

Article

Establishing Benchmark Percentiles for the Classification of Body Fat Percentage of Professional Male Athletes Competing in Combat Sports through Bioimpedanciometry

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Featured Application: This classification applied to body fat values of Lithuanian combat sports athletes may also encourage propositions for classifying the outcomes derived from skinfold thickness measurements and even dual-energy X-ray absorptiometry to assist sports medicine professionals and sports dietitians.

Abstract: Body composition as a meaningful factor can result in physiological responses in both the physical body and general health status. Nevertheless, the schemes for establishing cut-off points for identifying the classifications of the body fat percentage of athletes competing in combat sports still include gaps. The aim of this study was, by using bioimpedanciometry, to calculate the percentiles for the classification of body fat percentages in Lithuanian professional male athletes ($n = 52$) competing in combat sports with weight classes. A total of 52 Lithuanian professional male athletes competing in combat sports with weight classes were evaluated using a multi-frequency bioelectrical impedance analysis method with frequencies ranging from 1 kHz to 1000 kHz. Percentiles P_3 , P_{10} , P_{25} , P_{50} , P_{75} , P_{90} , and P_{97} were used to determine the classification. As a consequence, the following classification categories were assigned: 6.6–7.8% (extremely low); 7.9–10.9% (very low); 11.0–14.7% (below normal); 14.8–18.8% (normal); 18.9–21.5% (above normal); 21.6–29.3% (very excessive); and $\geq 29.4\%$ (extremely excessive). The assessment of body composition in combat sports athletes identified an inverse association between higher body fat levels and a decrease in the muscle-to-fat ratio ($\beta -1.3$, 95% confidence interval (CI): $-1.5; -1.0$, $p < 0.001$). The relationship between lower body fat percentage and lighter weight categories in which combat sports athletes from different combat sports were competing has been identified ($\beta 0.3\%$, 95% CI: $0.2; 0.3$, $p < 0.0001$). The established cut-off points may assist sports medicine professionals and sports dietitians in monitoring the adiposity of combat sports athletes.

Keywords: combat sports; athletes; body composition; adiposity; athletes' health



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1. Introduction

Body composition as a meaningful factor can result in physiological responses in both the physical body and general health status [1]. The fat component, as a vital endocrine organ of the body [2], not only has a multivariable impact on entire health [3], but can also impair the involvement in physical activities [4,5], and, in the case of increased body fat percentage levels, can lead to cardiometabolic risk [6]. Therefore, body composition measurements appear to be a common practice in many sports organizations [7]. Assessments of body weight and bodily components may be relevant in certain situations related to sporting activities that cover weight-category sports, such as combat sports (e.g., boxing, wrestling, judo, taekwondo, etc.) [1,7]. Within combat sports, sportsmen routinely strive

to attain a competitive advantage by lying about their body weight to fight in a weight category that is lighter than their typical 'training weight'. Athletes with lower levels of adiposity and higher fat-free mass are likely to participate more successfully in athletics championships [8]. However, the fall of body fat levels below the recommended minimum levels of 5% in males and below 15% in females [9] may result in malnutrition which contributes to negative outcomes for both health and athletic performance [10]. On the contrary, the assessment of adiposity, often calculated as a physical body fat percentage, is a very important factor since excessive fat levels can be recognized as 'dead weight' and considered not useful when the body opposes gravity forces in movements such as running, pulling, jumping, etc. [7,11–14]. Thus, in some cases, a self-implemented carbohydrate cycling program coupled with resistance training may be required to reduce body fat percentage and maintain muscle mass effectively in male athletes whose baseline means of body fat levels fluctuate between 9% and 15% [15].

Regardless of the significance of monitoring body composition in elite sports, there is no universally adapted assessment model; therefore, sports professionals often use devices with some restrictions that are appropriate for their routine work. The search for accurate body composition quantification methods has continued for decades. These scientific endeavors led to the development of many quantification approaches, including 'direct' methods, such as cadaver dissection, and many 'indirect' methods [1].

The 'indirect' evaluation of bodily properties, notably density, the distribution of fat-free mass, and fat mass, can be performed using technologies, namely magnetic resonance imaging, computed X-ray tomography, and dual-energy X-ray absorptiometry (DXA) [1]. However, these methods, being part of the second level of validity methods, are not only complicated but are also applied using highly specialized technologies, necessitating greater financial resources. Against this background, in an attempt to estimate the body composition in the samples of larger populations, more effortless 'indirect' body composition analysis techniques, such as anthropometry (skinfold thickness measures) and bioelectrical impedance analysis (BIA), referring to the third level of validity approaches, have been constructed [16]. The outcomes, determined with the third level of validity methods of both BIA and anthropometry, relate to a higher likelihood of errors compared to the second level of validity test models (e.g., DXA) and significantly depend on the specificity of characteristics in a sampled cohort [16]. Furthermore, previous research studies claim that professionals [17] and athlete groups [17–19], who vary depending on the high specificity of each particular sports discipline, are not being supported by the anthropometric equations applied to non-athletic populations.

Taking into account that it is necessary to approve the anthropometric equations for specific athlete populations, normative tables for body fat percentages determined using the BIA method should also be reconsidered. Furthermore, there are several reasons for the emergence of differences in fat percentages resulting from the measurements made using different technologies (BIA vs. anthropometry and BIA vs. DXA). In both cases, fat percentages measured using the BIA method are higher than the results obtained through anthropometry [8,20–25] or DXA [26–29]; however, previous normative tables for athletes' body fat percentages have been proposed according to the outcomes of DXA or assessments of skinfold thickness (Table A1 (Appendix A)) [9,30].

There is no gold-standard body composition analysis technique. Even DXA, which is preferred as the 'gold standard' approach, was associated with only average accuracy in estimating body fat levels [31–38]. Even though anthropometry has been replaced with BIA as a more advanced way of assessing the change in body composition [39], among groups of sports coaches and experts on 'athletic performance' [40], there still remains a gap in classifying fat percentages restricted by BIA. Therefore, providing reference values for the classification of body fat percentages could facilitate sports coaches and dietitians in choosing the most appropriate weight category for each athlete who competes in a weight-sensitive sport [1].

