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DIFFERENCES IN THE BODY COMPOSITION OF SELECTED JUDOKAS BASED ON WEIGHT CATEGORIES

Original research

ABSTRACT

This study explored body composition differences among elite Serbian judokas across three weight categories: lightweight, middleweight, and heavyweight. Thirty-two male judokas from Serbia's national team participated, with body composition metrics assessed using the Segmental Body Composition Analyzer InBody 720. Parameters measured included lean body mass percentage, skeletal muscle mass percentage, body fat percentage, waist-to-hip ratio, visceral fat area, bone mineral content, lean body mass index, and fat mass index. Heavyweights exhibited significantly lower lean body and skeletal muscle mass percentages than lightweights and middleweights ($p < 0.001$). Additionally, heavyweights had significantly higher body fat percentage, waist-to-hip ratio, and visceral fat area ($p < 0.001$). Bone mineral content was significantly higher in heavyweights compared to lightweights and middleweights ($p < 0.001$) and also differed significantly between lightweights and middleweights ($p < 0.01$). Lean body and fat mass index were significantly higher in heavyweights than lighter categories ($p < 0.001$). These findings highlight the importance of tailored training and nutritional strategies to optimize body composition for enhanced performance and health outcomes in judo. Effective weight management, focusing on reducing fat while maintaining muscle mass, is critical, particularly for heavyweight athletes. The study's methodology and representativeness align with international standards, supporting the applicability of findings to broader populations. Future research should include larger, more diverse samples and longitudinal designs to understand body composition dynamics over time and incorporate performance metrics for a holistic view of success factors in judo. Implementing these strategies will enhance athletic performance and promote long-term health and well-being among judokas

Keywords: lean body mass, body fat, weight categories, judo

INTRODUCTION

Judo, a martial arts and Olympic sport with global recognition, significantly emphasizes physical performance and body composition for an athlete's success. An athlete's body composition, including muscle mass and body fat, is significantly associated with muscle fitness, which might ultimately impact competitive outcomes (Milošević et al., 2024). Optimal body composition, characterized by a high muscle mass and low body fat percentage, is essential for judokas to maximize their strength, agility, and endurance. Few studies have delved into the intricate relationship between body composition

and athletic performance in judo. Previous research has scrutinized the physical and psychological profiles of elite judokas (Degoutte et al., 2003; Mitić et al., 2021), anthropometric profiles across different weight categories (Franchini et al., 2014), and the effects of specific training programs on athletes' body composition (Franchini et al., 2019). These studies underscore the critical need for tailored training regimens considering judokas' unique body composition needs in various weight categories. Judo competitions are held within clearly defined weight categories, implying that all competitors in a category approximately have similar

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body mass, while the body composition may differ. Defining the optimal body composition within lightweight, middleweight, and heavyweight categories is essential in modern judo due to the increasing issue of body mass correction before competing in the desired weight category (Artioli et al., 2010). The training process of judokas should differ depending on the competitor's weight category, so the training systems and methods should be selected to meet the needs of lightweight, middleweight, and heavyweight categories. This is crucial because one way to gain an advantage over the competition is by entering a lower-weight category through body mass correction, which involves maintaining muscle mass while reducing body fat (Lech et al., 2020).

Elite judokas typically exhibit a mesomorphic somatotype characterized by high muscle mass and low body fat percentages. Maintaining a body fat percentage below 10% is often associated with superior performance, especially in lighter-weight categories, though this threshold can be higher in the heaviest categories (Franchini et al., 2011; Franchini et al., 2005; Kubo et al., 2006; Sterkowicz-Przybycień et al., 2012). Research indicates that this optimal body composition not only supports the execution of powerful and precise judo techniques but also enhances overall athletic performance and reduces the risk of injury (Degoutte et al., 2003). Moreover, maintaining such a composition is crucial for achieving the strength and endurance required in high-level competition, allowing judokas to perform effectively throughout matches (Franchini et al., 2019). The careful management of body composition through tailored training and nutritional strategies might be essential for optimizing the competitive potential of elite judokas (Milošević et al., 2024).

