Variation in body composition during the ramadan fast in athletes following a varied sports training program: intersex variations

Variación en la composición corporal durante el ayuno de ramadán en atletas que siguen un programa de entrenamiento deportivo variado: variaciones intersexuales

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Abstract

Introduction and Objective. Ramadan fasting, characterized by diurnal abstinence from food and water, can significantly impact body composition, particularly in athletes undergoing intense training. This study aimed to evaluate gender-specific variations in body composition among university athletes following a varied sports training program during Ramadan.
Methodology. A total of 129 athletes (76 women, 53 men; aged 18-21 years) were assessed using multifrequency bioelectrical impedance analysis (InBody 770) before and during the fourth week of Ramadan. Measurements included fat mass, lean mass, body circumferences, and water parameters under controlled conditions.
Results. Male athletes exhibited a significant reduction in body weight (−0.46%, p = .045; Cohen's 0.21, 95% CI [0.01, 0.41]) and overall fat mass (−4.11%, p = .031; 0.25, 95% CI [0.05, 0.45]), including segmental fat mass, while maintaining lean body mass and skeletal muscle mass. Female athletes showed reductions in hip, abdominal, and arm circumferences, with significant decreases in fat mass and skeletal muscle mass. Both genders displayed a decrease in bone mineral content.
Conclusions. The findings highlight distinct metabolic and morphological adaptations between genders during Ramadan fasting, suggesting the need for personalized nutritional and training strategies to optimize performance and health outcomes. However, the absence of a non-fasting control group and the lack of precise dietary and hydration monitoring limit the interpretation of these results.

Keywords

Ramadan fasting, body composition, athletes, sex-specific variations, bioelectrical impedance analysis.

Resumen

Introducción y Objetivo. El ayuno de Ramadán, caracterizado por la abstinencia diurna de alimentos y agua, puede afectar significativamente la composición corporal, especialmente en atletas con entrenamientos intensos. Este estudio tuvo como objetivo evaluar las variaciones específicas por género en la composición corporal de atletas universitarios que siguieron un programa de entrenamiento deportivo variado durante el Ramadán.
Metodología. Se evaluaron 129 atletas (76 mujeres, 53 hombres; de 18 a 21 años) utilizando análisis de impedancia bioeléctrica multifrecuencia (InBody 770) antes y durante la cuarta semana del Ramadán. Las mediciones incluyeron masa grasa, masa magra, circunferencias corporales y parámetros hídricos bajo condiciones controladas.
Resultados. Los hombres mostraron una reducción significativa en el peso corporal (−0,46 %, p = 0,045; Cohen 0,21, IC 95 % [0,01, 0,41]) y en la masa grasa total (−4,11 %, p = 0,031; 0,25, IC 95 % [0,05, 0,45]), incluida la masa grasa segmentaria, manteniendo la masa magra y muscular esquelética. Las mujeres presentaron reducciones en las circunferencias de cadera, abdomen y brazo, con disminuciones significativas en la masa grasa y muscular esquelética. Ambos géneros mostraron una disminución en el contenido mineral óseo.
Conclusiones. Los hallazgos destacan adaptaciones metabólicas y morfológicas distintas entre géneros durante el ayuno de Ramadán, sugiriendo la necesidad de estrategias nutricionales y de entrenamiento personalizadas para optimizar el rendimiento y la salud. Sin embargo, la ausencia de un grupo control no ayunante y la falta de monitoreo preciso de la dieta e hidratación limitan la interpretación.

Palabras clave

Ayuno de ramadán, composición corporal, atletas, variaciones específicas de sexo, análisis de impedancia bioeléctrica.

Introduction

The modulation of energy and water homeostasis induced by intermittent Ramadan fasting (RF) provides a unique paradigm for studying gender-specific metabolic adaptations in athletes. Despite the advances made in the field regarding the endocrine determinants of nitrogen balance—namely, the roles of leptin, ghrelin, and cortisol—during RF, the interactions between prolonged daytime fasting, heterogeneous training load, and sexual dimorphism in the redistribution of body compartments remain poorly elucidated. This knowledge gap persists at a time when elite Muslim athletes must reconcile religious observance with the optimization of their morphotype, a key parameter directly influencing the power-to-weight ratio in cyclic sports and lactate kinetics in intermittent sports (Stellingwerff et al., 2019).

Recent meta-analyses indicate that resistance training (RT) induces an average 1.4 ± 0.3% reduction in fat mass (FM) in male athletes, correlated with a paradoxical 0.9% increase in lean mass (FFM) despite a negative energy balance (Aloui et al., 2021). These observations suggest a mitochondrial reprogramming that favors β-oxidation over protein catabolism, a process that may be mediated by upregulation of adiponectin and circadian suppression of insulinemia (Chaouachi et al., 2012). Nonetheless, the present work is afflicted by two significant methodological deficiencies: (1) an over-representation of male cohorts (83% of studies excluded women due to cultural bias), and (2) the utilization of single-frequency impedancemetry tools that fail to differentiate between intracellular water (ICW) and extracellular water (ECW) — a critical variable for interpreting water fluctuations in the context of intermittent dehydration (Kyle et al., 2004).

A review of the literature indicates that the combination of Ramadan fasting and exercise has been shown to have variable effects on body composition in female athletes (Scarbrough, 2023; Cienfuegos et al., 2022). The following text is intended to provide a comprehensive overview of the subject matter. In a recent study, Martinez-Rodriguez et al. (2021) reported a significant reduction in body fat among women engaging in high-intensity interval training during Ramadan. However, Memari et al. (2011) found no significant effect on muscle mass or physical performance in professional female taekwondoists.

