Relationship between body composition indicators and physical capacity of the combat sports athletes

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: In combat sports a modification of body weight should be based on an appropriate regulation of body composition, preferably after establishing the optimal level of tissue components. In view of the above the aim of this study was the relationship between body composition indicators and physical capacity of the combat sports athletes with prospect of most advantageous exercise-induced adaptation.

Material and Methods: The study involved 120 athletes, with the mean age of 22 years. Body composition of the athletes was analysed by electrical bioimpedance. Aerobic capacity was determined using exercise tests with increasing intensity using a Cosmed K4b² ergospirometer. Blood concentrations of biochemical markers were determined using a COBAS® 6000 analyser.

Results: A reduction of maximal oxygen consumption (VO_2max) was recorded with an increase in fat mass (FM).The highest VO_2max and ventilatory threshold (VT) was observed in athletes with the lowest FM. Assayed levels of biochemical blood markers were ambiguous, although at a low FM the anabolic-catabolic status seems the most advantageous. Among other things, correlations were found between FM and VO_2max, HR at VT, and also FFM and VO_2max, HR at VT and cortisol.

Conclusions: The levels of tissue components are significantly correlated with aerobic capacity and they may affect the level of biochemical adaptation. This indicates the importance of an appropriate regulation of body composition already in the training period, which would facilitate increased efficiency of the training procedure and eliminate the risk of reduced exercise capacity at a rapid weight loss before competitions.

Key words: adipose tissue • biochemical markers • body weight • maximal oxygen consumption • ventilatory threshold

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Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [44].

Division of the combat sports under forms of the direct confrontation – workings of weapons; hits (strokes); throws and grips of immobilisation of opponent's body [45].

Strike in combat sports and martial arts – can be strike weapons (fencing, kendo, etc.), hands (*boxing*), legs (*savate*), arms and legs (*karate, kick-boxing, taekwondo, muay thai*, etc.); in terms of the general strike hand to "punch" and synonyms, strike his leg a "kick" and synonyms [45].

Marker *noun* **1.** in games such as football and hockey, a player who stays close to an attacking player in the opposing team to prevent him or her from receiving the ball or scoring 2. a substance which reveals the use of a banned substance, found in drugs testing [44]

Biochemical marker – any biochemical compound such as an antigen, antibody, abnormal enzyme, or hormone that is sufficiently altered in a disease to serve as an aid in diagnosing or in predicting susceptibility to the disease [46].

Body weight loss – reduction of the total body mass. In combat sports, it is used for a preparation to start in a lower weight category.

Body composition – the amount of fat, fat-free mass and total water content, whose proportions in the body can significantly affect sporting performance.

Bioimpedance analysis – a method of estimating body composition.

Biochemical indexes – any hormone, enzyme, or other metabolite that is detected in blood and may serve as a sign of training adaptation and muscle metabolism.

Aerobic capacity – the ability to exercise using aerobic energy pathways, which may be determined using maximal oxygen uptake and ventilatory threshold.

Introduction

Contemporary combat sports requires from athletes a high training level and adaptation to various types of physical exercise under variable environmental conditions. However, in order to achieve the above a professional training strategy needs to be developed, comprising regular assessment of physical capacity, the state of nutrition, mental preparation and optimal biological renewal in athletes [1-7]. This is true particularly for the sports disciplines with weight categories, in which intensive weight loss before competitions is a common practice, which may have a negative effect on the results [8, 9]. During rapid weight loss it is impossible to reduce it rationally, i.e. by optimal reduction of fat mass constituting a certain burden, potentially contributing to reduced exercise capacity of athletes [10-12]. It needs to be stressed that methods to reduce body weight practiced by athletes before competitions are most frequently incorrect, as they include e.g. limited consumption of food and drink (including fasting), use of vapour-impermeable clothing, extended periods spent in a sauna or administration of pharmaceuticals, which leads to dehydration of the organism, disturbed thermoregulation, depletion of muscle glycogen, electrolyte imbalance, muscle protein degradation and an increased risk of injury and infection [11, 13-15].

