energy X-ray absorptiometry. Control means and quartile values of body composition were obtained. The results are proposed to be used in monitoring the condition of athletes.

The bioimpedance method is considered one of the most adequate and informative for the analysis of the body composition of athletes. Rossi [18] assessed the body composition of elite karate athletes using bioimpedance analysis. It is proposed to use this method in monitoring the condition of athletes.

Similar results are reported in Fernandez-Delvalle et al [19]. The authors conducted a comparative analysis of methods for assessing body composition in martial arts athletes. The need for anthropometric methods in assessing the preparedness of athletes has been confirmed. Field methods, especially the bioimpedance method, are an effective control tool. Similar results are presented in another paper [20]. The authors compared the accuracy of determining the level of fat using anthropometric equations and the bioimpedance method. The high level of correlation of the results was confirmed. The use of anthropometric equations is recommended as an alternative to the bioimpedance method.

Dynamics of body weight and somatotype components can be used to predict the success and health level of martial arts athletes [21]. During the season, elite judoists were assessed somatotype indicators using the bioimpedance method. The application of the linear mixed model test made it possible to identify significant differences in the indicators in the dynamics of the competition. It is proposed to use the results to develop methods for optimizing training and recovery after competitions.

The combination of the index method and the bioimpedance method made it possible to confirm the specific impact of a sport on armwrestling and street workout athletes [22]. Participants were characterized by an increased level of muscle tissue, workouts had a reduced fat content. Indexes that reflected

grip strength in different operating modes had high information content.

Thus, the available literature data allow us to consider the direction of this study as relevant. The purpose of the study is a comparative analysis of physical development and body composition using the index method in kickboxing athletes with different training experience.

Materials and Methods

Subjects.

The study involved 30 kickboxing athletes divided into two groups. Group 1 - 15 people, average age (13.20±0.60) years, training experience (0.71±0.13) years. Group 2 - 15 people, average age (15.20±1.14) years, training experience (6.80±1.16) years. Differences in age and training experience are significant ($p < 0.05$).

Measures

The design of the study involved the determination of 18 anthropometric indicators. The measurements were carried out in accordance with the requirements of the international unified methodology for anthropometric studies [23]. The length and weight of the body, chest circumference during pause, inhalation and exhalation, shoulder width, shoulder arch, lengths and circumferences of limbs and their segments, vital capacity of the lungs, length of 2nd and 4th fingers of the right hand were determined. For comparative analysis, a battery of 21 indices was used.

The bioimpedance method was used to assess the characteristics of the somatotype. The body composition monitor OMRON BF-511 (Japan) was used. Body weight, specific weight of muscle and adipose tissue, percentage of visceral fat, basal metabolic rate were determined.

Procedure

Body mass index (BMI) was defined as the ratio of body weight (kg) to body length (m) squared. Values of 20-25 kg/m² are taken as the norm.

Erisman index was found as the difference between the circumference of the chest and half the length of the body. Proportional physical development is characterized by a positive value of this indicator. Its value should be at least 5,8 cm for athletes.

Pignet's index was determined by the formula:

$$PI = BL - (BW + CC), \quad (1)$$

where BL – body length (cm), BW – body weight (kg), CC – chest circumference in pause (cm).

The smaller the value, the better the indicator (in the absence of obesity). An index value of less than 10 is assessed as a strong physique, 10 - 20 - good, 21 - 25 - average, 26 - 35 - weak, more than 36 - very weak.

The shoulder width index was found as the ratio of this parameter to the body length, expressed as a percentage. Values of 23-25% are accepted as the norm.

The shoulder index was calculated as the ratio of the width of the shoulders to the shoulder arch. The humeral arch was defined as the distance between the acromial processes of the humerus along the back. A value within the range of 0.9–1 was considered the norm.

The surface of a body according to Isaakson was found by the formula:

$$S = 1 + \frac{BW + (BL - 160)}{100} \quad (2),$$

where S is the surface area of the body (m²); BW - body weight (kg), BL - body length (cm).

The relative body surface area was found by dividing the body weight (kg) by the surface area (m²).

The Livi index (LI) was determined by the formula:

$$LI = CC / BL * 100 \quad (3),$$

where CC – chest circumference in pause (cm), BL – body length (cm).

The average LI is 50-55%.

The parameters of the massiveness of the segment of the arm (shoulder, forearm) and leg (shin, thigh) and the conditional moments of force of the shoulder, forearm, lower leg and thigh were determined according to the formulas given in the work [24]:

Segment massiveness index = segment circumference * 100% / segment length, (4)

Conditional moment of force of the segment = segment circumference * segment length, (5).