These disparities likely reflect the heterogeneity of training protocols and estrogenic modulation of muscle protein turnover, with estrogens exerting an anticatabolic effect via inhibition of the ubiquitin-proteasome pathway (Smith et al., 2020). Moreover, to the best of our knowledge, no study has hitherto quantified segmental variations in FM (trunk vs. limbs) under RF, despite the fact that such variations are influenced by their sex-linked distribution, which in turn affects thermoregulation and free fatty acid (FFA) bioavailability during exercise (Gagnon & Kenny, 2012).

Recent articles in Challenges. Nouvelles tendances en éducation physique, sport et loisirs (e.g., Durand et al., 2022; Lefèvre et al., 2023) have highlighted updated training guidelines and gender considerations that further underscore the need for differentiated protocols in fasting athletes

The objective of this study is to address this knowledge gap by evaluating sex-specific alterations in body composition among a cohort of university athletes participating in various sports. The study will elucidate the discrete metabolic and morphological adaptations experienced by male and female athletes. We hypothesize that Ramadan fasting will induce a greater relative fat mass reduction in male athletes, whereas female athletes will preserve fat stores but may experience lean mass loss due to hormonal modulation.

Method

Participants

The study encompassed 129 student athletes with a mean age of 18.9 years, with 58.9% of the sample
The study encompassed 129 student athletes with a mean age of 18.9 ± 1.1 years, with 58.9 % female, n = 76; 41.1 % male, n = 53. These individuals were enrolled in a university training program specializing

in physical and sports education. The Participants engaged in a multifaceted training regimen encompassing soccer, rugby, gymnastics, and track and field events, allocating five to ten hours per week since the onset of the year as an integral component of a university-sanctioned training program. This program is meticulously maintained throughout the year, including during the Ramadan period. The sample population for this study was derived from a larger cohort of 360 students enrolled in the same university program. The inclusion criteria were as follows: all participants were to be voluntary, Muslim, accustomed to Ramadan fasting since puberty, non-smokers, in good health, and residing in the university campus with a standardized diet at the university restaurant. To avoid hormonal fluctuations that could skew body composition metrics, female athletes were scheduled for measurements outside their menstrual period (Liao et al., 2020) instead of requiring complete amenorrhea . A non-fasting control group was not included; this limitation and the absence of precise records of dietary intake, training load intensity, and hydration status represent potential confounders (Rev A). The study was conducted in strict compliance with the ethical principles set out in the Declaration of Helsinki. Prior to their inclusion in the experimental protocol, written informed consent was obtained from all participants..

Procedure Study Design

The study was conducted in Casablanca, Morocco, in March 2024, during which time average climatic conditions were recorded as a temperature of 18-22°C and a relative humidity of 65-75%. The measurements were obtained at 12:00 p.m. (approximately seven hours after the last meal of the day), in a laboratory with controlled temperature conditions (22–24°C) and with the subject under a period of fasting. To standardize the metabolic conditions, the subject was required to abstain from physical exercise for 12 hours prior to the assessments (Merrigan et al., 2022; Aldobali et al., 2021). All participants fasted on water and food for a period of 8 hours, ensuring that their bladders were empty, and then stood for 15 minutes prior to analysis. The measurements were obtained at two distinct temporal points: the baseline, which corresponded to one week prior to Ramadan, and the fourth week of Ramadan. The measurements were collected in accordance with a standardized protocol.

Body composition measurement by Impedancemetry

Body composition was assessed by bioelectrical impedance (BIA) via the InBody 770 device (InBody, Seoul, South Korea). validated for its reliability in sports populations (McLeste et al., 2020 ; Merrigan, et al., 2022) : The accuracy of this device has been validated in several studies in comparison with the reference method DXA (Dual-Energy X-ray Absorptiometry) and provides reliable measurements of body tissue and fluids their segmental distribution (Ling et al., 2011; Kyle et al., 2004).

It's a non-invasive, fast and reliable method for quantifying the various compartments of the human body. It uses multi-frequency technology (1, 5, 50, 250, 500 and 1000 kHz). (DSM- BIA) using electrodes placed on the right and left hands and feet, measuring the resistance of various body tissues: muscle, fat, body fluid. Participants are measured in a stable standing position, with arms and legs slightly apart, for 15 minutes prior to analysis, to stabilize body fluid distribution. Measurement of body composition parameters, lasting 60 seconds, provides general and segmental data on arms, legs (right and left) and trunk, in terms of the following parameters

Measured parameters

Body circumferences:Waist-Hip Ratio (WHR), Arm Circumference (AC), Arm Muscle Circumference (AMC), Circumference of Neck (CN), Circumference of Chest (CC), Circumference of Abdomen (CA), Circumference of Hip (CH), Circumference of Right Arm (CRA), Circumference of Left Arm (CLA), Circumference of Right Thigh (CRT), Circumference of Left Thigh (CLT).Body fat: Body Fat Mass (BFM), Fat-Free Mass (FFM), % Body Fat (PBF), Visceral Fat Area (VFA), FFMI, Fat Mass Index (FMI), Ratios BFM/FFM. Segmental parameters measured at arm (right/left), trunk, leg (right/left): FFM (mass, %), BFM (mass, %).