We frequently neglect the fact that the above mentioned negative effects of incorrect weight loss methods may completely thwart the results of the preparations of several months, leading to reduced physical capacity, exercise capacity, motivation and the fighting spirit, as well as pose a threat to athletes' health and life [8, 12, 15]. Particularly adverse consequences may be connected with the reduction of aerobic potential, which in combat sports makes it possible to fight longer and more efficiently in terms of endurance, while at the same time provides a faster regeneration of the organism during competitions, when athletes have only short breaks between rounds or have to participate in several high-intensity fights at short intervals [16, 17].

Especially in the pre-competition period it is essential to maintain an adequate training and nutrition strategy, ensuring the desirable competition body weight thanks to a gradual and rational weight loss, based on the modification of the athlete's body composition, particularly reduction of fat mass [2, 3, 12]. In sports it facilitates a decrease in body weight, at the limitation of excessive weakening of the organism and maintenance of fat-free body mass, required when performing muscular work [18]. It is not recommended to excessively reduce the fat mass level, as it may be connected with slowed regeneration rate, hormonal imbalance and disorders in the function of certain organs [13]. At a rational regulation of body composition in athletes it thus seems necessary to determine the profile, indicating levels of tissue components, at which the athlete would reach the highest efficiency.

This would make it easier for both coaches and athletes to properly plan and incorporate in the training procedure the most effective weight modification strategy both in the competition period and in the pre-competition period. What is more, thanks to such objective recommendations based on scientific findings the common practices connected with rapid and excessive body weight loss should be limited [11, 12].

In view of the above mentioned aspects of great importance, at a lack of sufficient scientific data concerning e.g. recommendation of the optimal body composition for athletes in terms of physical and exercise capacity, was the aim of this study was to the relationship between body composition indicators and physical capacity of the combat sports athletes with prospect of most advantageous exercise-induced adaptation.

Material and methods

Participants

The study involved 120 male athletes aged 22 ±5 years (from 16 to 35 years of age), with body weight of 80.9 ±12.3 kg (from 53.4 to 117.5 kg) and 179 ±6 cm tall (from 166 to 192 cm) practicing combat sports belonging to the following category: a) throws and grips of immobilisation of opponent's body: wrestling (n = 27), judo (n = 36), Brazilian jiu-jitsu (n = 42); b); hits (strokes): karate (n = 15). All athletes training at sports clubs in the Wielkopolska region, Poland. Criteria qualifying for this study included e.g. meeting requirements concerning good health, having a currently issued medical certificate confirming their capacity to practice sports, at least a 5-year training period and a minimum of 4 training units a week connected with the practiced sports discipline. Analyses were conducted in the years 2009-2014, including athletes in different periods of the year in order to eliminate the potential effect of variable annual training cycles on the recorded results. In accordance with the Declaration of Helsinki all the participants expressed their free and conscious consent to participate in research procedures [19].

Procedures

Participants in this study were weighed and their height was measured using a WPT 60/150 OW medical anthropometer by RADWAG® (Poland). Body composition was analysed by determining values of body's electrical resistance and reactance using bioelectrical impedance with a BIA 101S analyser by AKERN-RJL (Italy) and the Bodygram 1.31 computer programme by AKERN-RJL (Italy). Body composition measurements were taken maintaining the recommended testing conditions, e.g. in the morning and in the fasting state. Athletes also declared abstaining from coffee, strong tea, caffeine-containing products and alcohol for at least 24 h preceding the test, as well as refraining from physical exercise for a minimum 18 h before measurements.

Exercise tests assessing selected physical capacity indexes were conducted on athletes in the morning hours at the Exercise Test Laboratory of the Dietetics Division, the Department of Human Nutrition Hygiene, the Poznan University of Life Sciences. Each time prior to the test athletes were thoroughly informed of the objective, procedure and method of exercise tests. The level of aerobic capacity of athletes was assessed based on the recorded maximal oxygen consumption (VO_2max) and ventilatory threshold (VT) using an exercise test consisting in the performance of exercise of increasing intensity on a Kettler X1 cycloergometer (Germany) following recommendations for such tests [20]. During exercise tests respiratory indexes were recorded, e.g. the volume of oxygen uptake (VO_2), the volume of exhaled carbon dioxide (VCO_2) and respiratory minute volume (VE) and heart rate (HR) using a portable $K4b^2$ ergospirometer (Cosmed, Italy) and the COSMED CPET Software Suite (ver. 9.1b, 2010). In this study reaching maximal exercise was interpreted at the moment of a lack increase in oxygen uptake (VO_2) and heart rate (HR) and/or refusal of the athlete to continue exercising. In order to determine the ventilatory threshold (VT) the *V-slope* method was applied, based on the analysis of linear regression for the curve of increasing CO_2 exhalation in relation to the curve of increasing O_2 uptake.