The aim of this study was, by using bioimpedanciometry, to calculate the percentiles for the classification of body fat percentage in Lithuanian elite male athletes competing in combat sports with weight classes.

2. Materials and Methods

2.1. Study Participants and Procedures

This quantitative observational cross-sectional study in design was carried out between 2018 and 2020 in Lithuania. The study was conducted on Lithuanian professional male athletes ($N = 62$) engaged in physical activity for Olympic disciplines such as Greco-Roman wrestling ($N = 32$), boxing ($N = 17$), and judo ($N = 13$). All athletes were voluntarily recruited and selected according to the list approved by the Lithuanian National Olympic Committee. Considering that 62 Lithuanian professional male athletes competing in combat sports constituted the whole target population, the determined representative sample size is equal to 54 cases at a 95% confidence level with a 5% margin of error [41]. The quota random sampling method was used to form a representative sample size for the study.

The inclusion characteristics were as follows: (1) professional male athletes with ≥ 4 years (one Olympic cycle) of regular practice of combat sports; (2) participants at national/international competitions and/or candidates for the Olympic Team; (3) participants in the preparatory period (non-competition or pre-competition phase); (4) participants trained under the 'Tokyo 2020' program approved by the Lithuanian National Olympic Committee; (5) participants who followed a 6-day workout schedule plan regularly (≥ 12 sessions of combat sports a week). The exclusion criteria were set as follows: (1) male athletes who were in the act of weight cutting; (2) participants who did not agree to participate in the study as volunteers.

Finally, originating from four major Lithuanian regions, namely Samogitia (western Lithuania), Aukstaitija (central and eastern Lithuania), Dzūkija (south-eastern Lithuania), and Sudovia (south-northern Lithuania), 52 professional male athletes aged 21.6 ± 3.4 years competing in combat sports were included and consequently allocated into three groups: Greco-Roman wrestlers ($n = 29$), boxers ($n = 14$), and judokas ($n = 9$). The mean training experience of combat sports athletes was 7.5 ± 3.4 years. Due to the constant tendency of weight cycling, combat sports athletes were not recruited through the pre-competition phase or the competition phase. All combat sports athletes who were enrolled in the study during the general preparatory phase had been selected during the early part of this period and targeted the development of a general physical base. The sports workouts were performed 5.6 ± 0.8 days per week, while the average duration of workout sessions was 152.3 ± 35.5 min per day. In addition, Table 1 displays the weight categories in which male athletes from combat sports were competing.

Table 1. Weight classes for elite male athletes from different combat sports.

Weight Classes (Upper Limit in kg)	Wrestlers (%)	Judokas (%)	Boxers (%)
60 kg ^{1,2} ; flyweight (52 kg) ³	17.2	44.4	14.3
67 kg ¹ ; 66 kg ² ; featherweight (57 kg) ³	17.2	22.2	50
77 kg ¹ ; 73 kg ² ; lightweight (63 kg) ³	24.1	–	14.3
87 kg ¹ ; 81 kg ² ; welterweight (69 kg) ³	31	–	–
97 kg ¹ ; 90 kg ² ; middleweight (75 kg) ³	3.4	22.2	7.1
130 kg ¹ ; 100 kg ² ; light heavyweight (81 kg) ³	6.9	–	7.1
>100 kg ² ; heavyweight (>91 kg) ³	–	11.1	–
Super heavyweight (>91 kg) ³	–	–	7.1

%—percentage of athletes for weight division; weight classes were expressed as upper limits (kg) of body weight: ¹—weight classes for Greco-Roman male wrestlers, ²—weight classes for male judokas, ³—weight classes for male boxers. All weight categories were adjusted according to the requirements for weight divisions of the 'Tokyo 2020 Olympics' [42,43].

2.2. Body Composition Assessment

The body composition of elite athletes was measured in a certified laboratory at the Lithuanian Sports Medicine Centre. The analyses of height, body weight, and body composition were performed via X-scan (Jawon Medical Co., Jinryang Industrial Complex, Gyeongsan, Republic of Korea, EN-ISO: 13488) using a multi-frequency bioelectrical impedance analysis (MFBI) method with frequencies ranging from 1 kHz to 1000 kHz and clinically developed by an isotope dilution method called the 'golden method', capable of predicting both intracellular and extracellular fluid values [43–46]. While applying a body composition analyzer, significant improvements were introduced for predicting extracellular fluid and total body water using MFBI, as the swept multi-frequency facility was able to differentiate the proportions of intra- and extracellular fluid. At low frequencies (<50 kHz), the bioelectrical current was assumed to pass through the extracellular fluid. In contrast, at frequencies above 100 kHz and up to 1000 kHz (100 kHz, 250 kHz, 550 kHz, and 1000 kHz), the current passed through all body fluids and tissues and consequently provided various ranges and more precise information about athletes' body composition.

All athletes were informed of the necessary preparation procedures prior to the bioimpedance evaluation. The study participants were informed to make the following preparations: (1) to starve for 4 h, during that time no solid or liquid foods were permitted; (2) to completely avoid taking part in moderate-intensity physical activities and using caffeine as well as diuretic medications 24 h before the testing; (3) to urinate prior to the evaluation [20,44].

The outcomes obtained via the MFBI are referred to height (m), fat-free mass (kg and %), muscle mass (kg and %), and body fat mass (kg and %). The values of body fat percentages were classified into 'extremely low', 'very low', 'below normal', 'normal', 'above normal', 'very excessive', and 'extremely excessive' and were, respectively, assigned to the percentiles of 3rd (P_3), 10th (P_{10}), 25th (P_{25}), 50th (P_{50}), 75th (P_{75}), 90th (P_{90}), and 97th (P_{97}) [47]. Additionally, indicators such as body mass index (BMI) (kg/m^2) [48] and muscle-to-fat ratio (MFR) were calculated. The BMI was calculated by dividing the body mass (kg) by height (m^2). The MFR was calculated as body fat mass (kg) divided by muscle mass (kg) [9].

2.3. Statistical Analysis

The data were tested for normality using the Shapiro–Wilk W test and assigned to the percentiles, namely P_3 , P_{10} , P_{25} , P_{50} , P_{75} , P_{90} , and P_{97} . If the data normality was verified, the one-way ANOVA test was used to identify the significance of the differences among the central tendency measures in the form of means \pm standard deviations (SDs) in more than two groups. The Bonferroni test was used in a post hoc procedure following the analysis of variance. More specifically, the Bonferroni test, in combination with the ANOVA, was applied in cases where the numerical outcomes were compared between three independent groups.