Lean body mass and skeletal muscle mass: Soft Lean Mass (SLM), Skeletal Muscle Mass (SMM).

Body water: Total Body Water (TBW), Intracellular Water (ICW), Extracellular Water, (ECW), Ratios calculated are ECW/TBW, TBW/FFM. Segmental parameters measured at arm (right/left), trunk, and leg (right/left) levels: TBW, ICW, ECW, ECW/TBW.

Metabolic parameters and tissue composition: Basal Metabolic Rate (BMR), Body Cell Mass (BCM), Proteins, Minerals, Bone Mineral Content (BMC).

Data Analysis

A two-way repeated-measures ANOVA evaluated main effects of fasting (pre-Ramadan vs. Ramadan) and sex (male vs. female), and their interaction, on all body composition variables. Normality was confirmed via Shapiro–Wilk (all p > .05), and homogeneity via Levene's test (p > .05). Where Mauchly's sphericity test was significant (p < .05), Greenhouse–Geisser corrections were applied. Effect sizes were reported as partial eta squared (η^2_p): small = 0.01, medium = 0.06, large = 0.14. Pairwise comparisons used Bonferroni-adjusted post-hoc tests. For non-normal paired comparisons, Wilcoxon signed-rank tests were used, with effect size $r = Z/\sqrt{N}$ and 95 % CI computed via Fisher's z-transformation. Statistical analyses employed IBM SPSS Statistics v26. Results are presented as mean ± SD (or mean ± SEM where indicated), with significance at adjusted p < .05.

Results

Body weight and indices

A significant decrease in body weight was observed in both male (-0.458%, p = .045) and female (-0.855%, p = .006) athletes at the end of the month of Ramadan (Table 1). Similarly, body mass index (BMI) decreased significantly in female athletes (-0.580%, p = .002), while in male athletes no significant change was noted (p = .801). These effects are confirmed by moderate effect sizes (Cohen's 0.45 for males and 0.63 for females), as detailed in Appendix Table A1.

Indices of adiposity and segmental distribution of fat variations

No significant change in percentage overall body fat (PBF) was observed in in either group , male athletes (p = .566) or in female athletes (p = .962) at the end of the month of Ramadan (Table 1). In contrast, a significant decrease in body fat mass (BFM) was observed in male athletes (−4.111%, p = .031; −0.45, 95% CI [−0.78, −0.12), while no significant change was detected in female athletes (p = .577; −0.03, 95% CI [−0.44, 0.39]). A significant decrease in fat mass index (FMI) was observed among male athletes (-4.401%, p = .030). However, no change was detected in female athletes (p = .583). Finally, no significant variation in visceral fat area (VFA) was observed in either male (p = .152) or female athletes (p = .149) at the conclusion of the month of Ramadan.

At the end of the month of Ramadan, male athletes showed a significant decrease in trunk fat mass

(-6.510%, p = .011; −0.47, 95% CI [−0.80, −0.14]), left arm fat mass percentage (-6.149%, p = .039), trunk fat mass percentage (-6.582%, p = .017), as well as right (-4.374%, p = .041) and left (-4.363%, p= .042) leg fat percentages. Conversely, no substantial variation was observed in the segmental fat parameters of female athletes (p > .05). These changes correspond to large effect sizes (r = 0.63–0.74), presented in Appendix Table A2.

Table 1. Body Mass index and indices of adiposity and segmental distribution of Variation of anthropometric measurements and derived ratios

	Male athletes			Female athletes		
Parameters	Before RF (Mean ±sd)	End of RF (Mean ±sd)	p value	Before (Mean ±sd)	End of (Mean ±sd)	p value
Weight	63.8415 ± 6.94	63.5491 ± 7.06	.045	57.47 ± 6.79	56.97 ± 6.60	.006
Body Mass Index (BMI)	20.1113 ± 1.72	20.02 ± 1.88	.801	20.87 ± 2.44	20.75 ± 2.44	.002
Body Fat Mass (BFM)	7.0687 ± 2.78	6.7781 ± 2.78	.031	15.71 ± 4.81	15.65 ± 5.09	.577
Fat-Free Mass (FFM)	56.3925 ± 5.98	56.3792 ± 6.08	.936	41.76 ± 3.47	41.35 ± 3.24	.022
Percent Body Fat (PBF)	11.07 ± 3.84	10.66 ± 4.25	.566	26.88 ± 5.78	26.87 ± 6.24	.962
Fat Mass Index (FMI)	2.2342 ± .87	2.1358 ± .85	.030	5.72 ± 1.78	5.69 ± 1.87	.583
Visceral Fat Area (VFA)	26.0057 ± 16.10	25.0340 ± 16.63	.152	67.05 ± 24.33	68.77 ± 27.13	.149
Fat-Free Mass of Right Arm (FFM)	2.9506 ± .42	2.9594 ± .44	.566	1.91 ± .24	1.89 ± .24	.064
FFM% of Right Arm	98.8245 ± 8.44	99.4868 ± 9.13	.161	93.76 ± 7.38	93.64 ± 8.27	.829
Fat-Free Mass of Left Arm (FFM)	2.9381 ± .42	2.9536 ± .44	.313	1.89 ± .25	1.86 ± .25	.011
FFM% of Left Arm	98.3509 ± 8.13	99.2396 ± 8.89	.053	91.90 ± 7.54	91.13 ± 8.64	.094
Fat-Free Mass of Trunk (FFM)	24.2019 ± 2.45	24.2404 ± 2.52	.628	18.08 ± 1.53	17.93 ± 1.56	.008
FFM% of Trunk	101.7038 ± 5.33	102.2849 ± 5.89	.068	97.22 ± 5.61	96.93 ± 6.40	.293

