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Between- and Within-Sex Differences in Body Composition Variables in Professional Mixed Martial Arts Fighters and Boxers

Original Research

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Abstract

Introduction: There is a dearth of data on professional fighters, particularly in mixed martial arts. Thus, this investigation aimed to describe the body composition variables of male and female professional fighters.

Methods: A total of 28 professional fighters participated in this investigation (n=22 male, n=6 female). The majority (68%) of the fighters competed in the Ultimate Fighting Championship (UFC) (n=19). The remaining fighters competed in various other promotions (e.g., WBO, IBF, UFC, Bellator, Eagle FC, Invicta.). Body composition was assessed via dual-energy x-ray absorptiometry (DXA). Total and regional body composition was determined.

Results: There were significant sex differences for Height: Male 180.3 ± 6.7 cm, Female 164.3 ± 6.8 cm ($P < .001$); Body mass: Male 86.5 ± 11.5 kg, Female 63.3 ± 4.9 kg ($P < .001$), lean body mass: Male 12.7 ± 2.7 kg, Female 46.7 ± 3.9 kg ($P < .001$), whole body bone mineral density: Male 1.53 ± 0.13 g/cm^2, Female 1.26 ± 0.10 g/cm^2 ($P < .001$), Z-score: Male 2.57 ± 0.88, Female 1.68 ± 1.06 ($P < .05$), regional bone mineral density (except for the head), regional percent fat (except for the head), and percent body fat; however, no differences were found for age or whole-body fat mass. In males, there was a significant relationship between body mass and lean mass with bone mineral density ($p < 0.005$, $R^2 = 0.357$). Furthermore, there existed within-sex differences for male fighters. Male fighters' percent fat was significantly different when comparing their left vs. right sides for both the upper and lower extremities.

Conclusions: It is evident that profound sex differences exist vis a vis body composition in professional fighters. It should be noted that bone mineral density is exceedingly high in this group of athletes. Furthermore, there tends to be asymmetry in the percent fat of the extremities in male fighters.

Key Words: Anthropometrics, Mixed martial arts, bone mineral density

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Introduction

Substantial sex differences in body composition and bone mineral density exist in the general population. Males tend to have higher lean body mass (LBM) levels and higher bone mineral density (BMD)[1]. Females have relatively higher

body fat levels, and body fat distribution differs from males for obvious anatomical reasons[1, 2]. Due to the training schedules and physical demands of sports, athletes have differences in body composition and BMD when compared to the general population. Physical activity, genetics, and nutrition are factors that influence bone health. The metabolic demands of training and sport activity are generally associated with a lower body fat percentage in athletes when compared to the general population. Bones adapt and change in response to stress, such as exercise[3, 4]. Athletes have been reported to have greater BMD when compared to physically inactive individuals[3-7]. Increased training volumes, especially those utilizing weight-bearing activities, contribute to the greater BMD observed in this population. Despite the lower body fat and greater BMD, sex differences are still present in the athletic population. Multiple studies have demonstrated sex differences in athletes across all sports and within specific sports [2, 7].

Fight sports encompass an array of disciplines, such as boxing, mixed martial arts (MMA), judo, taekwondo, kickboxing, and Brazilian jiu-jitsu. A mix of high-intensity and short explosive movements such as striking, grappling, and submissions are critical to success in fight sports[8]. Unlike other sports, fight sports competitions are organized according to weight class and a women's and men's division. Regardless of the level or outcome of a fight, athletes are engaged in high training loads, which entail complex technical skills training and strength and conditioning training methods. Athletes competing at the professional level require a high level of fitness, which is frequently, associated with muscular strength, cardiorespiratory endurance, and low body fat [5]. In weight division-sensitive sports, total weight is the deciding factor on whether the athlete will be allowed to compete or not. Fighters agree on a target weight (non-title fight has a 1lbs allowance), which must be met during the official weigh-ins date and time. Understanding body composition can ease the process of any approaches regarding methods that will help athletes meet their contracted weight [9, 10].

Much has been written about popular fight sports' physical characteristics and physiological demands. Many of these studies have focused on male athletes participating in different levels of fight sports. Thus, this investigation aimed to describe the body composition variables of male and female professional fighters.