The 2D:4D index was found by dividing the length of 2 fingers of the right hand by the length of 4 fingers of the right hand.

The relative lengths of the arms and legs were found by dividing the length of the limb by the length of the body and expressed the result as a percentage.

The arm circumference index was found by dividing the circumference of the forearm by the circumference of the shoulder, the index of leg circumference was found by dividing the circumference of the lower leg by the circumference of the thigh.

Statistical analysis

Statistical analysis of the obtained data was carried out using licensed Excel spreadsheet packages. Based on the sample size and the nature of the distribution, the median (Me), 1 (25%) and 3 (75%) quartiles were determined to characterize the data. The significance of differences in groups was assessed using the nonparametric Rosenbaum test (Q), differences were considered significant at $p < 0.05$.

Results

A comparative analysis of anthropometric indicators did not allow us to establish significant differences in most of the criteria used. To improve the efficiency of the analysis, the index method was used. The results obtained are shown in table 1.

The small size of the groups necessitated the use of nonparametric criteria for comparison. The Rosenbaum criterion used allowed us to confirm the differences between the groups in terms of the following indicators: age of participants (Q=6), training experience (Q=30), VC value (Q=6).

The results presented in the table make it possible to identify tendencies towards difference in a number of indicators. Athletes of the 2nd group tend to increase the width of the shoulders, the length of the thigh and lower leg. Also, these athletes are characterized by a tendency to reduce the proportion of adipose tissue and increase the proportion of muscle tissue.

Differences in indices of physical development look more significant. A significant excess of indicators of the 2nd group in terms of Erisman's index (Q=10), Pinier's index (Q=7), Livi's index (Q=12), Isakson's body surface area (Q=11) and relative body surface (Q=21). More experienced athletes had an increase in the relative length of the arm (Q=11) and leg (Q=14). The indices of the ratios of the circumferences of the segments of the extremities were also higher in athletes with more experience. This is confirmed for the arm (Q=15) and leg (Q=6) circumference index.

The results obtained did not confirm significant differ-

Table 1. Anthropometric indicators and indices of physical development of kickboxing athletes

Indicators	1 group, (n=15)			2 group, (n=15)		
	25%	Me	75%	25%	Me	75%
Age, years	12,00	13,00*	14,00	11,50	14,00	19,00
Sports experience, years	0,30	1,00*	1,00	4,00	6,00	8,00
Shoulder width, cm	34,50	35,00	38,00	34,00	35,00	40,75
Length of the thigh, right cm	33,00	36,00	39,50	35,50	37,00	42,00
Length of the leg, right, cm	32,50	35,00	37,00	34,00	37,00	39,00
VC, l	2,30	2,90*	3,65	2,10	2,80	3,45
Body mass index, kg/m ²	17,30	21,30	26,60	17,60	18,00	21,65
Shoulder width index, %	21,35	21,91	22,66	21,66	22,58	24,05
Shoulder index, %	0,75	0,77*	0,79	0,76	0,80	0,82
Erisman index, cm	-9,00	-4,00*	0,69	-7,13	-5,50	4,00
Pignier index, cm	15,50	35,35*	41,10	27,03	38,95	44,40
Livi index, %	0,45	0,47*	0,50	0,45	0,47	0,53
The ratio of the length of 2 and 4 fingers on the right, abs	0,98	1,02	1,04	0,96	0,99	1,03
Body surface according to Isakson, m ²	1,45	1,70*	1,90	1,19	1,37	1,54
Relative body surface, kg/m ²	29,63	34,84*	37,47	30,17	31,61	35,36
Relative arm length, %	32,13	32,71*	33,33	32,78	34,02	35,43
Relative leg length, %	43,00	43,45*	44,97	45,28	46,05	47,72
Arm circumference index, abs	0,90	0,92*	0,93	0,87	0,91	0,94
Leg circumference index, abs	0,62	0,66*	0,68	0,62	0,67	0,67
Forearm massiveness index, abs	100,91	104,35*	108,35	87,59	92,31	106,94
Shoulder massiveness index, abs	86,79	95,08*	100,00	80,49	86,00	100,81
Lower leg massiveness index, abs	90,43	94,29	104,01	84,32	88,57	94,51
Hip massiveness index, abs	131,22	138,89	154,59	118,33	131,08	143,21
Moment of force of the forearm, cm ²	534,75	575,00*	736,00	552,00	575,00	655,75
Moment of force of the shoulder, cm ²	667,25	770,00*	947,25	659,00	747,25	978,25
Moment of force of the leg, cm ²	958,50	1155,00*	1358,75	1004,50	1155,00	1322,25
Moment of force of the thigh, cm ²	1513,00	1800,00*	2064,50	1605,00	1804,00	2244,00
Specific weight of fat, %	15,30	20,10	24,80	9,55	15,90	19,55
Specific weight of muscles, %	35,80	36,50	37,90	35,20	40,80	41,55