Fat-Free Mass of Right Leg (FFM)	8.9891 ± .99	9.0253 ± .96	.566	6.53 ± .66	6.58 ± .66	.001
FFM% of Right Leg	107.8868 ± 7.43	109.3472 ± 8.12	.000	100.38 ± 7.68	101.50 ± 7.52	.001
Fat-Free Mass of Left Leg (FFM)	8.9191 ± .90	9.0089 ± .96	.013	6.53 ± .67	6.59 ± .66	.000
FFM% of Left Leg	107.7094 ± 7.52	109.1906 ± 8.44	.000	100.38 ± 7.74	101.96 ± 7.93	.000
Body Fat Mass of Right Arm (BFM)	.3196 ± .18	.3078 ± .18	.225	1.06 ± .38	1.06 ± .40	.906
BFM% of Right Arm	52.6570 ± 30.62	47.5744 ± 29.16	.085	108.49 ± 38.68	107.50 ± 40.24	.292
Body Fat Mass of Left Arm (BFM)	.3206 ± .17	.3077 ± .18	.275	1.07 ± .36	1.06 ± .38	.543
BFM% of Left Arm	51.8438 ± 28.71	48.6561 ± 28.30	.039	108.69 ± 36.68	109.38 ± 39.95	.659
Body Fat Mass of Trunk (BFM)	3.0118 ± 1.70	2.8157 ± 1.70	.011	7.66 ± 2.57	7.46 ± 2.74	.047
BFM% of Trunk	67.8029 ± 37.58	63.3404 ± 37.26	.017	134.48 ± 44.58	134.70 ± 49.25	.913
Body Fat Mass of Right Leg (BFM)	1.2510 ± .35	1.2230 ± .36	.178	2.51 ± .66	2.54 ± .76	.213
BFM% of Right Leg	69.9500 ± 20.06	66.8904 ± 18.08	.041	99.87 ± 24.83	100.34 ± 28.68	.710
Body Fat Mass of Left Leg (BFM)	1.2451 ± .35	1.2219 ± .35	.245	2.50 ± .66	2.54 ± .75	.134
BFM% of Left Leg	69.6073 ± 19.91	66.5702 ± 17.86	.042	99.73 ± 26.74	101.22 ± 29.98	.129

p significant at <.05, RF: Ramadan fasting

Variation of anthropometric measurements and derived ratios

The results are presented in Table 2. We found significant decreases at the end of the month of Ramadan on several parameters in athletes of both sexes. Waist-to-hip ratio (WHR) decreased by (−0.718 %, p = .026; r = 0.20, 95 % CI [0.03, 0.37]) in male athletes and (−1.078 %, p < .001; r = 0.27, 95 % CI [0.10, 0.44]) in female athletes, respectively. Hip circumference also decreased significantly in male (−0.232 %, p = .018; r = 0.21, 95 % CI [0.04, 0.38]) and females (−0.172 %, p = .022; r = 0.19, 95 % CI [0.02, 0.36]) athletes. Furthermore, arm circumferences decreased in female athletes (−0.430 %, p = .011; r = 0.22, 95 % CI [0.05, 0.39]) , while in male athletes, no significant variation was noted (p =.120). Concerning chest circumferences, a significant decrease was observed in female athletes (−0.632 %, p < .001; r = 0.25, 95 % CI [0.08, 0.42]), but no significant variation was found in male athletes (p = .774).

Table 2. Variation of anthropometric measurements and derived ratios.

Parameters	Male athletes			Female athletes		
	Before RF (Mean ±sd)	End of RF (Mean ±sd)	p value	Before RF (Mean ±sd)	End of RF (Mean ±sd)	p value
Waist-Hip Ratio (WHR)	.8009 ± .03	.7952 ± .03	.025	.85 ± .04	.85 ± .04	.000
Arm Circumference (AC)	28.2113 ± 1.94	28.0223 ± 1.96	.120	27.22 ± 1.98	27.10 ± 2.04	.011
Arm Muscle Circumference (AMC)	25.8348 ± 1.50	25.9462 ± 1.74	.248	23.39 ± 1.31	23.33 ± 1.31	.239
Circumference of Neck (CN)	35.2846 ± 1.48	35.4538 ± 1.66	.014	31.76 ± 1.37	31.83 ± 1.45	.325
Circumference of Chest (CC)	91.8594 ± 4.35	91.7906 ± 4.83	.774	85.82 ± 4.15	85.28 ± 4.20	.000
Circumference of Abdomen (CA)	73.7902 ± 4.01	73.3977 ± 4.34	.064	78.06 ± 6.38	77.22 ± 6.29	.000
Circumference of Hip (CH)	92.7377 ± 3.60	92.5226 ± 3.58	.018	91.19 ± 3.88	91.04 ± 3.99	.022
Circumference of Right Arm (CRA°	28.2755 ± 1.97	28.1792 ± 2.03	.127	27.31 ± 1.97	27.19 ± 2.04	.011
Circumference of Left Arm (CLA)	28.2113 ± 1.94	28.1302 ± 2.01	.171	27.22 ± 1.98	27.10 ± 2.04	.011
Circumference of Right Thigh (CRT)	49.8396 ± 2.67	49.6528 ± 2.59	.024	49.09 ± 2.65	49.03 ± 2.78	.459
Circumference of Left Thigh (CLT)	49.7434 ± 2.63	49.5660 ± 2.56	.028	48.98 ± 2.59	48.93 ± 2.74	.504