Blood sampling

Activity of selected enzymes (creatine kinase, lactate dehydrogenase) and concentrations of hormones (testosterone, cortisol) and lactate were assessed based on quantitative analyses in blood plasma of athletes in the fasting state performed using commercial diagnostic tests in cooperation with the Labo-Med Medical Diagnostics Laboratory based in Poznan. At 20-25 minutes after the exercise test of increasing intensity blood samples were collected from the examined athletes from the ulnar vein to two closed-system evacuated test tubes of 2.7 ml, with lithium heparine and sodium fluoride as anticoagulants (Sarstedt Monovette®, Germany), with collected plasma being subjected to further laboratory analyses on the same day. Activity of creatine kinase (CK) and lactate dehydrogenase (LDH) and concentration of lactate were assayed by a standardised colorimetric enzymatic method using a COBAS® 6000 analyser (module c 501, Roche Diagnostics, USA). Concentrations of testosterone and cortisol in blood plasma were assayed by ECLIA electrochemiluminescence using a COBAS® 6000 analyser (module e 601, Roche Diagnostics, USA).

Statistical analysis

All statistical calculations were performed using the Statistica 9.0 package (StatSoft, Inc., USA). Basic descriptive statistics were calculated for tested indicators. Results are presented as arithmetic means ($\bar{x}$), standard deviations (± SD) and median. In order to verify the potential relationship between body composition and values of individual indicators the recorded results were analysed after classifying athletes to individual groups depending on their fat mass levels. The Shapiro-Wilk test was applied in order to determine whether the random sample comes from a population with a normal distribution. Significance of differences between levels of investigated indicators and body composition of athletes was determined based on parametric tests (ANOVA, Tukey's test) and non-parametric tests (Kruskal-Wallis H-test). The relationship between analysed indicators was established using Spearman's correlation coefficients.

Results

Characteristics of body composition, aerobic capacity and biochemical markers in blood of athletes are presented in Table 1.

Assessment of investigated indicators depending on fat mass of athletes (Table 2) showed statistically significant differences in values of maximal oxygen consumption between groups. The highest VO_2max was recorded in athletes with the lowest fat mass level (61.6 ±6.6 ml·kg^{-1}·min^{-1}), while a significantly lower VO_2max ($p<0.05$) by 11% to 16% was recorded in athletes with FM >18%. Already in the group with FM of 15.1% to 18.0% values of this aerobic capacity index were by 6% lower in comparison to athletes with FM <10%. However, it is of great importance that with an increase in fat mass a significant and regular reduction in VO_2max was observed, which lowest values (51.5 ml·kg^{-1}·min^{-1}) were found in the group with the highest FM. Moreover, in athletes with a lower percentage of fat mass VT was recorded at a higher heart rate (HR_{VT}), although significant 7% differences in HR_{VT} ($p<0.05$) were shown only between athletes with the lowest and elevated FM levels (18.1% to 20.0%).

Assessment of biochemical blood markers depending on fat mass of athletes showed statistical significance only in the case of hormonal status.

Testosterone concentration was comparable in groups with different FM levels, although considerable differences (23.6%) were shown only between groups with FM = 10% to 12.5% and FM = 12.6% to 15.0%. In the case of the testosterone: cortisol ratio (T/C ratio) between athletes with FM of 10% to 12.5% and those with lower (<10%) and slightly higher FM (12.6% to 15.0%) the recorded differences were 34.3% and 32.6% at $p<0.02$. Despite a lack of statistical significance we need to stress here that in athletes with the lowest level of FM <10%, blood cortisol concentration was on average lower by over 20% in comparison to athletes with fat mass levels exceeding 18.1% body mass.