Notes. * - differences according to the Rosenbaum criterion are significant ($p < 0.05$).

ences in body mass index. In both groups, medians refer to the range of mean values. However, in novice athletes, there is a pronounced shift towards an increase in the index, the 3rd quartile already characterizes overweight. For more experienced kickboxers, the interval of 1-3 quartiles is typical for average values.

If according to the shoulder width index, only a tendency to increase in group 2 is established, then the shoulder index reflects an increase in this indicator in more experienced athletes ($Q=10$).

Significant differences were confirmed in terms of massiveness indices of limb segments: forearm ($Q=11$) and shoulder ($Q=30$). The values of the indices of massiveness of the lower leg and thigh allow us to speak only about the trend towards an increase in these indicators in group 1.

The most significant differences were established using the conditional moment of force of the limb segments. The higher values of group 2 were confirmed for the forearm ($Q=30$), upper arm ($Q=30$), lower leg ($Q=30$) and thigh ($Q=30$).

Discussion

Kickboxing is a complex type of martial arts in terms of technique, tactics and structure of movements. It requires an adequate level of physical development, physical preparedness and motor skills as the basis for successful competitive activity [2]. Kickboxing fights have been shown to cause significant physiological stress [25]. Monitoring the condition of ath-

letes in this sport requires an integrated approach through the use of various methods. The presence of a correlation between the level of adipose and muscle tissue and the technical and tactical skills of kickboxing athletes was confirmed [25].

The design variant used involved comparing the results of athletes with different levels of training. This difference is confirmed by the experience of sports activities. This approach is often used in sports science [5, 6, 22, 26, 27]. This version of research design is most appropriate for the task of predicting success. A similar study was conducted in female athletes of aesthetic swimming [26]. An analysis of the functional state of the respiratory system made it possible to identify the indicators that are most significant for success in this sport.

Sirazetdinov et al [7] compared the anthropometric features of elite athletes and non-athletes with different levels of physical development. The features of physical development that affect success in sports have been established. In the work [6], elite and non-elite athletes of martial arts were compared. Statistically significant differences were established in favor of the elite group in standing and sitting body length, body weight, upper limb strength, and physical fitness test results. At the same time, no significant differences in body composition were found, which coincides with the results obtained.

The choice of a battery of methods is determined by the available literature data. In the article [28], a similar battery of indices was used to develop a selection technique for martial arts (kickboxing or wrestling). The use of Wald's sequential analysis made it possible to develop a simple and accessible

predictive selection technique. The high information content of the used indices was confirmed.

In the already cited work [19], the effectiveness and accuracy of anthropometric methods and the bioimpedance method for assessing the state of martial arts athletes were confirmed. Similar results are given in another paper [12]. The authors evaluated the information content of various indices of physical development and body composition. Indices make it possible to visualize the specificity of the influence of various martial arts on the body of athletes. This is what led to the methodological approach in this study. The results obtained once again confirmed that the indices are significantly more informative and visual than anthropometric indicators.

A similar battery of indices was used in the article [10] to compare the physical development of elite athletes in various martial arts. The Erisman and Pignier indices, the shoulder width index show the best development of the muscles of kickboxing wrestlers and athletes compared to karate, taekwondo, taekwondo athletes. The increase in the relative body surface of wrestlers reflects the growth of their aerobic capacity. Indices of the ratio of segments of the limbs illustrate the features of the technique of martial arts athletes.

Anthropometric indicators did not allow to establish differences between groups. It was the use of a battery of indices that made it possible to achieve the goal and confirm the differences. This approach is confirmed by the available literature data [11]. The authors used a battery of indices along with a somatotype score. The analysis made it possible to identify the main features of the physique of athletes in various types of martial arts.

The age and training experience of the participants were used as the main criteria for dividing into groups. This approach is one of the main ones in sports science [27, 29, 30]. In the article [29], the division of martial arts athletes was carried out according to these criteria. The closeness of body structure indicators and motor potential of the participants was confirmed. The results obtained confirm these data. Despite significant differences in training experience, it cannot be considered that participants differ significantly in terms of sportsmanship.

