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Body Composition Analysis of Indian National Female Boxers: A Comparative Study among Various Weight Categories

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Abstract

Introduction: Body composition is a critical determinant of performance in weight-sensitive sports like boxing, influencing strength, endurance, and compliance with weight class requirements. This study examines body composition parameters among national junior and youth female boxers across weight categories. **Methods:** A total of 54 athletes, aged 15 to 18 years were categorized into three weight classes: Lightweight (46–54 kg), Middleweight (57–66 kg), and Heavyweight (70–80+ kg). Body composition parameters, including fat mass, fat-free mass, skeletal muscle mass, hydration, and basal metabolic rate, were assessed using a multifrequency BIA device. Statistical analyses, such as ANOVA and Pearson's correlation, were employed to examine differences and relationships among variables. **Results:** Heavier boxers had significantly higher fat mass (22.81 ± 6.20 kg), skeletal muscle mass (29.43 ± 2.51 kg), and basal metabolic rate (1506.06 ± 94.98 kcal/day) compared to lighter boxers ($p < 0.001$). However, skeletal muscle mass percentage decreased with weight class, reflecting a relative increase in adiposity. Hydration levels positively correlated with skeletal muscle mass (r=0.977) and inversely with fat mass (r=-1.000). Segmental analysis revealed heavier boxers had significantly greater lean mass in the trunk (23.87 ± 1.79 kg) and limbs, alongside higher fat accumulation in the trunk (11.84 ± 3.27 kg). Notably, energy expenditure metrics aligned with body composition, highlighting increased demands in heavier categories. **Conclusion:** Body composition differences across weight categories reflect the distinct physical demands of each class. Heavier boxers display greater absolute muscle and fat mass but lower relative muscle mass.

Keywords: Anthropometric characteristics, Body composition, bioelectrical impedance analysis, Segmental lean and fat mass, total body water

Resumen

Introducción: La composición corporal es un determinante crítico del rendimiento en deportes sensibles al peso como el boxeo, influyendo en la fuerza, la resistencia y el cumplimiento de los requisitos de la categoría de peso. Este estudio examina los parámetros de composición corporal entre boxeadoras nacionales juveniles y junior en todas las categorías de peso. Métodos: Un total de 54 atletas, de 15 a 18 años de edad, se clasificaron en tres categorías de peso: peso ligero (46-54 kg), peso medio (57-66 kg) y peso pesado (70-80+ kg). Los parámetros de composición corporal, incluida la masa grasa, la masa libre de grasa, la masa muscular esquelética, la hidratación y la tasa metabólica basal, se evaluaron utilizando un dispositivo BIA multifrecuencia. Se emplearon análisis estadísticos, como ANOVA y correlación de Pearson, para examinar las diferencias y relaciones entre las variables. Resultados: Los boxeadores más pesados tenían una masa grasa significativamente mayor (22,81 ± 6,20 kg), masa muscular esquelética (29,43 ± 2,51 kg) y tasa metabólica basal (1506,06 ± 94,98 kcal/día) en comparación con los boxeadores más ligeros ($p < 0{,}001$). Sin embargo, el porcentaje de masa muscular esquelética disminuyó con la categoría de peso, lo que refleja un aumento relativo de la adiposidad. Los niveles de hidratación se correlacionaron positivamente con la masa muscular esquelética (r=0,977) e inversamente con la masa grasa (r=-1,000). El análisis segmentario reveló que los boxeadores más pesados tenían una masa magra significativamente mayor en el tronco (23,87 ± 1,79 kg) y las extremidades, junto con una mayor acumulación de grasa en el tronco (11,84 ± 3,27 kg). En particular, las métricas de gasto energético se alinearon con la composición corporal, lo que destaca el aumento de las demandas en las categorías más pesadas. Conclusión: Las diferencias en la composición corporal entre las distintas categorías de peso reflejan las distintas exigencias físicas de cada categoría. Los boxeadores más pesados muestran una mayor masa muscular y grasa absoluta, pero una menor masa muscular relativa.