In turn, the conducted analysis of correlations between analysed variables showed significant dependencies between body composition of athletes and the investigated indicators, e.g.: FFM (%) and VO_2max ($r = 0.44$, $p<0.001$, Figure 1), FFM (%) and HR at VT $r = 0.23$, FFM (%) and cortisol $r = -0.18$ (both factors $p<0.05$, Table 3); FM (%) and VO_2max ($r = -0.43$, $p<0.001$, Figure 2), FM (%) and HR at VT ($r = 0.21$, $p<0.05$, Table 3); FM (%) and VO_2max ($r = -0.43$, $p<0.001$, Figure 1), FM (%) and HR at VT ($r = -0.21$, $p<0.05$, Table 3); testosterone and t at VT $r = 0.23$, cortisol and HR at VO_2max $r = 0.23$ (both factors $p<0.05$, Table 4).

Discussion

This study showed that body composition is connected with levels of aerobic capacity indicators and biochemical blood markers, which may considerably affect exercise capacity of athletes. What is more, athletes with the lowest fat mass level seem to have the most advantageous exercise-induced adaptation. It is particularly significant in the sports disciplines with weight categories

Table 1. Characteristics of the body composition, aerobic capacity and biochemical markers testing of combat sports athletes (n = 120)

Indicator	x̄±SD	Median	Indicator	x̄±SD	Median
Body composition					
FM (kg)	**13.0** ±5.5	**12.4**	FM (%)	**15.5** ±4.7	**15.5**
FFM (kg)	**68.0** ±8.2	**67.1**	FFM (%)	**84.5** ±4.7	**84.7**
TBW (l)	**49.7** ± 6.0	**49.1**	TBW (%)	**61.8** ±3.5	**61.9**
ECW (l)	**20.8** ± 2.5	**20.6**	ECW (%)	**41.8** ±2.4	**42.0**
Aerobic capacity					
VO_2max (ml·kg^{-1}·min^{-1})	**57.9** ±6.7	**57.6**	t. at VT (min	**8.8** ±1.6	**9.0**
HRmax (bpm)	**183** ±9	**183**	HR at VT (bpm)	**162** ±11	**162**
Biochemical markers (after the aerobic test)					
CK (U·l^{-1})	**297** ±231	**237**	Testosterone (ng·dl^{-1})	**490** ±176	**469**
LDH (U·l^{-1})	**318** ±60	**311**	Cortisol (μg·dl^{-1})	**18.9** ±6.1	**18.5**
Lactate (mmol·l^{-1})	**1.8** ±0.9	**1.5**	T/C ratio·100	**3.6** ±1.8	**3.1**

TBW total-body water; **CK** creatine kinase; **ECW** extracellular water; **FFM** fat free mass; **FM** fat mass; **HRmax** maximum heart rate; **LDH** lactate dehydrogenase; **t** at **VT t**ime at ventilatory threshold; **T/C ratio** testosterone/cortisol ratio; **VO_2max** maximal oxygen uptake

Table 2. Characteristics of physical capacity and levels of biochemical blood markers depending on fat mass level of combat sports athletes (n = 120)

	FAT MASS (%)						
Range of FM (%)	**FM<10.0 (1)**	**10. to 12.5 (2)**	**12.6 to 15.0 (3)**	**15.1 to 18.0 (4)**	**18.1 to 20.0 (5)**	**20.1 to 23.0 (6)**	**23.1 to 29.0 (7)**
Number of tested individuals (n)	17	16	24	25	17	15	6
Aerobic capacity indicators							
VO_2max (ml·kg^{-1}·min^{-1})	**61.6 ±6.6***,†,‡	**60.4 ±7.9**§	59.6 ±7.0	57.8 ±5.4	**54.8 ±5.1***	**54.4 ±5.2**†	**51.5 ±5.5**‡,§
HR at VO_2max bpm)	183 ±10	181 ±13	182 ±5	184 ±11	178 ±9	186 ±11	181 ±10
HR at VT (bpm)	**165 ±9**†	163 ±10	164 ±9	163 ±11	**154 ±11**†,‡	**163 ±13**‡	156 ±10
Levels of selected biochemical indicator (after aerobic test)							
CK (U·l^{-1})	308 ±209	273 ±178	237 ±129	**275 ±157**$^{\|}$	**400 ±333**$^{\|}$	337 ±357	263 ±234
LDH (U·l^{-1})	337 ±58	317 ±49	330 ±56	288 ±61	327 ±62	327 ±67	305 ±74
Lactate (mmol·l^{-1})	1.8 ±0.9	1.7 ±0.7	1.5 ±0.5	2.0 ±1.3	1.8 ±0.4	2.2 ±0.8	1.6 ±0.3
Testosterone (ng·dl^{-1})	512 ±320	**405 ±145**††	**530 ±130**††	483 ±137	473 ±117	518 ±152	510.5 ±172.8
Cortisol (µg·dl^{-1})	16.0 ±5.0	19.6 ±6.5	18.8 ±7.2	18.6 ±5.4	19.9 ±4.3	20.2 ±7.7	20.4 ±5.9
T/C ratio·100	**4.28 ±2.28**$^{\$}$	**2.81 ±1.28**$^{\$,**}$	**4.17 ±2.27****	3.60 ±1.70	3.09 ±0.98	3.68 ±1.92	3.27 ±1.21