Effective weight management is a critical aspect of competitive judo. Athletes must often adjust their body composition to fit specific weight categories while maintaining optimal performance. This process involves reducing body fat while preserving muscle mass, which can enhance strength and agility (Lech et al., 2020). However, excessive weight loss can impair performance and pose health risks, necessitating careful management (Artioli et al., 2010). The International Judo Federation recommends that competitors not lose more than 5% of their body weight. Control measurements have been introduced on the day of the competition to protect their athletes' health, allowing a weight increase of up to 5% from the moment of measurement to the competition.

While the influence of body composition on judo performance is well-recognized, there is a clear need for a more detailed analysis of the differences in body composition across various weight categories in elite

judokas. This study aims to address this gap by examining the body composition characteristics of elite judokas in different weight classes. By focusing on parameters such as lean body mass percentage, skeletal muscle mass percentage, body fat percentage, waist-to-hip ratio, visceral fat area, bone mineral content, lean body mass index, and fat mass index, this research seeks to provide a comprehensive understanding of how body composition varies among different weight categories, which can inform training and weight management strategies tailored to each category.

Therefore, this study aims to uncover the differences in body composition among elite judokas across various weight categories. These findings have significant practical implications for weight management strategies, as they can contribute to improved muscle fitness and health standards in judo.

METHODS

Participants

The study sample consisted of 32 male judokas from Serbia's national team, divided into three weight classes: light ($n=14$), middle ($n=12$), and heavy ($n=6$). This distribution ensures a representative sample, allowing for a comprehensive analysis of body composition metrics across various athletes. Participants were recruited during a national team training camp and underwent a medical examination to ensure no health issues could influence the results. Exclusion criteria included recent significant weight loss, accumulated training fatigue, or lack of motivation. Informed consent was obtained from all participants, with parental consent required for those under 18. The study received ethical approval from the Faculty of Sport and Physical Education Ethics Committee (R. 03-1912/43, approved 11 April 2019). All procedures adhered to the Helsinki Declaration and guidelines for research involving human subjects.

Study design

This research investigated the differences in body composition among young judokas categorized into three weight groups (lightweight, middleweight, and heavyweight). The parameters assessed were lean body mass percentage, skeletal muscle mass percentage, body fat percentage, waist-to-hip ratio, visceral fat area, bone mineral content, lean body mass index, and fat mass index. The study focused solely on body composition metrics without incorporating performance measures. This approach provided a detailed understanding of body composition

characteristics across different weight categories. Measurements were conducted in a controlled environment to ensure consistency and reliability. Participants were advised to refrain from intense physical activity for at least 24 hours before testing and to maintain their usual dietary and sleep habits to minimize external influences on the results. The measurements occurred in the National Youth Camp “Karataš” hall (Institute for Sport and Sports Medicine of the Republic of Serbia), with the hall temperature maintained at approximately 20 °C. Participants wore appropriate sports attire, including shorts, shirts, and shoes.

Measures and procedures

Anthropometric measurements were conducted following the recommendations of Eston and Reilly (2001). They included body height and mass, while the body composition measurements were performed using the Segmental Body Composition Analyzer InBody 720 (Biospace Co., Ltd., Seoul, Republic of Korea), a validated and reliable method for this population (Schubert et al., 2019). The specific parameters measured included body fat percentage (BF%), muscle mass percentage (MM%), lean body mass percentage (LBM%), waist-to-hip ratio (WHR), visceral fat area (VFA), bone mineral content (BMC), lean body mass index (LBMI), and fat mass index (FMI). These measurements provided a comprehensive profile of the participants' body composition. The InBody 720 analyzer employs bioelectrical impedance analysis (BIA) to estimate body composition, a non-invasive and rapid method suitable for large-scale assessments.

Statistical analysis

Data were analyzed using RStudio (version 2024.04.2+764). Descriptive statistics, including mean values, standard deviations (\pm SD), and 95% confidence intervals (CI), were calculated for each variable. The Shapiro-Wilk test was used to assess data normality. Differences between weight categories were examined using one-way ANOVA and post hoc Bonferroni tests for pairwise comparisons. ANOVA results included the F-statistic and associated p-value, with significance levels annotated for p-values less than 0.05.