Additionally, the multiple linear regression analysis was applied to reveal the association between body fat mass (%) and BMI (kg/m^2) as well as MFR. The single linear regressions were performed to identify how weight classes used in sports may associate with fat mass levels (%) and MFR in a sample of combat sports athletes. All the reported p -values were calculated on two-sided tests and compared to a significance level of 5%. Statistical analysis of cross-sectional study data was performed using Statistical Package for the Social Sciences (IBM SPSS Statistics) V.25 for Windows (IBM Co., Armonk, NY, USA).

3. Results

The data on the anthropometric measurements for elite combat male athletes are displayed in Table 2, namely the general characteristics of professional athletes from combat sports, information on height, body mass, fat-free mass, musculoskeletal mass, fat mass, body mass index (BMI), and muscle-to-fat ratio (MFR).

Table 2. Anthropometric characteristic values of the elite male athletes from combat sports.

Variable	Wrestlers ^a	Judokas	Boxers	Total
Height (m)	1.8 ± 0.1	1.7 ± 0.2	1.7 ± 0.1	1.7 ± 0.1
Body mass (kg)	74.9 ± 14.9 *	65.8 ± 22.9	62.1 ± 14.4	69.9 ± 17.1
Fat-free mass (kg)	62.7 ± 11.1 *	53.7 ± 14.0	53.0 ± 7.9	58.5 ± 11.7
Fat-free mass (%) _{BIA}	84.1 ± 4.2	83.8 ± 7.4	86.6 ± 6.4	84.7 ± 5.5
Musculoskeletal mass (kg)	58.3 ± 10.3 *	49.9 ± 12.8	49.4 ± 7.1	54.4 ± 10.8
Musculoskeletal mass (%) _{BIA}	78.3 ± 4.1	78.0 ± 7.3	80.7 ± 6.3	78.9 ± 5.4
Body fat mass (kg)	12.3 ± 5.0	12.1 ± 9.4	9.1 ± 6.9	11.4 ± 6.5
Body fat mass (%) _{BIA}	15.7 ± 4.1	16.1 ± 7.4	13.4 ± 6.4	15.2 ± 5.4
BMI (kg/m ²)	23.5 ± 3.2	22.5 ± 4.3	20.7 ± 3.2	22.6 ± 3.5
MFR	5.4 ± 2.0	6.0 ± 3.1	7.5 ± 3.8	6.1 ± 2.9

Data were displayed as means ± SD; SD—standard deviation; ^a—Greco-Roman wrestlers; BMI—body mass index; FMR—muscle-to-fat ratio; *—*p*-value (<0.05) from the Bonferroni post hoc test; fat-free mass (%), musculoskeletal mass (%) and body fat (%) were estimated with bioelectrical impedance.

The means ± SDs, as measures of the central tendency of BMI and MFR for male athletes playing different combat sports, were 22.6 ± 3.5 kg/m² and 6.1 ± 2.9. The mean fat mass was 15.2 ± 5.4% (11.4 ± 6.5 kg) for the combat male athletes.

While estimating the results of the Bonferroni test, significant differences (*p* < 0.05) related to higher body weight (in kg), fat-free mass (in kg), and muscle mass (in kg) were identified in the subgroup of Greco-Roman male wrestlers and later compared to those obtained in the subgroups of boxers and judokas. However, no significant differences were ascertained in fat-free mass (in %), body fat (in %), and MFR in the samples of wrestlers, judokas, and boxers (*p* > 0.05; all comparisons); therefore, it may be suggested that the study subgroups were homogeneous according to the characteristics of body composition.

Table 3 shows data indicating the cut-off points for the categorization of body fat (in %) in elite male athletes from combat sports. The body fat percentages within the range of between 14.8% and 18.8% were considered normal (equivalent to the 50th percentile) for combat sports athletes. Values below these scopes were classified as below normal, very low, and extremely low, whereas those that exceeded the median values were rated as above normal, very excessive, and extremely excessive.

Table 3. Cut-off points for body fat percentages in elite male athletes from combat sports.

Percentile	Body Fat Percentage (%)	Body Mass Index (kg/m ²)	Classification
P ₃	6.6–7.8	17.8–18.5	Extremely low
P ₁₀	7.9–10.9	18.6–19.9	Very low
P ₂₅	11.0–14.7	20.0–21.9	Below normal
P ₅₀	14.8–18.8	22.0–24.9	Normal
P ₇₅	18.9–21.5	25.0–27.7	Above normal
P ₉₀	21.6–29.3	27.8–31.4	Very excessive
P ₉₇	≥29.4	≥31.5	Extremely excessive

The measures of body mass index (kg/m²) and body fat percentage (%) were used only to reveal their increasing levels.

As shown in Figure 1, a multiple liner regression was obtained to reveal how the magnitude and variation of body fat mass (%) may predict both BMI and MFR in a sample of combat sports athletes. This study has detected that variations in the body fat mass of male athletes could cause variations in both BMI and MFR. More specifically, when body fat mass increases by 1%, BMI increases by 0.5 kg/m² (95% CI: 0.3; 0.7; *p* < 0.0001) and MFR decreases by a relative unit of 1.3 (95% CI: −1.5; −1.0; *p* < 0.001).

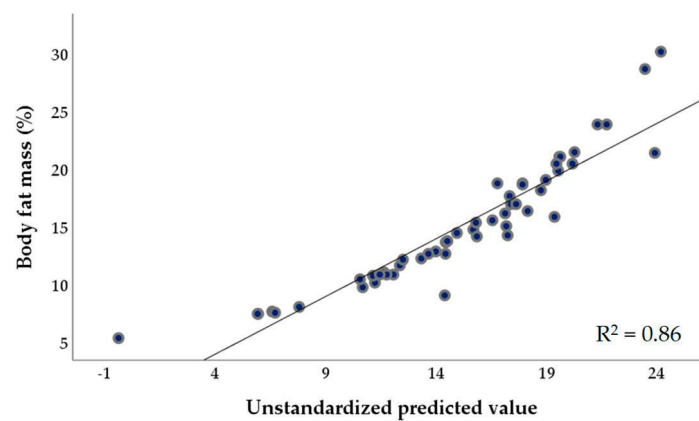


Figure 1. The association between body fat mass (%) and variables such as muscle-to-fat ratio and body mass index (kg/m^2) in male athletes from combat sports. $F(2, 49) = 151.1$, $p < 0.001$, $R^2 = 0.86$.