For comparisons ANOVA (Tukey's post-hoc test) was applied †,‡,§: p<0.05; *: p<0.01
For multiple comparisons the Kruskal-Wallis H-test was applied: $^{\|}$: p<0.043; $^{\$}$,**: p<0.02
CK creatine kinase; **HR** heart rate; **LDH** lactate dehydrogenase; **T/C ratio** testosterone/cortisol ratio; **VO$_2$max** maximal oxygen uptake; **VT v**entilatory threshold

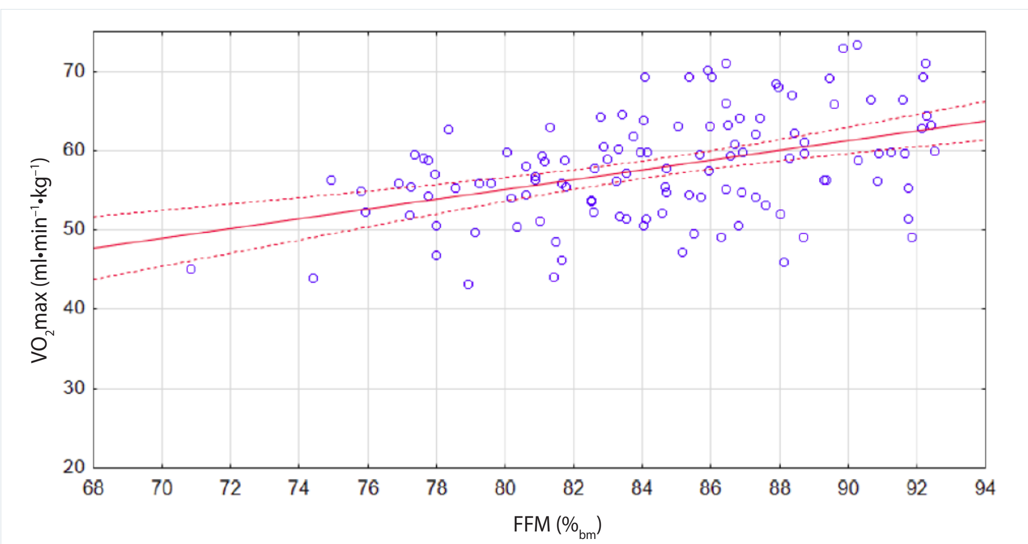

Figure 1. Correlation (r = 0.44, p<0.001) between maximal oxygen uptake (VO_2max) and fat free mass (FFM) combat sports athletes (n = 120)