RESULTS

Figure 1 illustrates significant differences in body composition metrics across the lightweight, middleweight, and heavyweight categories. In both lean body mass and skeletal muscle mass

percentages, the heavyweight category shows significantly lower values than the lightweight and middleweight categories, with no significant difference between the lighter categories.

Conversely, body fat percentage, waist-to-hip ratio, and visceral fat area are significantly higher in heavyweights than in lightweights and middleweights. Bone mineral content is considerably higher in the heavyweights than in the lightweights and middleweights, with no significant difference between the lighter categories. The lean body and fat mass index follow the same pattern, with the heavyweight group showing significantly higher indices than both lighter groups.

Therefore, individuals in the heavyweight category have significantly higher body fat percentage, waist-to-

Table 1: Descriptive statistics

Category	Mean \pm SD	Lower 95% CI	Upper 95% CI	SW Test W	p-value
Height (cm)					
light	172.29 \pm 5.33	169.21	175.36	0.93	0.329
middle	182.04 \pm 9.2	176.20	187.88	0.95	0.591
heavy	185.67 \pm 5.72	179.67	191.66	0.88	0.271
Weight (kg)					
light	64.16 \pm 4.5	61.57	66.76	0.86	0.027
middle	77.36 \pm 6.43	73.27	81.44	0.91	0.241
heavy	118.35 \pm 15.39	102.20	134.50	0.87	0.216
Lean Body Mass (%)					
light	89.57 \pm 2.63	88.06	91.09	0.95	0.611
middle	88.35 \pm 1.7	87.27	89.43	0.93	0.334
heavy	72.17 \pm 6.53	65.32	79.02	0.93	0.612
Skeletal Muscle Mass (%)					
light	50.56 \pm 1.53	49.68	51.44	0.94	0.360
middle	50.47 \pm 1.14	49.75	51.19	0.94	0.526
heavy	41.67 \pm 3.95	37.53	45.82	0.92	0.499
Body Fat (%)					
light	10.43 \pm 2.63	8.91	11.95	0.95	0.538
middle	11.65 \pm 1.67	10.59	12.71	0.92	0.305
heavy	27.82 \pm 6.54	20.96	34.68	0.93	0.614
Waist-to-Hip Ratio					
light	0.82 \pm 0.03	0.80	0.83	0.98	0.941
middle	0.83 \pm 0.03	0.81	0.85	0.98	0.962
heavy	1.02 \pm 0.06	0.96	1.07	0.98	0.961
Visceral Fat Area (cm²)					
light	24.46 \pm 10.5	18.40	30.53	0.97	0.819
middle	35.86 \pm 8.46	30.48	41.23	0.95	0.691
heavy	147.23 \pm 34.65	110.87	183.60	0.77	0.031
Bone Mineral Content (kg)					
light	3.1 \pm 0.23	2.97	3.23	0.94	0.368
middle	3.69 \pm 0.35	3.47	3.92	0.89	0.124
heavy	4.81 \pm 0.87	3.90	5.72	0.88	0.291
Lean Body Mass Index					
light	19.36 \pm 1.21	18.67	20.06	0.90	0.133
middle	20.63 \pm 1.06	19.96	21.30	0.94	0.529
heavy	24.65 \pm 2.8	21.71	27.59	0.88	0.255
Fat Mass Index					
light	2.27 \pm 0.63	1.91	2.63	0.94	0.427
middle	2.75 \pm 0.49	2.44	3.06	0.93	0.399
heavy	9.65 \pm 2.63	6.89	12.41	0.89	0.312

Legend: Category—weight category (light, middle, heavy);

Mean—arithmetic mean;

SD—standard deviation; 95% CI—confidence intervals;

SW Test—Shapiro-Wilk test for normality;

p-value—probability value associated with the Shapiro-Wilk test.