Scientific Methods

Participants

Twenty-eight men (n=22) and women (n=6) volunteered for this investigation. All participants were professional mixed-martial arts fighters or professional boxers (bare-knuckle or gloved). For this study, professional MMA fighters and Boxers are defined as fighters affiliated with one of the major professional fighting organizations (e.g., WBO, IBF, UFC, Bellator, Eagle FC, Invicta). In accordance with the Helsinki Declaration, the University's Institutional Review Board approved all procedures involving human subjects. Written informed consent was obtained prior to participation. Participants visited the laboratory on one occasion. Body composition and bone mineral density were assessed via a dual-energy X-ray absorptiometry machine (DXA).

Protocol

Total and regional body composition was assessed with a dual-energy X-ray absorptiometry machine (DXA) (Model: Hologic Horizon W, Hologic Inc., Danbury, CT, USA). Participants were instructed to come to the laboratory after at least a three-hour fast and no prior exercise that day. Quality control calibration procedures were performed on a phantom spine. Subjects had their weight determined on a calibrated scale. Subjects wore typical athletic clothing and removed all metal jewelry. They were positioned supine on the DXA within the borders delineated by the scanning table. Each whole-body scan took approximately seven minutes.

Statistical Analysis

An unpaired t-test was used to analyze differences between sexes; a paired t-test was used to analyze left vs. right-sided differences. All descriptive statistics (means and standard deviation) were calculated for physical characteristics (e.g., height, weight, age). All data presented in the tables are the mean ± SD. A linear regression analysis was used to examine the relationship between body mass and lean mass with bone mineral density. GraphPad (Prism 6) software was used for statistical analyses.

Results

The participant's physical characteristics are as follows (age: Male 32.0 ± 4.2, Female 29.5 ± 6.4; height : Male 180.3 ± 6.7 cm, Female 164.3 ± 6.8 cm ($P < .001$); Body mass: Male 86.5 ± 11.5 kg, Female 63.3 ± 4.9 kg ($P < .001$)). Body composition and bone mineral density characteristics are found in Table 1. Significant sex differences were found for the following measures: height, body mass, lean body mass, % body fat, segmental body fat (i.e., left arm, right arm,

trunk, left leg, right leg), and bone mineral content for all measures except head BMD and the T-score. In male fighters, there was a significant relationship between body mass and lean mass with bone mineral density (Figure 2a and 2b). Further analysis showed that male fighters had a significant left vs. right difference in lean arm mass, leg fat mass, arm bone mass, and the percentage of fat in both arms and legs (Table 2; Figures 3 and 4).

Table 1. Body Composition and Bone Mineral Density

	Male (n = 22)	Female (n = 6)	P value
Body Composition			
Whole Body	70.0 ± 9.3	46.7 ± 3.9	<0.0001**
Lean Body Mass (kg)	12.7 ± 2.7	14.0 ± 2.5	0.4690
Fat mass (kg)	14.6 ± 1.9	21.9 ± 4.1	<0.0001**
Body Fat %	3.85 ±0.56	2.55 ± 0.33	<0.0001**
BMC (kg)			
Segmental Fat %	13.1 ± 1.5	21.0 ± 4.7	<0.0001**
Left Arm	11.9 ± 2.0	19.0 ± 4.6	0.0008**
Right Arm	13.4 ± 1.9	17.7 ± 3.7	<0.0001**
Trunk	16.0 ± 3.0	27.2 ± 5.3	0.0008**
Left Leg	15.4 ± 3.1	27.6 ± 6.2	<0.0001**
Right Leg	22.2 ± 0.2	22.3 ± 0.3	0.8059
Head			
Whole Body BMD	1.53 ± 0.13	1.26 ± 0.10	<0.0001**
T-score	2.66 ± 0.93	1.82 ± 1.12	0.0707
Z-score	2.57 ± 0.88	1.68 ± 1.06	0.0447*
Left Arm	1.07 ± 0.09	0.81 ± 0.05	<0.0001**
Right Arm	1.08 ± 0.11	0.94 ± 0.24	0.0430*
Left Ribs	1.05 ± 0.11	0.85 ± 0.15	0.0011*
Right Ribs	0.99 ± 0.10	0.85 ± 0.15	0.0144*
Thoracic Spine	1.20 ±0.15	0.98 ± 0.12	0.0022*
Lumbar Spine	1.46 ± 0.26	1.29 ± 0.27	0.1545
Pelvis	1.57 ± 0.26	1.30 ± 0.17	0.0281*
Left Leg	1.73 ± 0.22	1.27 ± 0.13	<0.0001**
Right Leg	1.73 ± 0.29	1.24 ± 0.09	0.0005**
Head	2.63 ± 0.28	2.46 ±0.33	0.2047