Palabras Clave: Características antropométricas, Composición corporal, Análisis de impedancia bioeléctrica, Masa magra y grasa segmentaria, Agua corporal total

Introduction

Body composition is crucial in athletic performance, particularly in weight-sensitive sports like boxing. Parameters such as muscle mass, fat distribution, and hydration directly influence strength, endurance, and the ability to meet weight class requirements. Understanding these factors is essential for optimizing training, nutrition, and recovery strategies in weight-categorized sports (Artioli et al., 2010). Among the various methods available, bioelectrical impedance analysis (BIA) has emerged as a reliable, cost-effective, and non-invasive tool for assessing body composition, including fat mass, lean body mass, and hydration levels (Kyle et al., 2004). While techniques like DEXA and hydrostatic weighing offer high accuracy, logistical constraints make BIA more practical for evaluating athletes across large cohorts, (Lukaski, 2013).

Boxing demands high anaerobic power, agility, and endurance, with physical requirements varying across weight categories. Proper weight management is critical but challenging, especially given the prevalence of rapid weight-loss practices, which can lead to dehydration, muscle loss, and impaired performance if poorly managed (Ward, 2012). Research has primarily focused on male athletes, leaving gaps in understanding the unique needs of females, particularly during developmental stages marked by hormonal changes and growth spurts (Mountjoy et al., 2014). These physiological differences underscore the importance of gender-specific research for optimizing performance strategies.

Studies in other combat sports, such as judo, wrestling, and taekwondo have highlighted significant variations in body composition across weight categories. For instance, research on judo athletes revealed that lighter weight categories tend to have lower fat mass but comparable lean body mass to heavier categories, indicating similar training adaptations across divisions (Franchini et al., 2011). In wrestling and taekwondo, body composition analysis has revealed significant variations in fat-free mass and hydration status among weight divisions (Candreva et al., 2015). While these insights provide a framework, similar research focusing on female boxers is limited, necessitating further exploration of their specific needs.

Moreover, young female athletes face additional considerations, such as low energy availability, during adolescence, which significantly impact their body composition and performance (Melin et al.,2019). Hormonal fluctuations during adolescence influence fat distribution, lean mass development, and hydration, necessitating gender- and age-specific approaches (Nattiv et al., 2007). Research addressing these factors in the context of weight categories can provide invaluable insights, enabling evidence-based interventions that promote both athletic success and long-term athlete well-being.

The present study aims to analyse body composition parameters, including fat mass, fat-free mass, skeletal muscle mass, and hydration levels, in national junior and youth female boxers using the BIA technique. Examining variations across weight categories aims to align assessments with the specific demands of female boxing. The findings will offer valuable insights to optimize training, nutrition, and recovery strategies, enhancing performance and promoting the long-term health and development of female boxing, from grassroots to elite levels.

Material and Methods

The present cross-sectional study was conducted on 54 Indian national junior (15-16 years) and youth (17-18 years) female boxers, ages 15 to 18 years, during the boxing national camp at the Sports Authority of India, NSNIS, Patiala, India. The participants were categorized into three groups of 18 athletes each based on weight classes: Lightweight (L: 46–54 kg), Middleweight (M: 57–66 kg), and Heavyweight (H: 70–80+ kg). All participants were national-level athletes free from physical injury, or medication for the last three months. Data collection was done in the morning sessions and all participants were instructed to restrict alcohol and caffeine-containing drinks as well as to refrain from intense physical activity within 24 hours with a minimum of 12 hours fasting. The tests were conducted under laboratory conditions at a controlled temperature of 22 °C (Forejt et al., 2023). Informed consent was obtained from each athlete before data collection. The research was undertaken in compliance by following the guidelines of the Helsinki Declaration.