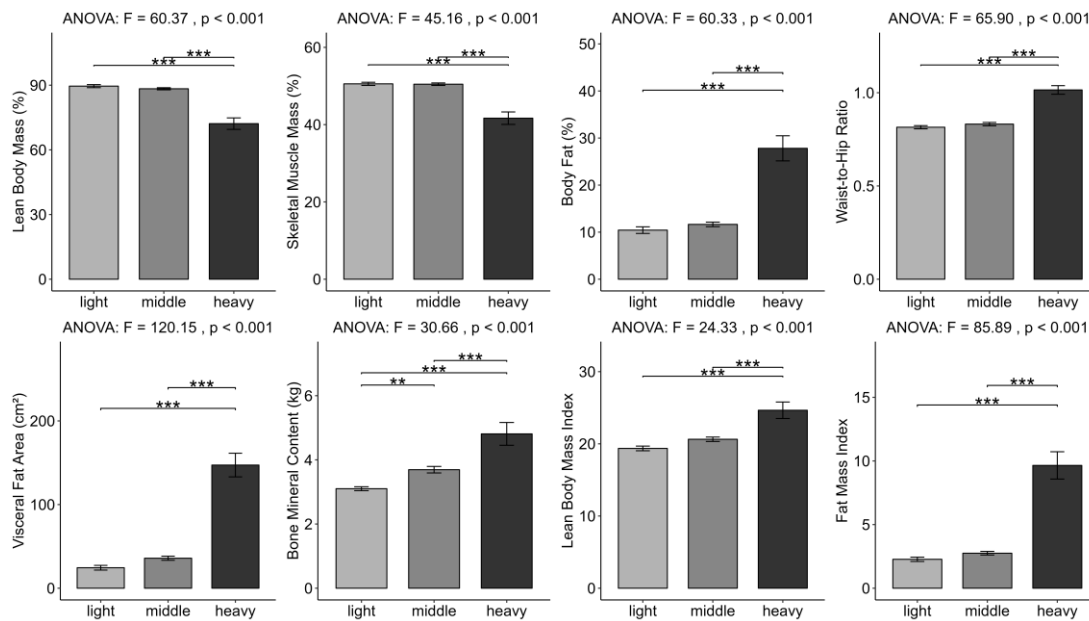


Figure 1: Body composition metrics across the light, middle, and heavyweight categories. Each panel displays the mean values with standard error bars, ANOVA F-statistics, and p-values. Significance levels from post hoc Bonferroni tests are annotated: $p < 0.05$ (*), $p < 0.01$ (**), and $p < 0.001$ (***)

hip ratio, visceral fat area, bone mineral content, lean body mass index, and fat mass index while having significantly lower lean body mass and skeletal muscle mass percentages than lighter categories. These findings highlight the considerable variations in body composition associated with different weight categories.

DISCUSSION

This study provides a comprehensive examination of the body composition of selected judokas across different weight categories, focusing on key indicators such as lean body mass percentage, skeletal muscle mass percentage, body fat percentage, waist-to-hip ratio, bone mineral content, visceral fat area, lean body mass index, and fat mass index. The findings are crucial in enhancing our understanding of how body composition differs between specific weight categories and can inform judo training and weight management strategies.

The analysis of lean body mass (LBM) and skeletal muscle mass (SMM) percentages revealed that judokas in the heavyweight category exhibited significantly lower values than those in the lightweight and middleweight categories. This pattern aligns with previous studies indicating that heavier athletes tend to have a lower proportion of muscle mass relative to their body weight (Franchini et al., 2014; Sterkowicz-Przybycień et al., 2012). This is consistent with the work of Mala et al. (2015), who found similar trends in Czech judokas. The uniform training processes applied to all weight categories may contribute to the

pronounced symmetry in LBM and SMM percentages between the light and middleweight categories. Maintaining a high lean body mass is also critical for performance, as it correlates with greater strength and power outputs necessary for effective judo techniques (Kubo et al., 2006). This study's findings suggest the importance of tailored strength training programs that prioritize lean muscle development, especially for heavyweight judokas, to balance muscle mass effectively and overall body weight. Furthermore, these results emphasize the need for continuous monitoring and adjustments in training regimens to ensure athletes in all weight categories maintain optimal body composition (Mala et al., 2015).