In addition, as shown in Figure 2, single linear regressions were performed to identify how weight classes used in sports relate to body fat mass levels (%) and MFR in combat sports athletes. As for body fat mass in association with weight division, male competitors from heavier categories had a higher body fat percentage with an average of 0.3% (95% CI: 0.2; 0.3; $p < 0.0001$). Meanwhile, the MFR values declined sequentially in line with the increasing weight category in which combat male athletes competed ($\beta -0.4$; 95% CI: -0.5 ; -0.2 ; $p < 0.0001$).

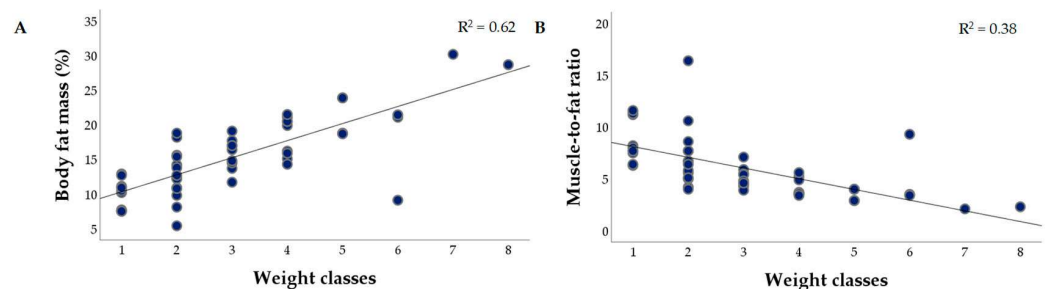


Figure 2. (A)—the association between weight categories and body fat mass (%) in male athletes from combat sports ($F(1, 50) = 79.2$, $p < 0.0001$, $R^2 = 0.62$); (B)—the association between weight categories and muscle-to-fat ratio in male athletes from combat sports ($F(1, 50) = 31.4$, $p < 0.0001$, $R^2 = 0.38$); Weight classes (WCs) in which combat male athletes were competing were allocated as follows: Greco-Roman wrestlers were competing in WCs namely: $1 \leq 60$ kg, $2 = 60.1\text{--}67$ kg, $3 = 67.1\text{--}77$ kg, $4 = 77.1\text{--}87$ kg, $5 = 87.1\text{--}97$ kg, $6 = 97.1\text{--}130$ kg; judokas were competing in WCs namely: $1 < 60$ kg, $2 = 60.1\text{--}66$ kg, $3 = 66.1\text{--}73$ kg, $4 = 73.1\text{--}81$ kg, $5 = 81.1\text{--}90$ kg, $6 = 90.1\text{--}100$ kg, $7 > 100$ kg; boxers were competing in WCs namely: $1 \leq 52$ kg, $2 = 52.1\text{--}57$ kg, $3 = 57.1\text{--}63$ kg, $4 = 63.1\text{--}69$ kg, $5 = 69.1\text{--}75$ kg, $6 = 75.1\text{--}81$ kg, $7 = 81.1\text{--}91$ kg, $8 > 91$ kg.

4. Discussion

Taking into consideration the demand to resolve cut-off points for the classification of body fat, BIA was applied to assure reliable measurements of the core elements of anthropometry in a population of elite male athletes from combat sports. The results of the present study could support sports professionals to derive cut-off values with respect to classifying body fat percentages. The relevance of the cut-off points demonstrated for BIA provides a new capability for allocating body fat levels in the following seven classes: ‘extremely low’, ‘very low’, ‘below normal’, ‘normal’, ‘above normal’, ‘very excessive’, and ‘extremely excessive’. On this basis, considering the fact that the preceding normative tables have not been specified for this athletic group, a body fat percentage classification for elite male athletes competing in combat sports has been proposed in this study. An equivalent classification was also defined for body mass index in mature persons: ‘severe

underweight', 'underweight', 'normal weight', 'overweight', 'moderate obesity', 'severe obesity', and 'morbid obesity' [49,50]. However, in the context of individual assessments, the body mass index does not appear to be effective in eliminating the risks associated with a waistline measurement, waist-to-hip ratio, and body fat as it displays low prognostic values and results in biases when it comes to the interpretation of outcomes [51].

According to a recent study conducted in 2020, depending on the data of the body composition analysis based on a DXA assessment, the mean body fat percentages among the international-level male athletes competing in boxing, wrestling, and judo accounted for 9.1%, 13.1%, and 14.5%, respectively [52]. In turn, our study identified that body fat mass equaled ~15.2% (range: from 5.4 % to 30.2%) with no significant differences in body fat percentage among athletes from different combat sports. After applying the BIA body composition analysis method, our study revealed higher body fat levels for athletes compared to the DXA assessment outcomes obtained in the study carried out by Reale et al. [52]. Nevertheless, Yang et al. [45] found very strong correlations between the DXA and different BIAs models in line with other scientific evidence, which also suggests that DXA tends to show higher estimates of fat mass when compared to the BIAs used [26]. Hence, in our case, the pertinence of the body fat classification was restricted to BIA. Furthermore, our study made it clear that new classification tables for body fat attained using different approaches should be delineated as the fluctuation of cut-off points may lead to an underestimation or overestimation of the values obtained. In this context, body composition monitoring using identical BIA measurement devices [26] is particularly important for combat sports athletes seeking to compete in the appropriate weight category while maintaining a 'safe weight', which, as suggested by the National Athletic Trainers' Association (NATA) position statement, should not be below a minimum cut-off of 5% of male body fat levels [30]. In addition, on the basis of the results of our study, it can be hypothesized that the minimum body fat percentage needed to maintain a 'safe weight' demonstrated slightly higher values than the limits suggested by the NATA; thus, the fat levels should not be below 6.6% to 7.8% according to the body composition of combat sports athletes' assessed using the BIA method.