Height (cm) was measured by using a calibrated Digital BMI Machine (SECA 284, Seca Deutschland, Germany) working with a precision of 0.1 cm. A calibrated tetra polar method using 8-touch electrodes and multifrequency (6-frequency: 1, 5, 50, 250, 550, 1000 kHz, measuring current: approx. 180µA) Bioelectrical Impedance Analysis **(**BIA) device (ACCUNIQ BC 720, SELVAS Healthcare Inc.) was used to measure body composition parameters namely body weight, body mass index (BMI), waist-hip ratio (WHR), fat mass (FM), fat-free mass (FFM), soft lean mass (SLM), skeletal muscle mass (SMM), total body water (TBW), skeletal muscle mass percentage (SMM%), body fat percentage (BF%), total body water percentage (TBW%), segmental analysis (Lean and fat mass of right arm, left arm, trunk, right leg and left leg respectively), basal metabolic rate (BMR), and total daily energy expenditure (TDE). The palms and soles of the participants were cleaned with isopropyl alcohol before testing. Participants were instructed to correctly grip the handle electrodes with fingers and palms, stretch both arms, and spread at a 30° angle with the body. The participants were asked to remove metal accessories and wear light clothes. Standard guidelines as per the manufacturer's manual were followed for the testing (Yang et al., 2018).

Statistical Package for Social Sciences (SPSS), version 21 (SPSS Inc., Chicago, Il, USA) was used to analyse the data statistically. Data were expressed as mean ± standard deviation (SD), Range, and Variance. Shapiro-Wilk and Levene's tests were conducted to check the normal distribution and homogeneity of the sample. The analysis includes the F-value from ANOVA testing and p-values to determine the statistical significance of differences across these categories, with post hoc (Bonferroni) comparisons identifying specific group differences. Further, Pearson's correlation is applied to examine the relationships between various body composition parameters.

Results

Table 1. Descriptive statistics of female boxers (N=54)

Variables	**Mean ± SD**	**Range**	**Variance**
Age (yrs.)	16.20±1.01	15-18	1.033
Height (cm)	165.46±6.92	153.30-182.90	47.917
Weight (kg)	62.65±11.1	44.70-90.10	123.211
BMI (kg/m^2)	22.79±3.20	18.0-31.50	10.210
WHR	0.79±0.08	0.67-1.00	0.007
FM (kg)	16.33±6.75	5.30-32.50	45.597
FFM (kg)	46.30±5.84	35.40-61.10	34.135
SLM (kg)	43.26±5.48	32.90-57.40	30.044
SMM (kg)	25.82±3.33	19.70-34.10	11.15
TBW (L)	33.94±4.25	26-44.60	18.069
BMR (kcal/d)	1369.83±126.09	1135-1689	15899.840
TDE (kcal)	2107.79±187.28	1747-2617	35074.392
SMM _P	41.67±3.66	32.61-48.40	13.367
BF_P	25.24±6.62	11.80-41.40	43.886
TBW_P	54.80±4.87	42.84-64.65	23.795
Segmental Lean Mass (kg)			
Right Arm	2.42±0.40	1.65-3.50	0.165
Left Arm	2.37±0.40	1.64-3.53	0.164
Trunk	21.00±2.40	16.74-27.60	5.795
Right Leg	6.95±1.05	5.02-9.38	1.113
Left Leg	6.99±1.03	5.13-9.32	1.069
Segmental Fat Mass (kg)			
Right Arm	1.10±0.53	0.29-2.40	0.286
Left Arm	1.02±0.52	0.30-2.40	0.280
Trunk	8.26±3.65	1.70-16.82	13.391
Right Leg	2.38±0.82	1.00-4.40	0.681
Left Leg	2.40±0.82	1.00-4.50	0.676

Values are expressed as mean ± SD; BMI= Body mass index; WHR= Waist-hip ratio; FM= Fat mass, FFM= Fat-free mass; SLM= Soft lean mass; SMM= Skeletal muscle mass; TBW= Total body water; BMR= Basal metabolic rate; TDE= Total daily energy expenditure; SMM_P=Skeletal muscle mass percentage; BF_P= Body fat percentage; TBW_P= Total body water percentage