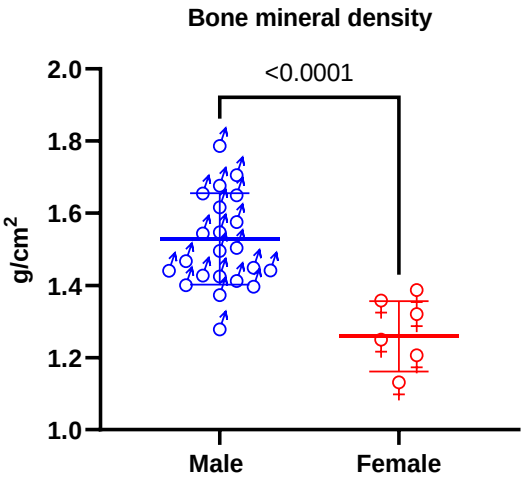
Data are expressed as the mean ± SD. Legend: BMC – bone mineral content; kg – kilogram.
Sex differences existed for all measures except fat mass, head % fat, T-score, lumbar spine bone mineral density, and head bone mineral density; *significance set at P ≤ 0.05; ** P <.001

Table 2. Body Composition – Left vs. Right Extremities in Male Fighters

	Left	Right	P value
Arm Lean Mass	4.38 ± 0.78	4.67 ± 0.83	<0.0001**
Leg Lean Mass	11.64 ± 1.94	11.70 ± 1.82	0.5064
Arm Fat Mass	0.70 ± 0.13	0.67 ± 0.15	0.0562
Leg Fat Mass	2.36 ± 0.61	2.28 ± 0.62	0.0226*
Arm Bone Mass	0.28 ± 0.05	0.30 ± 0.06	0.0077*
Leg Bone Mass	0.76 ± 0.13	0.74 ± 0.14	0.2900
Arm % Fat	13.13 ± 1.45	11.85 ± 1.97	0.0007**
Leg % Fat	16.00 ± 2.97	15.43 ± 3.07	0.0091*

Data are expressed as the mean ± SD; *significance set at P ≤ 0.05; ** P <0.001

Figure 1. Significant differences exist between male and female fighters in whole body BMD. The middle horizontal line represents the mean. The lines above and below represent the standard deviation. Each symbol represents individual data points.



	Male	Female
Mean	1.53	1.26
Std. Deviation	0.127	0.0972

Figure 2a. Simple linear regression demonstrates a significant relationship between body mass and bone mineral density (BMD) ($p < 0.005$, $R^2 = 0.357$). We did not find a significant relationship in female fighters (p=0.3414)