The findings of this study were also consistent with other evidence suggesting that combat sports athletes from lighter weight categories have a tendency to have a lower body fat percentage compared to sportsmen from heavier weight divisions [20,53]. In spite of that, our previous study also referred to the fact that almost 90% of combat athletes cut weight aggressively on average by 4.6% using the rapid weight loss method five days before taking part in competition [54]. Hence, it can be speculated that the body fat percentage varies during the athletic season, and for that reason, the monitoring of body fat mass is necessary for making the most acceptable decision on the ability of an athlete to compete in a specific weight division. Furthermore, the findings of this research could encourage periodic evaluations of body composition in relation to the fact that previous evidence showed poor eating habits among combat athletes [54–56].

In some sports, the body composition of different athletes is directly related to the physical constraints of the sport. In this respect, both high fat-free mass and low-adipose tissue levels were associated with improved athletic performance [57]. A lower body fat percentage could result in better aerobic fitness, powerful endurance, swift efficiency in movement, and flexibility, while a higher body fat percentage could act as a barrier to the development of these physical capabilities [57,58]. Our study also revealed that the magnitude and the variation of body fat mass may predict body composition assessments such as body mass index and muscle-to-fat ratio. Considering the evidence that an increase of 1% in body fat may result in an increase of 0.5 kg/m² in body mass index and a decrease of 1.3 in the muscle-to-fat ratio; consequently, the findings of this study additionally reinforce the importance of the recommendation for monitoring the outcomes of both adiposity and muscle-to-fat ratio among male athletes in combat sports.

As body composition plays a key role in the development of the physical fitness and performance of athletes taking part in weight-category competitions, the implications

we propose are consistent with the findings of the study carried out by Balci et al. [59], Durkalec-Michalski et al. [58], Ceylan et al. [60], and Arazi et al. [61], indicating a negative association between body fat percentage and body mass index in athletes. Aside from these findings, lower adaptations to both aerobic and anaerobic exercises in combat sports athletes were revealed. Furthermore, Syed-Abdul et al. [15] reported that if the percentage of body fat is below the average values, more intense training may be necessary to reduce body fat levels while maintaining muscle mass. However, emphasis should be laid on the fact that athletic performance is multivariable; therefore, it demands an analysis of physical, tactical, and technical attributes that ought not to be restricted only to anthropometric assessment, i.e., body fat percentage.

5. Strengths and Limitations

Our study holds some strengths. The study's guidelines can help combat sports athletes strategically manage their body composition for improved performance within specific weight categories. By discouraging extreme low body fat levels, the study prioritizes athlete health while ensuring sustainable practices for both performance and well-being. The study's clear classification of body fat percentages aids coaches and athletes in effective training, nutrition planning, and competition strategies.

The limitations of our study are related to the evidence that the advanced cut-off points for the classification of body fat were completed along with the body composition assessment via the BIA method, which therefore is not in a position to be assigned for the results obtained from the second level of validity methods such as computed X-ray tomography, magnetic resonance, and DXA or the third level of validity method such as anthropometry [7,40]. In addition, the readings of the BIA devices are generated on the basis of proprietary forecasting equations concealed from potential users [40], which may lead to biases in the interpretation of fat mass assessment results.

Taking into consideration that our study focused on combat sports male athletes with weight categories who engaged in weight cycling before the competitions, the results might not apply universally to athletes from various sports and sex. These suggestions are maintained by the fact that, depending on bodily hormone variability, female athletes have higher body fat levels compared to male athletes [62–64].

Therefore, further research is needed to calculate the percentiles for the classification of body fat percentage in the populations of female athletes playing weight-sensitive sports. On the other hand, the well-developed muscle-to-fat ratios of Lithuanian male athletes playing boxing, judo, and wrestling matched the body composition profiles of elite male athletes from other countries [52,60,65,66]. Therefore, our proposal for fat classification could be generalized for well-trained elite male athletes representing combat sports in other countries.

Another limitation of our study concerns the relatively small, but representative, sample size. An international multi-center sample size may be more beneficial for disclosing the empirical data more accurately. Taking into account that the proportion of professional male athletes from combat sports who were candidates for the Olympic games was relatively low in Lithuania, the external validity of the findings of our study should be assessed with caution.

Finally, perspective cohort studies in design are needed to investigate the changes in body composition in response to training load in combat sports athletes.

6. Conclusions

The assessment of body composition in combat sports athletes identified an inverse association between higher body fat levels and the decreasing muscle-to-fat ratio. Furthermore, this study found a relationship between lower body fat percentages and lighter weight categories, in which professional male athletes from different combat sports competed. Consequently, our study has revealed and suggests that the cut-off points for the classification of body fat percentages may result in maintaining the optimal weight category

in which male athletes from combat sports will fight in coherence with the relative level of fatty tissue.

Given that the bioelectrical impedance analysis method has been distributed globally, it is contemplated that an advanced classification of body fat values in male athletes from combat sports may also encourage classification propositions for outcomes derived using skinfold thickness measurements and even dual-energy X-ray absorptiometry to assist sports medicine professionals and sports dietitians. Finally, future experimental studies in design should focus on the validation of our findings in cohorts of athletes from different sports.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Vilnius Regional Committee of Biomedical Research Ethics (protocol code 158200-17-898-419, of 11 April 2017).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available on request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Normative cut-off points for body fat percentages and muscle-to-fat ratios in male athletes.

Classification	Body Fat Percentage	Muscle-to-Fat Ratio	Classification
Too low	<5%	≤2	Insufficient
Lean	5–9%	2.1–3.39	Too small
Optimal	10–14%	3.4–4.69	Moderate
Acceptable	15–19%	4.7–6	Extensive
Excessive	20–24%	>6	Maximum

The normative table was adapted by Skernevicius et al. [9].