The descriptive statistics summarize the physical and body composition characteristics of 54 junior and youth female boxers (Table 1). The group averages 16.20±1.01 years in age (range: 15–18), with a mean height of 165.46±6.92 cm and weight of 62.65±11.1 kg. Their average BMI of 22.79±3.20 kg/m² falls within the healthy range. Body composition variables include a mean WHR of 0.79±0.08, FM of 16.33±6.75 kg, and FFM of 46.30±5.84 kg, reflecting athletic musculature. SMM averages 25.82±3.33 kg, while TBW is 33.94±4.25 L, indicating hydration aligned with lean mass. BMR averages 1369.83±126.09 kcal/day, and TDE is 2107.79±187.28 kcal, highlighting training demands. BF% averages 25.24±6.62 %, while TBW% is 54.80±4.87 %, reflecting lean mass distribution. Segmental analysis reveals balanced lean mass, with arms (~2.4 kg), legs (~7 kg each), and trunk (~21 kg) indicating core strength. Fat mass is higher in the trunk (~8.26 kg) compared to arms (~1.1 kg) and legs (~2.4 kg), with minor variability.

Table 2. Comparison of anthropometric variables among various weight category female boxers

Variables	L (18)	M (18)	H (18)	F value	p- Value	Post hoc
Age (yrs.)	16.05 ±0.87	15.88 ±1.02	16.61 ±1.14	2.477	0.094[NS]	----
Height (cm)	160.28 ±4.22	164.85 ±5.13	171.26 ±6.38	19.318	< 0.001***	LvMH, MvH
Weight (kg)	50.82 ±3.06	61.68 ±2.76	75.44 ±6.69	132.904	< 0.001***	LvMH, MvH
BMI (kg/m²)	19.81 ±1.20	22.77 ±1.84	25.80 ±2.82	37.881	< 0.001***	LvMH, MvH
WHR	0.75 ±0.07	0.79 ±0.05	0.85 ±0.08	8.184	0.001**	LvH
FM (kg)	9.90 ±2.16	16.28 ±3.26	22.81 ±6.20	41.754	< 0.001***	LvMH, MvH
FFM (kg)	40.91 ±2.94	45.39 ±2.10	52.62 ±4.39	58.045	< 0.001***	LvMH, MvH
SLM (kg)	38.27 ±2.7	42.36 ±2.10	49.16 ±4.23	55.039	< 0.001***	LvMH, MvH
SMM (kg)	22.72 ±1.67	25.30 ±1.17	29.433 ±2.51	58.86	< 0.001***	LvMH, MvH
TBW (L)	30.02 ±2.15	33.26 ±1.56	38.53 ±3.19	57.723	< 0.001***	LvMH, MvH
BMR (kcal/d)	1253.28±63.40	1350.17±45.67	1506.06±94.98	58.055	< 0.001***	LvMH, MvH
TDE (kcal)	1933.06±97.82	2082.61±72.98	2307.72±138.30	56.450	< 0.001***	LvMH, MvH
SMM_P	44.74 ±2.22	41.08 ±2.38	39.19 ±3.76	17.250	< 0.001***	LvMH, MvH
BF_P	19.48 ±3.99	26.28 ±4.34	29.94 ±6.49	19.764	< 0.001***	LvMH,
TBW_P	59.10 ±2.91	54.01 ±3.15	51.31 ±4.76	20.545	< 0.001***	LvMH,

Values are expressed as mean ± SD, NS= not significant, *= p < 0.05, **= p < 0.01, ***= p<0.001, BMI= Body mass index; WHR= Waist-hip ratio; FM= Fat mass, FFM= Fat-free mass; SLM= Soft lean mass; SMM= Skeletal muscle mass; TBW= Total body water; BMR= Basal metabolic rate; TDE= Total daily energy expenditure; SMM_P=Skeletal muscle mass percentage; BF_P= Body fat percentage; TBW_P= Total body water percentage, L= Light weight, M= Middle weight, H=Heavy weight; LvH = Light weight Vs Heavy weight; LvMH =Light weight vs Middle weight, Heavy weight; MvH = Middle weight vs Heavy weight