The body fat percentage and fat mass index (FMI) were significantly higher in the heavyweight category compared to the lighter categories. This finding is consistent with results from studies on other populations of judokas, such as Brazilian and Czech athletes (Franchini et al., 2014; Mala et al., 2015). Excessive body fat can impair performance by reducing the power-to-weight ratio, which is critical for executing judo techniques effectively (Artoli et al., 2010). Green et al. (2007) highlighted that higher body fat percentages also increase the risk of injuries, emphasizing the need for judokas to manage their body composition carefully. Moreover, higher body fat can negatively impact aerobic capacity and recovery times, further affecting performance during prolonged competitions (Franchini et al., 2011). Therefore, weight management strategies should reduce body fat while preserving lean muscle to optimize performance and health outcomes. The findings from this study

corroborate previous research suggesting that targeted interventions can help judokas achieve a more favorable body composition (Artioli et al., 2010). These interventions include dietary modifications and specific conditioning programs to enhance lean muscle mass and reduce excess body fat (Després et al., 2008).

The waist-to-hip ratio (WHR) and visceral fat area (VFA) were also significantly higher in the heavyweight category. Elevated WHR and VFA are associated with increased health risks, including cardiovascular disease and metabolic disorders (Vissers et al., 2016). The high VFA observed in heavyweight judokas highlights the need for targeted interventions to reduce visceral fat through improved dietary habits and tailored training programs. Visceral fat is particularly concerning as it can increase blood pressure, disrupt digestive function, and disturb hormonal balance, posing direct health risks to athletes (Vissers et al., 2016). Additionally, managing visceral fat is crucial for preventing long-term health issues, such as diabetes and chronic inflammation, which can severely impact an athlete's career longevity (Després et al., 2008). Interventions should include nutritional counseling and specific exercise regimes to reduce central adiposity and improve overall metabolic health. Addressing visceral fat is essential not only for competitive performance but also for the long-term health of athletes (Vissers et al., 2016). These health benefits can significantly extend an athlete's competitive career and improve their quality of life post-retirement (Després et al., 2008). Furthermore, Milošević et al. (2024) highlighted the critical role of managing body composition for improved muscle fitness and overall athletic performance in judokas, further supporting the need for strategic interventions in this area.

Bone mineral content (BMC) was significantly higher in the heavyweight category compared to the lighter categories. This increase in BMC may be attributed to the more significant mechanical loading experienced by heavier athletes, which stimulates bone density (Nikander et al., 2010). However, the higher BMC in heavyweights does not necessarily translate to better performance, as excess fat mass can offset the advantages of higher bone density. Studies such as those by Nikander et al. (2010) suggest that while high BMC benefits overall skeletal health, it must be balanced with appropriate lean mass and body fat levels for optimal athletic performance. The findings indicate the need for a holistic approach to training that enhances bone density and optimizes body composition. This balance is crucial to prevent injuries and improve functional performance in heavyweights. Also, maintaining optimal BMC is important for preventing bone-related injuries, common in contact sports like judo (Pocecco et al., 2013; Prouteau et al., 2006). Regular bone health assessments and tailored

training programs that enhance bone density and muscle strength are essential for sustaining high performance and reducing injury risks.

The lean body mass index (LBMI) was significantly higher in the heavyweight category. This finding indicates that despite having a higher overall body fat percentage, heavyweight judokas also possess substantial lean mass. Effective training programs should maximize lean mass while minimizing fat mass to enhance performance. Schubert et al. (2019) validated using bioelectrical impedance analysis (BIA) to assess body composition, highlighting its reliability for tracking changes in LBMI. Furthermore, maintaining a high LBMI is essential for the strength and endurance required in judo, suggesting that heavyweight athletes should incorporate resistance and hypertrophy training into their regimens (Franchini et al., 2014). Programs should be designed to ensure that gains in lean mass are not accompanied by disproportionate increases in fat mass, which can impair performance. This approach aligns with the findings of Franchini et al. (2011), who demonstrated the importance of balancing lean and fat mass for optimal athletic performance. By improving LBMI, coaches can help athletes achieve better performance outcomes and reduce the risk of injury associated with excessive body fat (Franchini et al., 2014).