References

- Ackland, T.R.; Lohman, T.G.; Sundgot-Borgen, J.; Maughan, R.J.; Meyer, N.L.; Stewart, A.D.; Müller, W. Current status of body composition assessment in sport: Review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the IOC Medical Commission. *Sports Med.* **2012**, *42*, 227–249. [[CrossRef](#)]
- Kershaw, E.E.; Flier, J.S. Adipose tissue as an endocrine organ. *J. Clin. Endocrinol. Metab.* **2004**, *89*, 2548–2556. [[CrossRef](#)]
- Harvey, I.; Boudreau, A.; Stephens, J.M. Adipose tissue in health and disease. *Open Biol.* **2020**, *10*, 200291. [[CrossRef](#)]
- Sundgot-Borgen, J.; Meyer, N.L.; Lohman, T.G.; Ackland, T.R.; Maughan, R.J.; Stewart, A.D.; Müller, W. How to minimize the health risks to athletes who compete in weight-sensitive sports review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition, Health and Performance, under the auspices of the IOC Medical Commission. *Br. J. Sports Med.* **2013**, *47*, 1012–1022. [[CrossRef](#)] [[PubMed](#)]
- Gabbett, T.J. Science of rugby league football: A review. *J. Sports Sci.* **2005**, *23*, 961–976. [[CrossRef](#)] [[PubMed](#)]
- Guh, D.P.; Zhang, W.; Bansback, N.; Amarsi, Z.; Birmingham, C.L.; Anis, A.H. The incidence of comorbidities related to obesity and overweight: A systematic review and meta-analysis. *BMC Public Health* **2009**, *9*, 88. [[CrossRef](#)]
- Kasper, A.M.; Langan-Evans, C.; Hudson, J.F.; Brownlee, T.E.; Harper, L.D.; Naughton, R.J.; Morton, J.P.; Close, G.L. Come back skinfolds, all is forgiven: A narrative review of the efficacy of common body composition methods in applied sports practice. *Nutrients* **2021**, *3*, 1075. [[CrossRef](#)] [[PubMed](#)]
- Andreato, L.V.; Lara, F.J.D.; Andrade, A.; Branco, B.H.M. Physical and physiological profiles of Brazilian Jiu-Jitsu athletes: A systematic review. *Sports Med. Open* **2017**, *3*, 9. [[CrossRef](#)]

9. Skernevicius, J.; Milašius, K.; Raslanas, A.; Dadelienė, R. Fitness training. In *Athlete Skills and Training Them*, 1st ed.; Čepulėnas, A., Saplinskas, J., Paulauskas, R., Eds.; Lithuanian University of Educational Sciences Press: Vilnius, Lithuania, 2011; pp. 165–217.
10. Silva, M.R.; Paiva, T. Low energy availability and low body fat of female gymnasts before an international competition. *Eur. J. Sport Sci.* **2015**, *15*, 591–599. [[CrossRef](#)]
11. Franchini, E.; Nunes, A.V.; Moraes, J.M.; Del Vecchio, F.B. Physical fitness and anthropometrical profile of the Brazilian male judo team. *J. Physiol. Anthropol.* **2007**, *26*, 59–67. [[CrossRef](#)]
12. Franchini, E.; Takito, M.Y.; Bertuzzi, R.C. Morphological, physiological and technical variables in high-level college judoists. *Arch. Budo* **2005**, *1*, 1–7.
13. Athayde, M.S.S.; Detanico, D.; Kons, R.L. Influence of body fat on countermovement jump performance in judo athletes from different weight categories. *Rev. Bras. Educ. Fis. Esporte* **2018**, *31*, 345–353. [[CrossRef](#)]
14. Kubo, J.; Chishaki, T.; Nakamura, N.; Muramatsu, T.; Yamamoto, Y.; Ito, M.; Saitou, H.; Kukidome, T. Differences in fat-free mass and muscle thicknesses at various sites according to performance level among judo athletes. *J. Strength Cond. Res.* **2006**, *20*, 654–657.
15. Syed-Abdul, M.M.; Dhvani, S.; Jason, D.W. Effects of self-implemented carbohydrate cycling and moderate to high intensity resistance exercise on body fat in body builders. *Gazz. Med. Ital. Archivio Sci. Med.* **2019**, *178*, 221–224. [[CrossRef](#)]
16. Duren, D.L.; Sherwood, R.J.; Czerwinski, S.A.; Lee, M.; Choh, A.C.; Siervogel, R.M.; Chumlea, W.C. Body composition methods: Comparisons and interpretation. *J. Diabetes Sci. Technol.* **2008**, *2*, 1139–1146. [[CrossRef](#)] [[PubMed](#)]
17. Forsyth, H.L.; Sinning, W.E. The anthropometric estimation of body density and lean body weight of male athletes. *Med. Sci. Sports* **1973**, *5*, 174–180. [[CrossRef](#)]
18. Oliver, J.M.; Lambert, B.S.; Martin, S.E.; Green, J.S.; Crouse, S.F. Predicting football players' dual-energy x-ray absorptiometry body composition using standard anthropometric measures. *J. Athl. Train.* **2012**, *47*, 257–263. [[CrossRef](#)]
19. White, J.; Mayhew, J.L.; Piper, F.C. Prediction of body composition in college football players. *Sports Med. Phys. Fit.* **1980**, *20*, 317–324.
20. de Souza Cerqueira, B.; Baú Cerqueira, M.; Costa Ferreira, W.; Mendes de Oliveira, F.; Vidal Andreato, L.; dos Santos-Junior, R.B.; Valdés-Badilla, P.; Magnani Branco, B.H. Proposal of a normative table for classification of body fat percentage in Brazilian Jiu-Jitsu athletes. *Int. J. Morphol.* **2022**, *40*, 57–61. [[CrossRef](#)]
21. da Silva, B.V.C.; de Moura, S.; Mário, A.; Marocolo, M.; Franchini, E.; da Mota, G.R. Optimal load for the peak power and maximal strength of the upper body in Brazilian Jiu-Jitsu athletes. *J. Strength Cond. Res.* **2015**, *29*, 1616–1621. [[CrossRef](#)]
22. Báez, E.; Franchini, E.; Ramírez-Campillo, R.; Cañas-Jamett, R.; Herrera, T.; Burgos-Jara, C.; Henríquez-Olguín, C. Anthropometric characteristics of top-class Brazilian Jiu Jitsu athletes: Role of fighting style. *Int. J. Morphol.* **2014**, *32*, 1043–1050. [[CrossRef](#)]
23. Diaz-Lara, F.J.; García, J.M.G.; Monteiro, L.F.; Abian-Vicen, J. Body composition, isometric hand grip and explosive strength leg—Similarities and differences between novices. *Arch. Budo* **2014**, *10*, 211–217.
24. Pietraszewska, J.; Burdukiewicz, A.; Stachoń, A.; Andrzejewska, J.; Stefaniak, T.W. Body build and the level of development of muscle strength among male Jiu-Jitsu competitors and strength-trained adults. *Hum. Mov.* **2014**, *15*, 134–140. [[CrossRef](#)]
25. Øvretveit, K. Anthropometric and physiological characteristics of Brazilian Jiu-Jitsu athletes. *J. Strength Cond. Res.* **2018**, *32*, 997–1004. [[CrossRef](#)]
26. de Faria, E.R.; de Faria, F.R.; Gonçalves, V.S.; Franceschini, S.D.C.C.; Peluzio, M.D.C.C.; Sant'Ana, L.F.; Priore, S.E. Prediction of body fat in adolescents: Comparison of two electric bioimpedance devices with dual-energy X-ray-absorptiometry. *Nutr. Hosp.* **2014**, *30*, 1270–1278. [[PubMed](#)]
27. McLester, C.N.; Nickerson, B.S.; Kliszczewicz, B.M.; McLester, J.R. Reliability and agreement of various InBody body composition analyzers as compared to dual-energy X-ray absorptiometry in healthy men and women. *J. Clin. Densitom.* **2020**, *23*, 443–450. [[CrossRef](#)] [[PubMed](#)]
28. Lemos, T.; Gallagher, D. Current body composition measurement techniques. *Curr. Opin. Endocrinol. Diabetes Obes.* **2017**, *24*, 310. [[CrossRef](#)]
29. Houtkooper, L.B.; Mullins, V.A.; Going, S.B.; Brown, C.H.; Lohman, T.G. Body composition profiles of elite American heptathletes. *Int. J. Sport Nutr. Exerc. Metab.* **2001**, *11*, 162–173. [[CrossRef](#)]
30. Turocy, P.S.; DePalma, B.F.; Horswill, C.A.; Laquale, K.M.; Martin, T.J.; Perry, A.C.; Somova, M.J.; Utter, A.C.; National Athletic Trainers' Association. National Athletic Trainers' Association position statement: Safe weight loss and maintenance practices in sport and exercise. *J. Athl. Train.* **2011**, *46*, 322–336.
31. Bilsborough, J.C.; Greenway, K.; Opar, D.; Livingstone, S.; Cordy, J.; Coutts, A.J. The accuracy and precision of DXA for assessing body composition in team sport athletes. *J. Sports Sci.* **2014**, *32*, 1821–1828. [[CrossRef](#)] [[PubMed](#)]
32. Paton, N.I.J.; Macallan, D.C.; Jebb, S.A.; Pazianas, M.; Griffin, G.E. Dual-energy X-ray absorptiometry results differ between machines. *Lancet* **1995**, *346*, 899–900. [[CrossRef](#)] [[PubMed](#)]
33. Nana, A.; Slater, G.J.; Stewart, A.D.; Burke, L.M. Methodology review: Using dual-energy X-ray absorptiometry (DXA) for the assessment of body composition in athletes and active people. *Int. J. Sport Nutr. Exerc. Metab.* **2015**, *25*, 198–215. [[CrossRef](#)]
34. Nana, A.; Slater, G.J.; Hopkins, W.G.; Halson, S.L.; Martin, D.T.; West, N.P.; Burke, L.M. Importance of standardized DXA protocol for assessing physique changes in athletes. *Int. J. Sport Nutr. Exerc. Metab.* **2016**, *26*, 259–267. [[CrossRef](#)]
35. Deutz, R.C.; Benardot, D.; Martin, D.E.; Cody, M.M. Relationship between energy deficits and body composition in elite female gymnasts and runners. *Med. Sci. Sports Exerc.* **2000**, *32*, 659–668. [[CrossRef](#)] [[PubMed](#)]