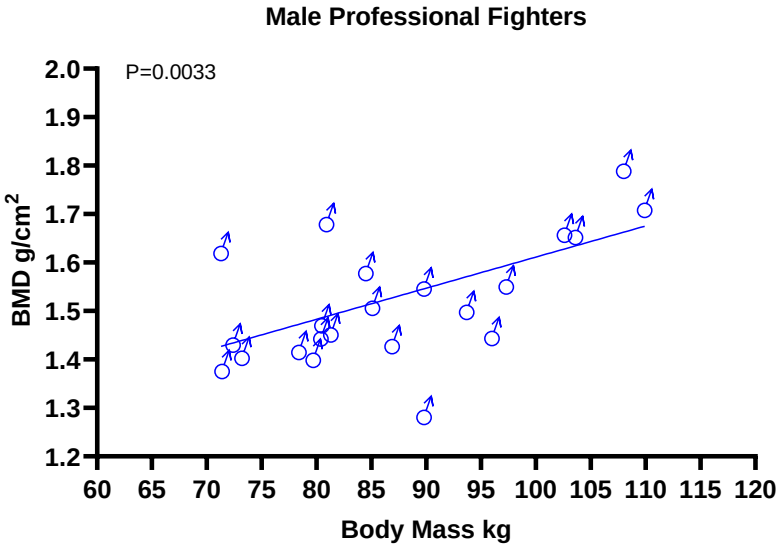
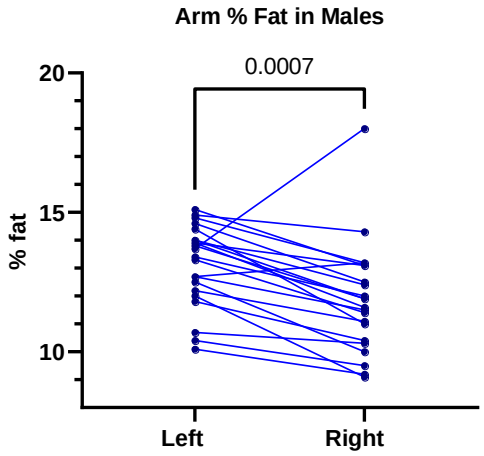
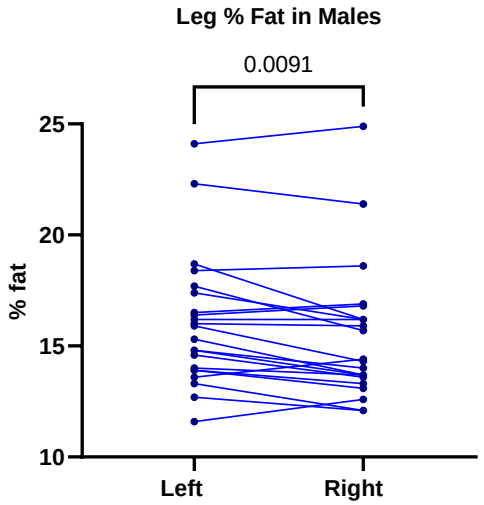


Figure 3. Significant differences between left and right arm body fat % in male fighters. Each symbol represents individual data.



	Left	Right
Mean	13.1	11.9
Std. Deviation	1.45	1.96

Figure 4. Significant differences exist in % fat between left and right leg in male fighters. Each symbol represents individual data points.



	Left	Right
Mean	16.00	15.43
Std. Deviation	2.969	3.073

Discussion

Monitoring and assessing body composition are essential for optimizing the health and performance of professional athletes. Previous studies assessing body composition in fight sports have used methods such as skinfolds or bioelectrical impedance.[11] This study aimed to assess anthropometrics in male and female professional fighters using DXA. DXA is a validated method to assess BMD and body composition in healthy individuals[7, 12]. Significant differences between male and female fighters were reported. In male fighters, lean body mass was positively correlated with bone mineral density and significant differences in body fat percentage in right and left arms were found.

Compared to other sports such as football, basketball, handball, and rugby, professional male fighters have lower body fat percentages [7, 13, 14]. When comparing this investigation's body fat percentage results to other fight sports, our values are in the middle. It has been reported that MMA fighters range from 8.5 to 14.9[15] . Sagayama et al. (2020) reported similar body fat percentages in male wrestlers (11.2±1.9) and judoka (15.6±2.4) athletes. Other studies have reported male boxers to have body fat percentages ranging from 9-17%[16, 17].

Interestingly, Imamura et al.[18] reported lower body fat percentages overall and no significant differences between novice (12.6±4.5) and competitive (10.7±2.0) karate practitioners. This investigation reported segmental differences in body fat and lean body mass, specifically in upper and lower limbs. The variability observed in body fat percentages among male fighters is attributed to differences in fight discipline, weight category, training regimen, and where a fighter is in relation to their next fight.