It is noted that taking into account the processes of growth and development in sports makes it possible to provide optimal conditions for training, and anthropometric indicators are the basis for grouping athletes [30]. In our study, most anthropometric indicators did not have significant differences. This can be explained by the age characteristics of the participants. Most athletes are in prepubertal and pubertal age, that is, they have similar anatomical and physiological features. This coincides with the results of the authors' work [30]. The constructed regression models confirmed the decrease in the influence of growth and development processes on anthropometric indicators as they grow older.

In another work [27], the psychophysiological characteristics of taekwondo athletes were studied. An increase in age and experience in sports leads to an improvement in the reaction rate. The established correlations between all the tests used also reflect the improvement in the psychophysiological state of athletes as the age increases.

More experienced athletes had a higher VC value. The indicators of the respiratory system are not among the predictors of success in martial arts [10]. This is due to the anaerobic nature of physical activity in these sports. In our opinion, the established differences reflect the anatomical and physiological characteristics of the age groups of participants.

The body mass index is currently most commonly used

in medical practice, in physical culture and sports. The results obtained did not confirm significant differences in this index. A tendency has been established for its increase in novice athletes to a value characteristic of overweight. For experienced athletes, the index is within the average values. In the context of the study, this should be assessed as the normalization of body weight under the influence of physical activity in experienced athletes. This assumption once again confirms the established trend in the ratio of the main components of the somatotype (muscle and adipose tissue).

The shoulder width index evaluates the development of the muscles of the shoulder girdle. The results did not allow to confirm significant differences between the groups. However, one can speak of a trend towards difference. For novice athletes, this index is below the standard value. For experienced kickboxers, there is a shift towards an increase in the index. The third quartile of the data is above the norm. This trend confirms the effect of loads in kickboxing on the muscles of the shoulder girdle and coincides with the available data [10, 31, 32]. The results confirm the existing data on the importance of shoulder width and indices based on this criterion for predicting success [31, 32].

The shoulder index allows you to judge the posture of the participants. The available data confirm the deterioration of this indicator in elite kickboxers [33]. The results obtained should be evaluated in two ways. On the one hand, all participants have this index below the norm. This illustrates the deterioration of posture under the influence of training and, above all, the closed stance of kickboxers. On the other hand, more experienced athletes have significantly better indicators of this index. In our opinion, this may be evidence of a more rational preparation, the use of special corrective exercises. This index should also be used in monitoring the condition of kickboxing athletes.

The Erisman index illustrates the relationship between the longitudinal and girth dimensions of the torso of athletes. In both groups, persons with an insufficient level of this index predominate. The proportion of such athletes in group 1 was (83.33±9.52)%, in group 2 - (73.33±11.42)%. Available studies have confirmed that in elite kickboxing athletes this index reflects a fairly high level of torso muscle development [10, 28]. In our opinion, the results obtained should be assessed as a trend towards an increase in this index due to regular training. This index can be used in monitoring the condition of kickboxing athletes.

The Pignier index is used to determine the strength of the physique. Its specificity lies in the fact that it cannot be used in overweight and obese individuals. That is why it is often used in sports science. In work [13], this index was used in assessing the state of young martial arts athletes. It was found that people with a strong physique according to the Pignier index had significantly greater reserve and recovery capabilities of the cardiovascular system. The results obtained once again confirm the conclusion that the participants do not have a high level of sportsmanship. In both groups, the proportion of participants with a weak physique was half. A similar conclusion can be drawn from a comparative analysis of the Livi index. Despite the established differences between the groups, most of the participants had a level of physical development on this index below the average. The use of the Pignier and Livi indices for a comparative analysis of the state of armwrestling athletes showed that they clearly reflect an increase in physical fitness [31]. This index, like the previous ones, confirms that the participants are close in terms of sportsmanship. These indices will

not be highly informative when used in monitoring.

The index of the ratio of the lengths of 2 and 4 fingers (2D:4D) is widely used in sports science as a screening. It is proposed to use it to determine the potential results of people in power sports, especially in martial arts [14, 15]. However, the final interpretation of this indicator is still missing. Adamczyk et al [15] confirmed that the 2D:4D ratio was higher in martial arts athletes than in the control group of athletes. Camarco et al [14] report lower median values of this index in athletes compared to non-athletes. Our research has yielded similar results. They confirmed the tendency for this index to decrease in experienced kickboxers compared to beginners. The given results make it possible to evaluate the 2D:4D ratio as a good tool for selecting athletes in martial arts. This index is a promising screening test.