36. Billsborough, J.C.; Kempton, T.; Greenway, K.; Cordy, J.; Coutts, A.J. Longitudinal changes and seasonal variation in body composition in professional Australian football players. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 10–17. [CrossRef]
37. Bartlett, J.D.; Hatfield, M.; Parker, B.B.; Roberts, L.A.; Minahan, C.; Morton, J.P.; Thornton, H.R. DXA-derived estimates of energy balance and its relationship with changes in body composition across a season in team sport athletes. *Eur. J. Sport Sci.* **2020**, *20*, 859–867. [CrossRef]
38. Milsom, J.; Naughton, R.; O’Boyle, A.; Iqbal, Z.; Morgans, R.; Drust, B.; Morton, J.P. Body composition assessment of English Premier League soccer players: A comparative DXA analysis of first Team, U21 and U18 Squads. *J. Sports Sci.* **2015**, *33*, 1799–1806. [CrossRef]
39. Carrion, B.M.; Wells, A.; Mayhew, J.L.; Koch, A.J. Concordance among bioelectrical impedance analysis measures of percent body fat in athletic young adults. *Int. J. Exerc. Sci.* **2019**, *12*, 324–331. [PubMed]
40. Dimitrijevic, M.; Paunovic, V.; Zivkovic, V.; Bolevich, S.; Jakovljevic, V. Body fat evaluation in male athletes from combat sports by comparing anthropometric, bioimpedance, and dual-energy X-ray absorptiometry measurements. *Biomed Res. Int.* **2022**, *2022*, 1–8. [CrossRef]
41. Sullivan, K.M. Documentation for Sample Size for a Proportion. Available online: <https://www.openepi.com/PDFDocs/SSProporDoc.pdf> (accessed on 25 August 2023).
42. Binner, A. A Breakdown: Weight Categories for Olympic Boxing Qualifiers. Available online: <https://olympics.com/en/news/boxing-olympics-qualification-weight-categories> (accessed on 24 September 2019).
43. Binner, A. What Different Weight Classes are at Olympic Wrestling? Available online: <https://olympics.com/en/news/weight-classes-olympics-wrestling-tokyo> (accessed on 28 September 2019).
44. Branco, B.H.M.; Andreato, L.V.; Ribeiro, E.D.; de Oliveira, H.G.; Almeida, F.N.; Junior, N.N. Development of tables for classifying judo athletes according to maximal isometric strength and muscular power, and comparisons between athletes at different competitive levels. *Sport Sci. Health* **2018**, *14*, 607–614. [CrossRef]
45. Yang, S.W.; Kim, T.H.; Choi, H.M. The reproducibility and validity verification for body composition measuring devices using bioelectrical impedance analysis in Korean adults. *J. Exerc. Rehabil.* **2018**, *14*, 621–627. [CrossRef]
46. Body Fat Analyzer (Professional) X-Scan II. Available online: [https://www.tradekorea.com/product/detail/P434715/Body-Fat-Analyzer-\(professional\)-X-Scan-II-.html](https://www.tradekorea.com/product/detail/P434715/Body-Fat-Analyzer-(professional)-X-Scan-II-.html) (accessed on 26 August 2023).
47. Cole, T.J.; Green, P.J. Smoothing reference centile curves: The LMS method and penalized likelihood. *Stat. Med.* **1992**, *11*, 1305–1319. [CrossRef]
48. World Health Organization. *Body Mass Index—BMI*; World Health Organization: Geneva, Switzerland, 2018. Available online: <http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi> (accessed on 15 June 2021).
49. Zierle-Ghosh, A.; Jan, A. Physiology, Body Mass Index. In *StatPearls*; StatPearls Publishing: Treasure Island, FL, USA, 2023. Available online: <https://www.ncbi.nlm.nih.gov/books/NBK535456/> (accessed on 12 January 2023).
50. Bradbury, K.E.; Guo, W.; Cairns, B.J.; Armstrong, M.E.; Key, T.J. Association between physical activity and body fat percentage, with adjustment for BMI: A large cross-sectional analysis of UK Biobank. *BMJ Open* **2017**, *7*, e011843. [CrossRef]
51. Rezende, F.A.; Rosado, L.E.; Franceschini, S.C.; Rosado, G.P.; Ribeiro, R.C. The body mass index applicability in the body fat assessment. *Rev. Bras. Med. Esporte* **2010**, *16*, 90–94. [CrossRef]
52. Reale, R.; Burke, L.M.; Cox, G.R.; Slater, G. Body composition of elite Olympic combat sport athletes. *Eur. J. Sport Sci.* **2020**, *20*, 147–156. [CrossRef]
53. Ratamess, N.A. Strength and conditioning for grappling sports. *Strength Cond. J.* **2011**, *33*, 18–24. [CrossRef]
54. Baranauskas, M.; Kupčiūnaitė, I.; Stukas, R. The association between rapid weight loss and body composition in elite combat sports athletes. *Healthcare* **2022**, *10*, 665. [CrossRef] [PubMed]
55. Andreato, L.V.; Santos, J.F.S.; Esteves, J.V.D.C.; Panissa, V.L.G.; Julio, U.F.; Franchini, E. Physiological, nutritional and performance profiles of Brazilian Jiu-Jitsu athletes. *J. Hum. Kinet.* **2016**, *53*, 261–271. [CrossRef]
56. Baranauskas, M.; Tubelis, L.; Stukas, R.; Švedas, E.; Samsonienė, L.; Karanauskienė, D. The influence of short-term hypocaloric nutrition on bodyweight reduction in Lithuanian Olympic Team wrestlers. *Balt. J. Sport Health Sci.* **2011**, *4*, 5–12.
57. Suchomel, T.J.; Nimphius, S.; Stone, M.H. The importance of muscular strength in athletic performance. *Sports Med.* **2016**, *46*, 1419–1449. [CrossRef] [PubMed]
58. Durkalec-Michalski, K.; Podgórski, T.; Sokolowski, M.; Jeszka, J. Relationship between body composition indicators and physical capacity of the combat sports athletes. *Arch. Budo* **2016**, *12*, 247–256.
59. Balci, A.; Tortu, E.; Kabak, B. Investigation of the body composition and maximal oxygen consumption capacity of elite boxing and wrestling athletes. *Turk. J. Phys. Med. Rehabil.* **2020**, *22*, 452–457.
60. Ceylan, B.; Gurses, V.V.; Akgul, M.S.; Baydil, B.; Franchini, E. Anthropometric profile, wingate performance and special judo fitness levels of Turkish Olympic judo athletes. *Ido Mov. Cult. J. Martial Arts Anthropol.* **2018**, *18*, 15–20.
61. Arazi, H.; Noori, M.; Izadi, M. Correlation of anthropometric and biomotor attributes with Special Judo Fitness Test in senior male judokas. *Ido Mov. Cult. J. Martial Arts Anthropol.* **2017**, *17*, 19–24.
62. Karastergiou, K.; Smith, S.R.; Greenberg, A.S.; Fried, S.K. Sex differences in human adipose tissues—The biology of pear shape. *Biol. Sex. Differ.* **2012**, *3*, 13. [CrossRef]