Table 2, presents a comparison of anthropometric variables across three weight categories for female boxers. Height, weight, BMI, and WHR increase as the weight class progresses. The lightweights group averages 160.28 cm in height, 50.82 kg in weight, and a BMI of 19.81, while the heavyweights group averages 171.26 cm, 75.44 kg, and a BMI of 25.80. Statistical analysis reveals highly significant differences across all categories for height (F = 19.318, p < 0.001), weight (F = 132.904, p < 0.001), BMI (F = 37.881, p < 0.001), and WHR (F = 8.184, p = 0.001). These findings highlight significant increases in size and changes in body composition from lightweights to heavyweights, with notable differences in body fat distribution supported by a post hoc test.

FM and BF% increase across weight categories, from 9.90 ± 2.16 kg and 19.48 ± 3.99% in lightweights to 22.81 ± 6.20 kg and 29.94 ± 6.49% in heavyweights, indicating higher adiposity in heavier boxers. Conversely, FFM, SLM, and SMM also rise, with heavyweights having significantly greater muscle mass (SMM: 29.43 ± 2.51 kg) compared to lightweights (SMM: 22.72 ± 1.67 kg). However, the SMM% decreases from 44.74% in lightweights to 39.19% in heavyweights, reflecting a lower proportion of muscle mass relative to body weight in heavier boxers. Energy expenditure metrics, including BMR and TDE, were highest in heavyweights due to their greater muscle mass and overall size. BMR ranged from 1253.28 ± 63.40 kcal/day in lightweights to 1506.06 ± 94.98 kcal/day in heavyweights, while TDE showed a similar pattern, increasing from 1933.06 ± 97.82 kcal/day to 2307.72 ± 138.30 kcal/day across categories.

Table 3. Comparison of segmental lean and fat mass among various weight category female boxers

Variables	L (18)	M (18)	H (18)	F value	p- Value	Post hoc
Segmental Lean Mass (kg)						
Right Arm	2.06±0.20	2.33±0.15	2.86±0.30	57.137	< 0.001***	LvH, MvH
Left Arm	2.02±0.20	2.29±0.16	2.82±0.31	53.921	< 0.001***	LvH, MvH
Trunk	18.78±1.08	20.56±0.84	23.87±1.79	64.434	< 0.001***	LvMH, MvH
Right Leg	6.01±0.61	6.86±0.55	7.98±0.84	37.822	< 0.001***	LvMH, MvH
Left Leg	6.06±0.58	6.91±0.51	8.02±0.81	41.096	< 0.001***	LvMH, MvH
Segmental Fat Mass (kg)						
Right Arm	0.54±0.17	0.99±0.27	1.49±0.55	29.471	< 0.001***	LvH, MvH
Left Arm	0.55±0.16	1.00±0.27	1.50 ±0.53	31.093	< 0.001***	LvMH, MvH
Trunk	4.77±1.23	8.17±1.75	11.84±3.27	44.046	< 0.001***	LvMH, MvH
Right Leg	1.58±0.26	2.39±0.36	3.16±0.77	41.727	< 0.001***	LvMH, MvH
Left Leg	1.61±0.25	2.41±0.36	3.18±0.77	41.211	< 0.001***	LvMH, MvH

Values are expressed as mean ± SD, *= p < 0.05, **= p < 0.01, ***= p<0.001, L= Light weight, M= Middle weight, H=Heavy weight; LvH = Light weight vs Heavy weight; LvMH =Light weight vs Middle weight, Heavy weight; MvH = Middle weight vs Heavy weight.