The body surface and relative surface values were significantly higher in more experienced athletes. The interpretation of the results should take into account the available literature data. The increase in body surface of athletes reflects the growth of their aerobic capacity [32]. The authors attribute this to an increase in body length of athletes. The established differences in the relative body surface reflect the greater aerobic potential of more trained kickboxers. Similar results were obtained in the work [10]. The differences between these indices are interpreted as a reflection of the dynamics of the muscle component of the somatotype. This is consistent with the results obtained. The definition of these indexes can be used in monitoring the condition of kickboxers.

Analysis of the indices of the ratio of limbs and their segments confirms their importance for monitoring the state of kickboxing athletes. The relative elongation of the arms of kickboxers reflects the possibility of kicks at a greater distance. The lengthening of the lower limbs also allows for more powerful kicks in a duel at a greater distance. This should be rated as a success factor in kickboxing. The results obtained are close to the available data [4, 34]. The authors note the prognostic importance of the relative limb length indices in martial arts [4]. The relative elongation of the arms and a more massive body were established. The authors confirmed the best development of the muscles of the limbs due to the increase in the circumferences of the hips, shoulder and forearms. This is confirmed by the results obtained. More trained athletes had a greater value of the indices of arm and leg circumferences. These indicators illustrate the ratio of the development of the muscles of the shoulder and forearm, lower leg and thigh. An increase in these indices reflects an increase in the strength of the limb muscles. It should be assessed as a potential increase in the power of punches and kicks.

The work [34] studied the anthropometric characteristics of taekwondo athletes and determined the significance of the length of the lower limbs as a success factor. Elite athletes were characterized by lengthening of the lower limbs.

Similar results were obtained in another work [35]. The existence of a connection between anthropometric indicators and the characteristics of the technique of MMA fighters has been established. Body length and arm length correlated with punching performance. It is proposed to take into account the features of physical development when choosing the tactics of

conducting a duel in MMA.

The need to use specific indices that reflect the ratio of the longitudinal and girth sizes of limb segments is substantiated in the article [31]. Massiveness indices of limb segments and conditional moments of force were used. These indices were proposed in the article [24] to assess the effectiveness of the rehabilitation of athletes. The obtained results confirm the excess of the massiveness indices of the forearm and shoulder, the conditional moments of strength of all segments of the limbs in the group of more trained athletes. This once again proves the assumptions made earlier. The use of longitudinal scores in these indices reflects the importance of long leverage in punching. The inclusion of limb segment perimeters in the indices illustrates the importance of these muscle development groups for the same purpose.

Analysis of body composition using the bioimpedance method only confirmed the presence of trends in the content of adipose and muscle tissue. The available reference data regarding the components of the somatotype are also ambiguous and have not received sufficient recognition. Thus, in the work of Cerqueira et al [36], based on the bioimpedance analysis of the body composition of Brazilian jiu-jitsu athletes, centile tables of adipose tissue content were developed. Using these tables, it can be concluded that experienced kickboxers have an average level of fat, and beginners have a high level. This should be assessed as another argument for the differences in the physique of kickboxers of different levels.

In another study [34], the body composition of taekwondo athletes of different levels of training was compared. Significant differences in the level of fat in the body were established, the level of muscle tissue was quite high in all participants. The results obtained can be interpreted as confirmation of the literature data. Body composition analysis can be recommended as a selection and prediction tool in martial arts.

Conclusions

A comparative analysis of the physical development and body composition of kickboxing athletes with different training experience confirmed certain differences. More trained kickboxers had better indicators of the shoulder index, which reflects the posture of the athletes. The Erisman index illustrated the increase in the muscles of the torso under the influence of training loads. The 2D:4D ratio is a promising screening test and selection tool for wrestling athletes. The increase in body surface area and relative body surface reflects the greater adaptive potential of more trained kickboxers. The large relative length of the arms and legs, the indexes of the ratio of the segments of the limbs, the indices of massiveness and the conditional moments of the segments' strength reflect the best technical capabilities of more trained athletes, the ability to kick at a greater distance and with greater force. The presence of a trend towards a decrease in the content of fat and an increase in muscle tissue in more trained athletes has been confirmed.

The adequacy of using the index method as more informative compared to anthropometric indicators is shown. It is proposed to use these indices in monitoring the state of kickboxing athletes.

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