The existing body of research in female fight sports is lacking considerably. However, there are few studies on female fighters, which offer some comparative value. One investigation reported that adult female judo athletes have an average body fat percentage of 23.57±4.23[19]. Jagiełło et al. (2007)[20] reported different body compositions amongst different weight classes in adult female judo athletes. Body fat percentages ranged from 20.8±2.95 to 29.8±1.82 as weight class increased[20]. Similarly, Arakawa et al. (2020)[21] reported differences in body fat percentages between weight classes and age categories in Japanese female wrestlers. The study reported body fat percentages ranging from 11.8±3.4 to 20.4±4.0. These investigations assessed body composition via skinfold calipers or bioelectrical impedance, which should be taken into consideration when comparing our results. Only two studies assessed body composition via DXA in female fighters. Trutschnigg et al. (2018) reported body fat percentages in female boxers as 14.64 ± 1.97[22]. Reale et al. (2019) assessed anthropometrics in Olympic athletes competing in fight sports. The body fat percentages for various sports were as followed: Boxing 22.0±6.2, judo 24.9±7.6, taekwondo 23.1±3.1, wrestling 21.6±14.2. Our findings and those of Reale et al. (2019) are greater than Trutschnigg et al. (2018).

Athletes engaged in sports, which involve high-impact forces such as football or fight sports have higher BMD compared to low-impact sports such as swimming [5, 7, 14]. Collegiate football players are reported to have T-scores ranging from 3.4±1.1 to 2.1±0.8 [14, 23]. Our findings demonstrate that fighters have very high bone mineral densities like those reported in sports that involve repeated high impacts, such as football. Our study reported whole body BMD of 1.26±0.10, and lumbar BMD 1.29±0.27, for female fighters. Our findings are similar to other studies. Reported whole body BMD for female fighters is as follows: boxers 1.21±0.06 [22], judo and wrestling 1.238[7], "other combat sports" 1.21[7] . Trutschnigg et al. (2018) reported spine BMD as 1.30±0.14[22]. Based on the available literature and this investigation, whole body BMD, as well as segmental BMD for spine and lower limbs, were significantly higher in female boxers compared to physically active females[22, 24].

The current investigation reports very high BMD for male fighters (i.e., mean of 1.53 g/cm^2). Santos et al. (2019)[7] conducted a comprehensive study assessing BMD in various athletes using DXA. The average whole-body BMD for judo and wrestlers was 1.365 for males and 1.261 for "other combat sports". Other combat sports were not explicitly defined in this study. Andreoli et al. (2002)[12] reported BMD for male judo (1.40 ± 0.06) and karate (1.36 ± 0.08). Nasri et al. (2015)[25], reported BMD in male athletes participating in fight sports: whole body bone mineral density was 1.26±0.1, pelvis BMD was 1.33±0.1, arms 0.94±0.07 and legs 1.45±0.1. Unlike our study, the target population in Nasri et al. study were adolescent male fighters. It is still worth noting that even adolescents participating in fight sports exhibit greater BMD. Sagayama et al. (2020)[5] compared BMD in male athletes engaged in weight class sports to endurance athletes and non-athletes. Whole body bone mineral content for wrestlers (1.366±0.060 g/cm^2) and judoka (1.282±0.066 g/cm^2) were reported. Interestingly, wrestlers in the study had the largest amount of skeletal muscle mass and highest Z-scores. These observations are similar to those reported in our study. The findings of the aforementioned study and our study suggest greater body mass as well as lean mass predict a higher BMD. It has been postulated previously that higher levels of lean body mass may have a protective effect in maintaining bone density [26]. Our investigation suggests that both male and female professional fighters possess higher than normal BMD, irrespective of nutrition habits, rapid weight loss strategies, or gender. Fight sports have a greater osteogenic effect due to the high impact aspect of training and competition.

Based on the findings of this study, differences in body composition between males and females are present at the professional level. This is congruent with the abundance of available literature demonstrating a clear sexual dimorphism in athletic and general populations [2, 7, 14, 17, 27]. Moreover, the asymmetry in male fighters between the left and right

upper and lower extremities regarding percent fat, lean arm mass, leg fat mass, and arm bone mass is the first of its kind reported in the literature. It is unclear if this results from years of training or genetics. Furthermore, whether this is of any physiologic significance is unknown.

Conclusions

Clear differences in body composition exist between male and female fighters at the professional level. In addition, male professional fighters have an asymmetry regarding percent fat of the upper and lower extremities.

Acknowledgments

Not applicable

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