Table 4. Pearson correlation coefficient among selected anthropometric variables

Variables	Weight	BMI	WHR	BMR	TDE	TBW_P
SMM_P	-.719**	-.860**	-.481**	-.276**	-.258	.977**
BF_P	.741**	.879**	.474**	.307*	.287*	-1.000**

*Correlation is significant at the 0.05 level (2-Tailed); **Correlation is significant at the 0.01 level (2-Tailed); BMI= Body mass index; WHR= Waist-hip ratio; BMR= Basal metabolic rate; TDE= Total daily energy expenditure; TBW_P= Total body water percentage; SMM_P= Skeletal muscle mass percentage; BF_P=Body fat percentage

Table 3 compares segmental lean and fat mass among female boxers in three weight categories. Heavier boxers exhibited significantly higher lean mass across all segments. For example, right arm lean mass was 2.06 ± 0.20 kg (lightweight), 2.33 ± 0.15 kg (middleweight), and 2.86 ± 0.30 kg (heavyweight) (F = 57.137, p < 0.001), with significant differences among all groups. Similar trends were noted for the left arm, trunk (18.78 ± 1.08 kg to 23.87 ± 1.79 kg, F = 64.434, p < 0.001), and legs, with heavier boxers consistently showing greater lean mass. For segmental fat mass, heavier boxers had significantly greater fat mass across all body segments. In the right arm, fat mass was 0.54 ± 0.17 kg (lightweight), 0.99 ± 0.27 kg (middleweight), and 1.49 ± 0.55 kg (heavyweight) (F = 29.471, p < 0.001), with significant differences among categories. Similar trends were noted for the left arm, trunk (4.77 ± 1.23 kg to 11.84 ± 3.27 kg, F = 44.046, p < 0.001), and legs, all showing significant variations by weight category.

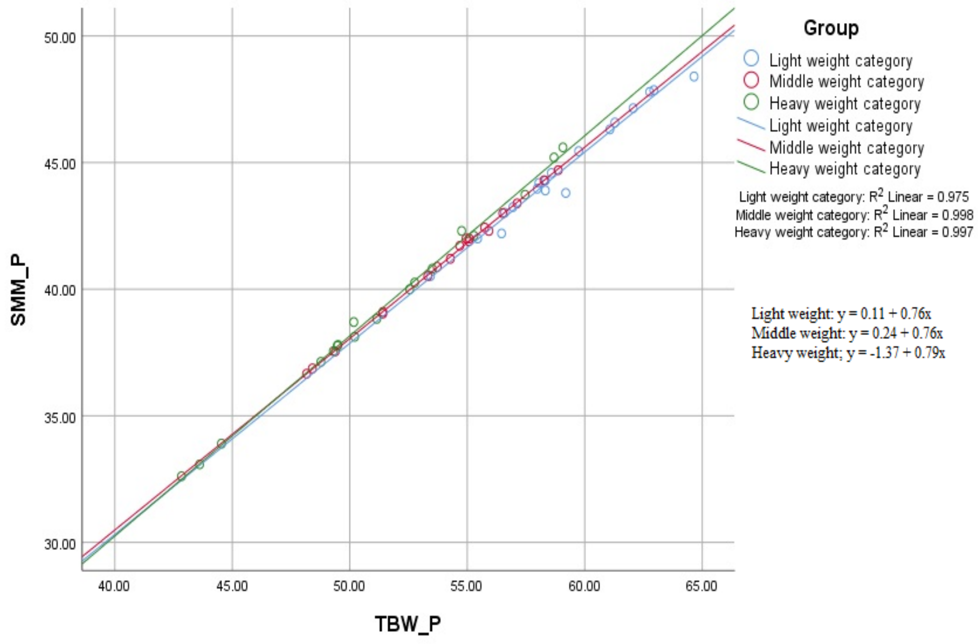

Fig. 1 (A)