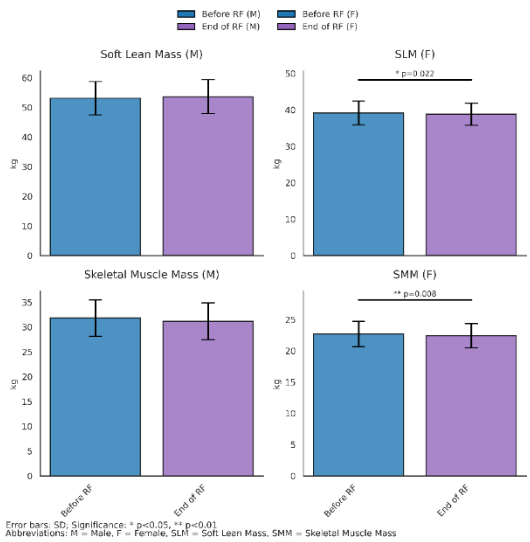
p significant at <.05, RF: Ramadan fasting

Finally, abdominal circumference decreased in female athletes by (−1.070 %, p < .001; r = 0.27, 95 % CI [0.10, 0.44]), with no significant change in male athletes (p = .064). As for right and left arm circumferences, a significant decrease was observed in female athletes (right arm: -0.429%, p = .011; left arm: -0.117%, p = .011), while in male athletes, no significant change was noted (p > .05). Finally, right and left thigh circumferences decreased significantly in male athletes (−0.357 %, p = .028; r = 0.19, 95 % CI [0.02, 0.36]), while in female athletes, no significant variation was observed (p >.05).

Lean body mass and skeletal muscle mass variations

Analysis of changes in lean body mass (LBM) and skeletal muscle mass (SMM) reveals distinct trends between the sexes during the Ramadan fast (Table 3). In male athletes, no significant variation in lean mass was observed (p = .816), nor in skeletal muscle mass (p = .801). In female athletes, on the other hand, lean body mass decreased significantly by (−0.98 %, p = .022; r = 0.19, 95 % CI [0.02, 0.36]), as did skeletal muscle mass (−1.19 %, p = .008; r = 0.21, 95 % CI [0.04, 0.38]). This analysis highlights significant increases in segmental lean mass (FFM) in men, with notable variations at the end of the month of Ramadan (Table 2). For segmental lean mass men showed a significant increase in legs, (right leg: +1.354%, p < .001; left leg: (+1.375 %, p < .001; r = 0.30, 95 % CI [0.13, 0.47]), but also an increase in left arm and trunk were noted left arm (+1.413 %, p = .011; r = 0.20, 95 % CI [0.03, 0.37]) ; trunk (+0.844 %, p = .008; r = 0.21, 95 % CI [0.04, 0.38]) . Regarding FFM, no significant variation was observed in women (p >.05).

Figure 1. Lean Body Mass and Skeletal Muscle Mass Variations (M vs. F Atheletes)



Body water compartmentalization and segmental fluid analysis

Total body water (TBW) and extracellular water (ECW) levels showed no significant variation in either sex at the end of the month of Ramadan (Table 3). Similarly, intracellular water (ICW) showed no significant change in either women (p = .758) or men (p = .758) ; r = 0.18, 95 % CI [0.01, 0.35]. Our results at ratio level show a significant increase in ECW/TBW and TBW/FFM in men (+0.447%, p = .003 for ECW/TBW; +0.111 %, p < .001; r = 0.28, 95 % CI [0.11, 0.45] ,for TBW/FFM), while in women, no significant variation was observed (p > .05).

The data presented in Table 3 show significant increases in TBW, ICW and ECW in the right and left legs for men (TBW: +1.034%, p = .016; r = 0.19, 95 % CI [0.02, 0.36]) and +1.060%, p = .011; ICW (+0.776 %, p = .043; r = 0.18, 95 % CI [0.01, 0.35]; ECW: (+1.489 %, p = .005; r = 0.21, 95 % CI [0.04, 0.38]) and +1.506%, p = .004).In women, no significant variation was observed in these parameters (p > .05). The ECW/TBW ratio of the legs also showed a significant increase in men for the right leg (+0.506%, p = .003), with no significant variation in women (p > .05). In women, there was no significant decrease in TBW, ICW and ECW of the arms and trunk (p > .05).

Table 3. Body water compartmentalization and segmental fluid analysis

	Male athletes			Female athletes		
Parameters	Before RF (Mean ±sd)	End of RF (Mean ±sd)	p value	End of RF (Mean ±sd)	Before RF (Mean ±sd)	p value
Total Body Water (TBW)	41.2208 ± 4.35	41.2717 ± 4.43	.672	30.48 ± 2.53	30.32 ± 2.49	.102
Intracellular Water (ICW)	25.9264 ± 2.81	25.9038 ± 2.85	.758	18.93 ± 1.57	18.72 ± 1.50	.008
Extracellular Water (ECW)	15.2943 ± 1.55	15.3679 ± 1.59	.163	11.55 ± .99	11.55 ± .93	.887
ECW/TBW	.3713 ± .01	.3729 ± .00	.003	.37905 ± .00	.38071 ± .00	.000
TBW/FFM	73.1075 ± .22	73.1887 ± .22	.000	72.99 ± .14	73.11 ± .16	.000
Total Body Water of Right Arm (TBW)	2.2926 ± .33	2.3006 ± .34	.514	1.49 ± .18	1.47 ± .18	.063
Total Body Water of Left Arm (TBW)	2.2509 ± .29	2.2785 ± .32	.135	1.47 ± .19	1.44 ± .19	.008
Total Body Water of Trunk (TBW)	18.7864 ± 1.89	18.8308 ± 1.95	.466	14.08 ± 1.19	13.92 ± 1.13	.015
Total Body Water of Right Leg (TBW)	6.9330 ± .71	7.0047 ± .75	.016	5.08 ± .51	5.12 ± .51	.000