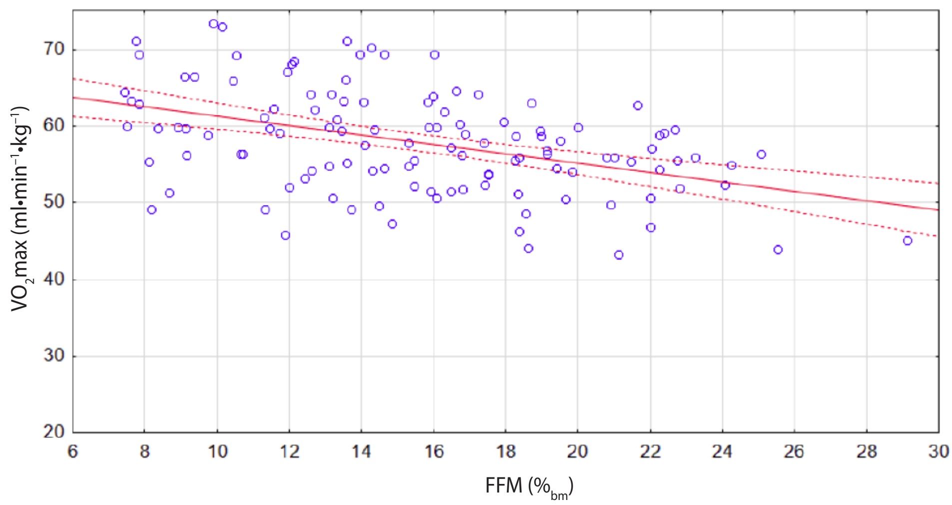

Figure 2. Correlation (r = –0.43, p<0.001) between maximal oxygen uptake (VO_2max) and fat mass (FM) combat sports athletes (n = 120)

Table 3. Correlations between body composition and selected physical capacity indicators of combat sports athletes (n = 120)

Physical capacity indicators	Body composition indicators	
	FFM (%)	FM (%)
Hrmax (bpm)	0.01	–0.01
HR at VT (bpm)	**0.21***	**–0.21***
Cortisol ($\mu g \cdot dl^{-1}$)	**–0.18***	0.14

FFM fat free mass; **FM** fat mass; **HRmax** maximum heart rate; **VT t**ime at ventilatory threshold; * p<0.05

Table 4. Correlations between physical capacity indicators and biochemical blood markers of combat sports athletes (n = 120)

Biochemical blood markers	Physical capacity indexes			
	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR at VO_2max (bpm)	t at VT (min)	HR at VT (bpm)
CK ($U \cdot l^{-1}$)	–0.05	**–0.19***	0.01	**–0.22**
LDH ($U \cdot l^{-1}$)	0.11	**–0.21***	0.02	–0.14
Testosterone ($ng \cdot dl^{-1}$)	0.07	0.01	**0.23***	0.02
Cortisol ($\mu g \cdot dl^{-1}$)	0.12	**0.23***	0.02	0.10
T/C ratio ·100	–0.01	–0.10	–0.01	–0.09
Lactate ($mmol \cdot l^{-1}$)	–0.01	0.14	0.18	0.02

CK creatine kinase; **HR** heart rate; **LDH** lactate dehydrogenase; **t** at **VT** time at ventilatory threshold; **T/C ratio** testosterone/cortisol ratio; **VO_2max** maximal oxygen uptake; * p<0.05

for contestants, such as combat sports, where the results may be determined e.g. by body weight and composition of athletes [10, 21].

Observations recorded in this study as well as those presented by other authors indicate that athletes reducing their body weight before competitions do not pay sufficient attention to proper modification and regulation of body composition, which should be based mainly on decreasing fat mass levels [2, 3, 8, 9, 11-13, 18]. It was shown in literature on the subject that the proportions of fat-free and fat body mass have a significant effect on exercise tolerance of the organism [10, 21-23]. Athletes participating in this study had fat mass levels of 15.5 ±4.7%, which was similar to the results reported by other authors in well-trained combat sports athletes [10, 21, 22, 24, 25]. Moreover, the analysed group had a high level of aerobic capacity (VO_2max: 57.9 ±6.7 $ml \cdot kg^{-1} \cdot min^{-1}$), corresponding with that reported in studies involving athletes practicing combat sports (mean VO_2max: 51-65 $ml \cdot kg^{-1} \cdot min^{-1}$) [10, 12, 26].

In this study the greatest aerobic potential was found in athletes with a low fat mass profile, particularly below 12.5% body mass. What is more, interesting findings are connected with correlations between levels of aerobic capacity indexes and both FFM and FM, showing a significant role of body composition. In a study conducted with the participation of Iranian female judoists a negative correlation was found between maximal oxygen consumption and fat mass level ($r = -0.63$; $p<0.01$) [27]. Also in Brazilian judoists an inverse dependence was shown between VO_2max values (estimated based on the results of the Cooper test) and FM percentage ($r = -0.83$) [10]. We emphasize that in the above mentioned study Franchini et al. [10] showed a negative correlation ($r = -0.70$) between FM and specific exercise capacity in combat sport judo which is qualified to the category throws (and grips of immobilisation of opponent's body) assessed using the throw test (*Special Judo Fitness Test – SJFT*). Moreover, they showed a close relationship between SJFT results and VO_2max values ($r = 0.79$), which confirmed earlier, similar observations by Sterkowicz et al. [22].