63. Al-Khelaifi, F.; Diboun, I.; Donati, F.; Botrè, F.; Alsayrafi, M.; Georgakopoulos, C.; Suhre, K.; Yousri, N.A.; Elrayess, M.A. A pilot study comparing the metabolic profiles of elite-level athletes from different sporting disciplines. *Sports Med. Open* **2018**, *4*, 2. [[CrossRef](#)]
64. Sansone, P.; Makivic, B.; Csapo, R.; Hume, P.; Martínez-Rodríguez, A.; Bauer, P. Body fat of basketball players: A systematic review and meta-analysis. *Sports Med. Open* **2022**, *8*, 26. [[CrossRef](#)] [[PubMed](#)]
65. Domingos, C.; Matias, C.N.; Cyrino, E.S.; Sardinha, L.B.; Silva, A.M. The usefulness of Tanita TBF-310 for body composition assessment in Judo athletes using a four-compartment molecular model as the reference method. *Rev. Assoc. Med. Bras.* **2019**, *65*, 1283–1289. [[CrossRef](#)] [[PubMed](#)]
66. Lai, Y.-K.; Ho, C.-Y.; Lai, C.-L.; Taun, C.-Y.; Hsieh, K.-C. Assessment of standing multi-frequency bioimpedance analyzer to measure body composition of the whole body and limbs in elite male wrestlers. *Int. J. Environ. Res. Public Health* **2022**, *19*, 15807. [[CrossRef](#)]

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