Total Body Water of Left Leg (TBW)	6.9232 ± .70	6.9966 ± .75	.011	5.08 ± .52	5.14 ± .52	.000
Intracellular Water of Right Arm (ICW)	1.4368 ± .21	1.4392 ± .21	.734	.93 ± .12	.92 ± .12	.045
Intracellular Water of Left Arm (ICW)	1.4300 ± .21	1.4357 ± .21	.411	.91 ± .12	.90 ± .12	.006
Intracellular Water of Trunk (ICW)	11.8038 ± 1.22	11.8211 ± 1.26	.663	8.70 ± .70	8.61 ± .72	.003
Intracellular Water of Right Leg (ICW)	4.4002 ± .48	4.4343 ± .51	.043	3.16 ± .31	3.18 ± .31	.039
Intracellular Water of Left Leg (ICW)	4.3553 ± .44	4.3904 ± .47	.028	3.16 ± .32	3.18 ± .32	.002
Extracellular Water of Right Arm (ECW)	.8575 ± .13	.8637 ± .14	.242	.57 ± .08	.56 ± .07	.032
Extracellular Water of Left Arm (ECW)	.8521 ± .12	.8658 ± .14	.120	.56 ± .07	.54 ± .07	.004
Extracellular Water of Trunk (ECW)	6.9826 ± .68	7.0509 ± .76	.156	5.35 ± .45	5.32 ± .43	.148
Extracellular Water of Right Leg (ECW)	2.5725 ± .29	2.6108 ± .30	.005	1.92 ± .20	1.95 ± .20	.000
Extracellular Water of Left Leg (ECW)	2.5675 ± .26	2.6062 ± .29	.004	1.92 ± .21	1.96 ± .20	.000
ECW/TBW of Right Arm	.3735 ± .00	.3741 ± .00	.147	.38 ± .00	.38 ± .00	.964
ECW/TBW of Left Arm	.3735 ± .00	.3739 ± .00	.357	.38 ± .00	.38 ± .00	.837
ECW/TBW of Trunk	.3721 ± .00	.3725 ± .01	.390	.38 ± .00	.38 ± .00	.000
ECW/TBW of Right Leg	.3690 ± .01	.3709 ± .01	.003	.38 ± .01	.38 ± .01	.000
ECW/TBW of Left Leg	.3714 ± .01	.3727 ± .01	.102	.38 ± .01	.38 ± .00	.000

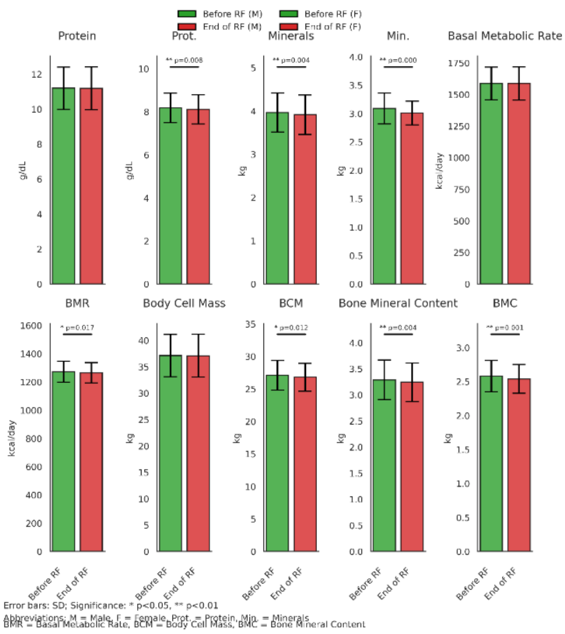
: p significant at <.05, RF: Ramadan fasting

Metabolic parameters and tissue composition

At the end of the month of Ramadan, male athletes showed a significant decrease in minerals (−1.511 %, p = .004; r = 0.19, 95 % CI [0.02, 0.36]) and bone mineral content (BMC) (−1.411 %, p = .004; r = 0.19, 95 % CI [0.02, 0.36]) (Table 5) Female athletes showed a significant decrease in minerals (-2.59% , p = .000) bone mineral content (BMC) (-1.55% , p = .001) , protein (-0.85% , p = .008), as well as body cell mass (BCM)

(-1.07%, p = .012).Basal metabolic rate (BMR) decreased significantly in female athletes (p = .017), while in male athletes it remained stable (p = .974). Finally, body cell mass (BCM) showed a slight, significant decrease in female athletes (-1.07%, p = .012), while in male athletes there was no change (p = .815).