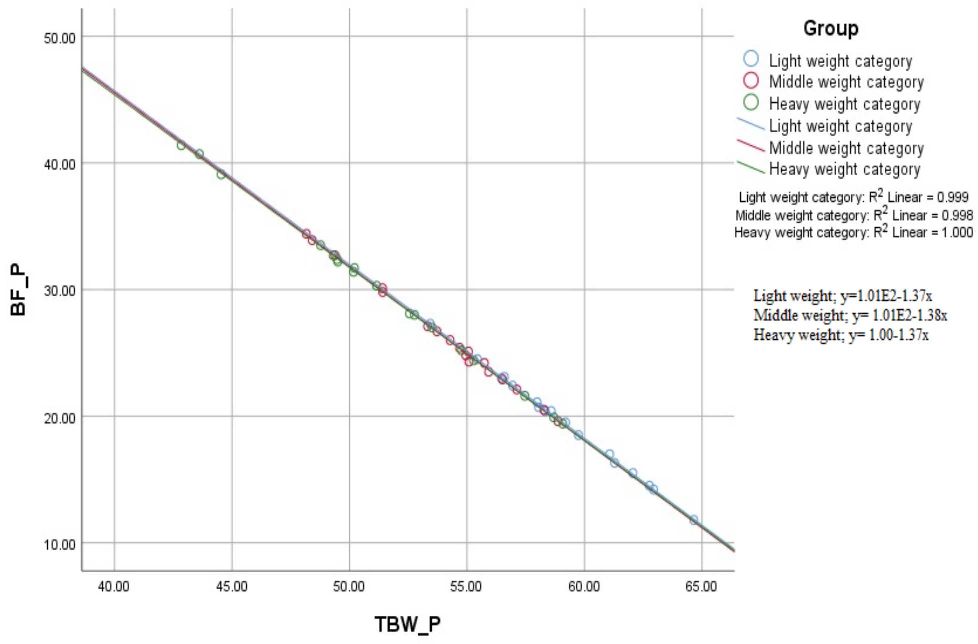

Fig. 1 (B)

Figure 1. Compares relationships between body composition parameters across three weight categories.

Figure 1(a) shows a strong positive correlation between SMM% and TBW%. All weight categories exhibit similar slopes (~0.76), with R^2 values ranging from 0.975 to 0.997. Figure 1(b) illustrates a strong negative correlation between BF% and TBW%, with nearly identical slopes (~-1.37) across groups and R^2 values of 0.988–1.000.

Table 4 presents Pearson correlation coefficients among selected anthropometric variables. SMM% is negatively correlated with weight (r = -0.719), BMI (r = -0.860), WHR (r = -0.481), and BMR (r = -0.276), with BMI showing the strongest negative correlation. SMM% positively correlates with TBW% (r = 0.977). In contrast, body fat percentage (BF%) is positively correlated with weight (r = 0.741), BMI (r = 0.879), and WHR (r = 0.474), while showing weaker positive correlations with BMR (r = 0.307) and TDE (r = 0.287). A negative correlation (r = -1.000) between BF% and TBW% highlights their inverse relationship.

Discussion

The anthropometric data highlight a progressive increase in height, weight, and BMI from the lightweight to the heavyweight category. The significant differences in height and weight (F-values of 19.318 and 132.904, respectively) reflect the natural trend of increased body size in higher weight categories. Whereas, a notable finding is the marked increase in FM and BF% as weight categories increase. Lightweights (9.90 ± 2.16 kg FM) have significantly less fat mass compared to heavyweights (22.81 ± 6.20 kg FM), with BF% rising from 19.48 ± 3.99% in lightweights to 29.94 ± 6.49% in heavyweights. Other studies also observed the same finding among male boxers (Davis & Beneke, 2016; lal Khanna & Manna, 2006; Meetei & Singh, 2017; Singh et al., 2023). These differences in fat mass reflect the role of fat in overall weight gain, particularly in the heavier weight categories where increased adiposity is observed.

Moreover, FFM, SLM, and SMM also increase progressively across weight categories. The significant increase in lean mass (FFM: 40.91 ± 2.94 kg in lightweights to 52.62 ± 4.39 kg in heavyweights) reflects the growing muscle mass associated with increased size and strength required for heavier weight categories in boxing. Despite the higher absolute muscle mass in heavyweights their SMM% (39.19%) was found to be less in both middleweights (41.08%) and lightweights (44.74%), suggesting that, while heavier athletes have more muscle in absolute terms, their muscle mass is less proportionate to overall body weight (Drid et al., 2015; Keogh et al., 2007; Micheli et al., 2014; Van Der Ploeg et al., 2015). This reduction in SMM% highlights the challenge faced by heavyweights in maintaining a high proportion of muscle relative to body weight, which may impact their agility and endurance.