The basic statistical parameters for young Serbian judokas' body composition were similar to those of elite judokas from other countries. For example, the body fat percentage for middleweight Serbian judokas (11.65 ± 1.67) is comparable to Czech judokas in the same category (Mala et al., 2015). The muscle mass percentages of Serbian judokas (50.56 ± 1.53 for lighter categories and 50.47 ± 1.14 for middleweight categories) align with those of Spanish juniors and seniors (Franchini et al., 2011) and Slovenian national team members (Šimenko et al., 2024). This consistency underscores the representativeness of the sample used in this study. Additionally, these findings highlight that Serbian judokas are on par with their international counterparts regarding body composition metrics, suggesting effective national training and nutritional programs. The comparability also validates the study's methodology and the reliability of the InBody 720 analyzer used for measurements. This alignment with international standards supports the findings' generalizability and applicability to broader populations of judokas. Such consistency across different countries also underscores the universal importance of specific body composition parameters in judo, reinforcing the relevance of targeted training and dietary strategies worldwide. Furthermore, we should emphasize that international-level competitors have greater lean body mass and lower fat percentages than national-level athletes (Fukuda et al., 2013). This

difference emphasizes optimizing body composition to achieve higher competitive standards, highlighting the need for rigorous and tailored training and nutritional programs to bridge this gap. Such programs are essential to prepare national-level athletes to compete successfully on the international stage, underscoring the critical role of body composition in elite judo performance.

The findings from this study underscore the importance of tailored training and weight management strategies for judokas in different weight categories. Reducing body fat while preserving or increasing muscle mass can enhance strength and agility, which are critical for judo performance. Moreover, addressing high visceral fat levels in heavyweight judokas through dietary interventions and specific training programs can improve health outcomes and competitive performance. It is recommended that coaches and trainers develop personalized plans that include resistance training, cardiovascular exercises, and proper nutrition to optimize body composition. Regular monitoring and adjustments based on body composition assessments can help maintain the desired physical state (Després et al., 2008). These strategies will enhance athletic performance and promote long-term health and well-being among judokas. Implementing these recommendations can help judokas achieve and maintain optimal body composition, improving performance and health outcomes (Franchini et al., 2019). Furthermore, integrating psychological support to manage the stress associated with weight management and competition could further enhance judokas' overall well-being and performance (Mitić et al., 2021).

This study has several limitations. The sample size, particularly in the heavyweight category, was relatively small, which may affect the generalizability of the findings. Additionally, the study's cross-sectional design limits the ability to establish causal relationships between body composition and muscle fitness. Future research should include larger sample sizes and longitudinal designs to understand better the dynamics of body composition changes over time. Moreover, incorporating performance metrics alongside body composition measurements could provide a more holistic understanding of the factors contributing to judo success. Studies exploring the impact of specific training and dietary interventions on body composition across different weight categories would also be beneficial. Expanding the demographic diversity of the sample to include female judokas and athletes from various competitive levels could further enrich the findings and their applicability. Additionally, more advanced imaging techniques such as DEXA scans could provide more detailed insights into body

composition changes and their impact on performance.

CONCLUSION

This study highlights significant differences in body composition among elite judokas across various weight categories, emphasizing the necessity of tailored training and nutritional strategies for optimal performance and health outcomes. Heavyweight judokas displayed higher body fat percentages, waist-to-hip ratios, and visceral fat areas, with lower lean body mass and skeletal muscle mass percentages than lighter counterparts. These findings underscore the importance of interventions focused on maintaining or increasing lean mass while reducing fat mass, particularly for heavyweight athletes, to enhance performance and reduce injury risks. The representativeness of the Serbian judoka sample aligns with international standards, validating the study's methodology and supporting the applicability of the findings. Future research should involve larger, more diverse samples and longitudinal designs to better understand body composition dynamics over time and include performance metrics for a holistic view of success factors in judo. In conclusion, individualized training, nutrition, and psychological support are essential for judokas to achieve competitive success and long-term health benefits.

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Conflict of Interest

The authors do not have any conflicts of interest to disclose. All co-authors have reviewed and concurred with the manuscript's content, and no financial interests need to be reported.