Figure 2. Metabolic parameters and tissue composition



Discussion

The results of our study show a significant reduction in body weight in both male and female athletes at the end of the month of Ramadan, with respective reductions of - 0.458% (p =.045) and -.855% (p =.006). This change is probably attributable to caloric restriction and changes in eating habits associated with Ramadan fasting, in particular reduced meal frequency and reduced water intake (Maughan et al., 2010). In addition, body mass index (BMI) decreased significantly in female athletes, while no significant variation was observed in male athletes. This could be explained by differences in basal metabolism and nutritional coping strategies between the sexes, women potentially being more sensitive to caloric deficits (Bencharif et al., 2017).

Our results concur with the findings of several studies that have observed the decrease in body weight in athletes during Ramadan (Hamouda et al., 2019; Trabelsi et al., 2020; Aloui al., 2019). However, the variability of results found in the significant decrease of Ramadan on body mass index (BMI) in women, and stability in male athletes has also been noted by Bouhlel et al., 2006; Chennaoui et al., 2009; Meckel et al., 2008). These results highlight a gender-differentiated response. The absence of a non-fasting control group and precise diet/hydration records—limitations in our design—must be noted (Rev A).

With regard to general body fat indicators, no significant variation was observed in the percentage of overall body fat in either male or female athletes at the end of the month of Ramadan. However, a significant decrease in body fat mass (BFM) was noted in male athletes (-4.111%, p = 0.031), which was not observed in female athletes.

The results obtained are in line with those of Chaouachi et al. (2009), who observed a significant reduction in body fat in men, but not in women. In contrast, other studies, such as Fernando etal. (2019), found no significant difference in body fat, which could be explained by differences in training programs and dietary intake (Trabelsi et al., 2012; Chtourou et al., 2012).

Segmental body fat analysis revealed a statistically significant reduction in trunk fat mass (−6.510%, p = .011), left arm fat mass percentage (−6.149%, p = .039), and both right (−4.374%, p = .041) and left (−4.363%, p = .042) leg fat mass percentages among male athletes. In contrast, no significant changes were detected in female participants.

These findings align with existing literature demonstrating sex-specific differences in body composition alterations. Previous studies have reported similar declines in trunk and limb adiposity in male athletes (Aloui et al., 2019; Correia et al., 2019), whereas female athletes exhibited no substantial modifications in fat distribution during comparable periods (Memari et al., 2021; Trabelsi et al., 2020; Fernand et al., 2019).These observations suggest a preferential mobilization of lipid reserves in the trunk and limbs in men, possibly due to increased activation of lipolysis in these regions (Horowitz, 2007; Aloui et al., 2019), implying a different metabolic adaptation according to gender. In male athletes, the decrease in body fat mass (BFM) and localized fat mass (trunk and legs) suggests an increased mobilization of lipid reserves to meet energy needs, favored by a male hormonal profile (testosterone and low leptin) and increased metabolic sensitivity to caloric deficit. In female athletes, on the other hand, the absence of significant variation can be explained by protective hormonal mechanisms linked to oestrogen, which favours the conservation of lipid reserves ... particularly during periods of energy deficit. These differences reflect inter-sexual variability in physiological responses to prolonged fasting.

An analysis of changes in lean body mass (LBM) and skeletal muscle mass (SMM) revealed distinct gender trends during the Ramadan fast. No significant variation in lean mass in male athletes (p = .0816).) can be explained by a reduction in protein catabolism and a metabolic adaptation to fasting, which favours the mobilization of lipid reserves while preserving muscle proteins (Fenni et al., 2025). In female athletes, on the other hand, there was a significant decrease in lean body mass (-0.98%, p = 0.022) and skeletal muscle mass (-1.19%, p = 0.008). This discrepancy could be attributed to a heightened glucose dependence in women and a diminished anabolic protection resulting from reduced testosterone levels (Memari et al., 2011).

These results contrast with those of Chaouachi et al. (2009), who observed an increase in lean mass in men during Ramadan fasting, but align with those of Correia, et al. (2024), who reported a slight decrease in lean mass in male athletes during Ramadan, due to a reduction in protein intake. The difference could be due to variations in diet, exercise duration or training conditions. In terms of limitations, our sample consisted solely of young adults, restricting the generalizability of results to other populations, including older adults or children

The significant decrease in waist-to-hip ratio (WHR) in athletes of both sexes at the end of the month of Ramadan could indicate a redistribution of abdominal fat mass. These changes may be linked to improved insulin sensitivity and increased lipid mobilization during fasting periods (Nachvak et al., 2019; Al-Rawi et al., 2023; Trabelsi et al., 2021;). Previous studies have also indicated a reduction in body circumferences during Ramadan, consistent with our observations in female athletes (Saleh et al., 2005; Al-Jafar et al.,2023).However, results in male athletes showed some discrepancies. In particular, while some studies report notable decreases in limb circumferences (e.g., a reduction in fat mass and body mass in adult athletes during Ramadan (Nachvak et al., 2019; Al-Rawi et al., 2023), our data show an absence of significant variation in male arms. This could be explained by the difference in intensity of physical activities performed during this period, as suggested by recent studies on the effects of Ramadan fasting on body composition and physical performance (Correia et al., 2021; Faris et al., 2019). A limitation of our study lies in the difficulty of monitoring participants' exact dietary intake, despite the similarity of rations at the university restaurant. This limitation is also highlighted in other work , which shows that individual variations in energy and water intake can influence results, particularly with regard to lean and fat mass (Trabelsi et al., 2023; Aloui et al, 2019).