Additionally, Katralli et al. [21] also found an inverse correlation between fat mass in Indian judoists and SJFT results ($r = -0.69$; $p<0.001$). The above observations concerning the relationship between body composition and aerobic capacity in combat sports are also confirmed by studies conducted by Beekley et al. [28], in which in well-trained sumo athletes a negative correlation was recorded between fat mass percentage and VO_2max ($r = -0.75$, $p<0.05$). What is more, in some studies differences in results e.g. between women and men were attributed by the authors to the sex-related difference in body composition [26, 28]. Moreover, a correlation was shown between fat-free body mass level and maximal oxygen consumption as well as other specific physical capacity indicators in combat sports, such as e.g. speed, force, mean and maximal power as well as functional threshold power, which may be significant factors determining sports successes of athletes [10, 27, 29, 30].

Thus it seems that an increase in fat-free body mass and a reduction of fat mass level as well as an increase in aerobic potential of the organism, observed in elite athletes, result from proper adaptation of the organism to effective performance of exercise in practiced sports disciplines [21, 31]. This is confirmed also by studies on Polish wrestlers, in which athletes participating in international competitions had lower fat mass in comparison to athletes competing at the national level (FM: 11.4% vs. 12.9%) [25]. Thus the above mentioned studies as well as observations recorded in this study show a significant role of an adequate proportion of tissue components and the related high aerobic potential, which may directly determine success of athletes in these sports, in which weight categories are binding.

In professional sport a significant role in the assessment of adaptation of the organism and systemic homeostasis is also played by monitoring of selected biochemical markers. Studies conducted with the participation of 821 men showed a negative correlation between testosterone concentration and fat mass, as well as a positive relationship between the concentration of this hormone and fat-free body mass [32].

In combat sports (wrestling), based on analyses of the effect of the competitive season on body composition, physical capacity and levels of biochemical blood markers of wrestlers no correlation was observed between these indicators [33]. In comparison to their values before the training season the resting testosterone concentration decreased by almost 15% during the season, particularly in wrestlers participating in sports competitions (on average by approx. 25%). Moreover, a greater reduction of fat mass was recorded in the group of athletes participating in competitions (2.6% vs. 0.9%). In the competitive season wrestlers were also found to have the T/C ratio lower by 17.9%. In contrast, no considerable changes were recorded in blood cortisol concentrations and hematocrit values.

The above observations confirm the results of studies by Roemmich and Sinning [34], in which lower testosterone levels were recorded in wrestlers during the competitive season (3.6 ±0.4 $ng \cdot ml^{-1}$) in comparison to the values both before the season (4.9 ± 0.4 $ng \cdot ml^{-1}$) and after the season (5.7 ±0.4 $ng \cdot ml^{-1}$). However, they were not accompanied by significant changes in blood cortisol levels [34]. It needs to be mentioned here that the authors of the above mentioned study associated changes in levels of analysed biochemical markers mainly with nutritional restrictions introduced by the athletes and the related weight loss. Even a short-term reduction of body mass may lead to considerable disturbances in the anabolic status of the organism. In elite wrestlers applying rapid weight loss (2-3 weeks: 8.2 ±2.3%) a reduction of fat mass (–16%) and fat-free body mass (–7.9%) was recorded, which was accompanied by a decrease ($p<0.001$) in the concentrations of testosterone (–63%) and the luteinizing hormone (–54%) [35]. Moreover, the above mentioned studies showed a correlation between the volume of body weight loss and a decrease in testosterone concentration in blood serum ($r = 0.53$; $p=0.02$).