Analysis of energy metrics such as BMR and TDE provides further insights into the physical demands placed on the athletes. Both BMR and TDE are highest in heavyweights (Yang et al., 2022), heavyweights have a BMR of 1506.06 ± 94.98 kcal/day and TDE of 2307.72 ± 138.30 kcal/day, compared to lightweights with a BMR of 1253.28 ± 63.40 kcal/day and TDE of 1933.06 ± 97.82 kcal/day. These reflect the greater energy requirements of larger athletes, driven by their increased muscle mass and higher overall metabolic demands.

The segmental analysis of lean and fat mass reveals significant differences across weight categories, confirming that as body size increases, both lean and fat mass increase in absolute terms. Heavyweight boxers consistently show a higher lean mass in all body segments, with the trunk and legs showing the most significant gains. This is in line with the increased musculature seen in heavier athletes, particularly in the trunk (23.87 ± 1.79 kg in heavyweights vs. 18.78 ± 1.08 kg in lightweights) and legs (7.98 ± 0.84 kg in heavyweights vs. 6.01 ± 0.61 kg in lightweights). Similarly, fat mass increases in the trunk and limbs as weight categories progress, with heavyweights showing the highest fat mass across all segments, particularly in the trunk, which reflects the centralization of body fat in this area (De Lorenzo & Andreoli, 2003; Di Vincenzo et al., 2020; Esco et al., 2015).

The Pearson correlation analysis provides deeper insights into the relationships between various anthropometric variables. The negative correlation between SMM% and weight, BMI, and WHR suggests that heavier boxers while having greater absolute muscle mass, tend to have a lower proportion of muscle relative to their body weight (Reljic et al., 2013). Further, the strong positive correlation between SMM% and TBW% (r = 0.977) indicates that athletes with more muscle mass tend to have more body water, essential for hydration and muscle function. BF% shows positive correlations with weight, BMI, and WHR, indicating that as these variables increase, BF% also rises. This supports the observation that higher weight and BMI categories tend to have greater fat reserves, critical for understanding body composition in different weight classes. The negative correlation between BF% and TBW% (r = -1.000) further underscores the inverse relationship between fat and lean mass, supporting that higher fat mass tends to be associated with lower hydration levels and reduced lean tissue mass which corresponds to unwanted muscle cramps, limiting muscle strength, post-exercise recovery and hinders the performance (Lee et al., 2017).

The study has several limitations. The sample size is relatively small, which may limit the generalizability of the findings to all female boxers. The study focuses exclusively on female boxers, so findings may not apply to male counterparts, limiting broader applicability within boxing. While the study focuses on body composition variables, it does not incorporate direct performance metrics (e.g., agility, endurance, punching power) that could strengthen correlations between body composition and boxing performance. Variations in training regimes and dietary practices among participants are not controlled, which could affect body composition and metabolic rates independently of weight category.

Conclusion

The anthropometric comparison across lightweight, middleweight, and heavyweight categories among junior and youth female boxers reveals clear, significant differences in body composition, muscle distribution, and energy requirements, aligning with each weight class's demands. Heavier boxers tend to have increased height, body mass, BMI, and body fat percentage, reflecting a body type suited to the physical needs of their category. Meanwhile, lighter weight classes display higher SMM% and TBW%, indicative of a leaner, more muscular composition that favours agility and speed. Energy expenditure is directly linked to body size, with heavyweights requiring more energy due to their larger muscle mass and size. Correlations between BF, SMM, and TBW highlight the balance between lean and fat mass, with increased adiposity in higher weight categories reducing hydration levels. These findings highlight the importance of customized training and nutrition strategies that cater to each weight category's unique physiological characteristics and performance needs, fostering optimal athletic development and competitive advantage for junior and youth female boxers. Future research should address the limitations of this study, including the small sample size, and explore the relationship between body composition and boxing performance metrics.

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Data availability

Full access to data on request.

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The Authors have no conflict of interest to declare

Informed Consent Statement

All the athletes included in the study provided written informed consent.