The above observations were also confirmed by Yanagawa et al. [36], who in the course of a 12-day intensive weight loss before the competitions (on average by 3.7 kg), accompanied by reduction of fat mass from 8.6 ±5.0 kg to 8.5 ±5.0 kg (8 days before weigh-in) and 6.5 ±4.7 kg (the weigh-in day; $p<0.001$), recorded a reduction of testosterone concentration from 6.8 ±1.5 $ng \cdot ml^{-1}$ to 5.8 ±1.6 $ng \cdot ml^{-1}$ (8 days; $p<0.05$) and 4.4 ±1.9 $ng \cdot ml^{-1}$ (the weigh-in day; $p<0.001$). Additionally, after the next 9 days (from the weigh-in day) it was found in athletes that with the return of body weight to initial values an increase was recorded in testosterone concentration (7.0 ± 1.7 $ng \cdot ml^{-1}$; $p<0.001$), although it was not accompanied by a significant increase in fat mass (7.1 ± 4.5 kg). Similar observations were made in the case of judoists, as after 7-day period of a 5% reduction of body mass (FFM: –2.3 kg; FM: –0.8%) their testosterone concentration and T/C ratio were lower by 22% and 25%, respectively, on the day of a simulated competition exercise test [37]. Moreover, their cortisol level increased by 24%, which seems to confirm the inverse correlation observed in this study between the concentration of this hormone and fat-free body mass of athletes.

The specific character of training loads may also influence the anabolic-catabolic status to a greater extent (than only the body composition profile). The above thesis seems to be confirmed by a study of Purge et al. [38], who showed a correlation between the training level and concentrations of testosterone ($r = 0.42$; $p<0.01$), cortisol ($r = 0.53$; $p<0.001$) and creatine kinase activity. These observations also confirm examinations of wrestlers, as an increase was observed in the concentrations of testosterone, cortisol and creatine kinase activity after the fight in relation to the values assayed before it [39]. In the course of successive fights (2nd to 5th fight) mean post-exercise concentrations of testosterone decreased, whereas opposite dependencies were shown in the case of cortisol and the activity of creatine kinase. In turn, in judoists Umeda et al. [40] recorded a significant increase ($p<0.05$) in the activity of creatine kinase at 1 day before the competition both in the group with rapid and in that with slight body weight loss, with its high values being maintained for as long as almost 7 days.

The significant importance of a proper hormonal status of the organism in sports seems to be confirmed by studies, in which higher testosterone levels (by 31%) and T/C ratio values (43%) as well as lower concentrations of cortisol (15%) and lactate (19%) [41] were assayed in boxer winning their fights. Similar observations were also conducted in tennis players: both in males T (testosterone): +27%; C (cortisol): +1%, and females: T +27%; C –3%. What is more, in athletes losing their fights opposite dependencies were shown (males: T –16%; C +30%; females: T –11%, C +31%) [42].

Literature data show that in the sports disciplines with binding weight categories an intensive regulation of body mass has a negative effect on physical capacity and levels of biochemical markers, reflecting e.g. their hormonal status, energy processes taking place in muscles and the degree of their damage. Unfortunately, there are few available studies on dependencies between levels of these indicators and body composition in athletes in the training period, in which the organism is not additionally burdened with intensive weight loss. They seem necessary for the development of proper recommendations for trainers and athletes, concerning conscious and rational regulation of not only body weight, but particularly body composition [43]. By making it possible to reach an adequate level of tissue components, it would facilitate reaching an optimal exercise adaptation and qualification to individual weight categories, at the same time avoiding excessive weakening of the organism, reduced physical capacity, a disturbed anabolic-catabolic status as well as an increased risk of injury or other health problems in athletes.

Conclusions

Athletes with the body composition profile characterised by a lower fat mass exhibit higher aerobic capacity, which decreases with an increase in the share of this tissue component in the organism. In turn, analysis of biochemical blood markers does not show a clear relationship with the body composition profile, although some results concerning e.g. the anabolic-catabolic status seem to indicate advantageous thresholds in athletes with the lowest fat mass level. However, the most interesting finding is connected with the correlations between analysed indexes and body composition in athletes, as well as selected aerobic capacity indexes and levels of biochemical blood markers. This suggests that in terms of exercise adaptation the most effective approach is to reach a profile with a low fat mass level. Thus it seems crucial to consider potential advantages of enhanced efficiency of the training regime thanks to a conscious regulation of body composition in athletes both in the competitive period and in the training period.

Practical applications

Based on the results of this study trainers and athletes practicing combat sports and other sports disciplines with binding weight categories should focus on reaching an optimal body composition profile and regulating tissue component levels, connected mainly with the rational reduction of fat mass already in the training period. This will not only facilitate qualification to a specific weight category thanks to weight loss, but it may also contribute to the maintenance of systemic homeostasis, increased aerobic capacity and exercise capacity of the organism, as well as provide a desirable physiological response of the organism, assessed e.g. using biochemical blood markers.

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