The lack of significant variation in TBW, ECW and ICW in both sexes suggests that Ramadan fasting, combined with sports training, does not critically alter overall water balance. These results concur with those of Maughan et al. (2010), who showed that hydration can be maintained during fasting through adequate management of fluid intake outside the fasting hours. However, the increased ECW/TBW and TBW/FFM ratios in men could indicate a slight redistribution of extracellular fluids, potentially due to metabolic adaptation or a different response to water-stressed training (Maughan & Shirreffs, 2010). These results partially diverge from those of Shirreffs and Sawka (2011), who reported a decrease in TBW in water-deficient athletes. A limitation of our study is the absence of strict control of water and food intake, which could influence the results. In addition, the duration of fasting (one month) may not be sufficient to observe more pronounced changes. The increase in TBW, ICW and ECW in the legs in men could reflect a physiological adaptation to water-stress training, with possible water retention in the stressed muscles (Ribeiro et al, 2014 ; Taniguchi, et al., 2020). However, the lack of variation observed in women indicates a gender-specific response, possibly attributable to hormonal or metabolic differences (Mitchell, 1992). Women appear to be better able to maintain their water balance under stress, a phenomenon that could be influenced by hormonal levels modulating body water distribution. The lack of detailed dietary and hydration records may confound these fluid findings

The results show a significant decrease in minerals was observed in men (-1.32%, $p = 0.004$) and women (-2.59%, $p < 0.001$), as well as bone mineral content (BMC) in men (-1.41%, $p = 0.004$) and women (-1.55%, $p = 0.001$). These findings contrast with studies by These findings contrast with some studies, such as those by Trabelsi et al. (2012) and Norouzy et al. (2016), which did not report significant bone loss during Ramadan fasting. This discrepancy could be attributed to differences in study populations, training protocols, or nutritional intakes, particularly calcium, which were not strictly controlled in our study. Al Zunaidy et al., 2024). On the other hand, our results align with those of Bahijri et al. (2015), who observed a reduction in bone mineral density in fasting adults, suggesting an impact of fasting on bone metabolism.

These losses could result from reduced calcium intake or hormonal changes (Shapses & Sukumar, 2012; Chaouachi et al., 2009). In men, a temporary drop in testosterone or an increase in the catabolic hormone cortisol could stimulate bone resorption by osteoclasts. In women, estrogen fluctuations linked to the hormonal cycle may also reduce bone formation by osteoblasts, accentuating this loss. Our data indicate a significant decrease in protein (-0.85%, $p = 0.008$) in women, while no significant variation was observed in men ($p = 0.784$). In addition, body cell mass (BCM) an indicator of active muscle mass, decreased significantly in women (-1.07%, $p = 0.012$), but not in men ($p = 0.815$). This loss of BCM is consistent with a reduction in lean body mass (LBM) and skeletal muscle mass (SMM), suggesting greater metabolic stress in women. These results align with those of Aloui et al. (2019), who reported slight muscle loss in female athletes during Ramadan, but contrast with Chaouachi et al. (2009), where men preserved their lean mass, probably thanks to adequate protein intakes.

Basal metabolic rate (BMR) remains stable in male athletes but decreases significantly in females, probably due to the slight loss of FFM. This reduction in women is probably linked to the loss of lean body mass, BMR being strongly correlated with the amount of metabolically active tissue (Alogaiel et al., 2025). In men, the stability of BMR, despite fat loss, could result from the preservation of lean mass and a metabolic adaptation favoring the use of lipids as an energy source.

The observed gender differences highlight distinct adaptive responses influenced by hormones and bone load (Weaver, 2016). However, limitations such as the absence of longitudinal measurements and some metabolic markers (Fernando et al., 2019) restrict the interpretation of our results, and individual variations within subjects may have influenced the observed changes in body composition. We suggest more in-depth hormonal analyses involved in the regulation of substrates and energy requirements, e.g. estrogen/testosterone ratio, free fatty acids (FFA), glycerol, leptin and ghrelin.

Absence of a control group, lack of precise dietary and hydration monitoring, and reliance on BIA under dehydration conditions limit generalizability. Future research should incorporate hormonal assays (e.g., estrogen/testosterone ratio, FFA, glycerol, leptin, ghrelin) and use DXA or MRI for more accurate body composition assessment.

Conclusions

The study reveals marked gender differences in body composition changes in university athletes during Ramadan fasting combined with varied training. Men showed a marked reduction in fat mass, with preservation of lean mass, reflecting a preferential mobilization of lipids. In women, a slight reduction in lean body mass and body circumference was observed, with no significant variation in fat mass, suggesting a more cautious metabolic adaptation. These results indicate distinct physiological responses, potentially linked to sex hormone factors, although water levels remain broadly stable in both groups.

These observations partially corroborate the existing literature on intermittent fasting, particularly the work showing increased lipolysis in men. However, lean mass loss in women diverges from some previous studies, possibly due to variations in training protocols or nutritional intakes. These differences underline the importance of considering gender when analyzing the effects of fasting.

On a practical level, men could benefit from caloric adjustment to maximize fat loss without compromising performance, while women would require increased protein and mineral intake to limit muscle breakdown. These strategies could optimize training management during Ramadan.Study limitations include the small sample size and short duration, which restrict the scope of the conclusions. The absence of hormonal measurements also limits interpretation of the underlying mechanisms. Future research should examine the long-term effects of intermittent fasting and incorporate hormonal analyses to clarify these gender-specific adaptations.

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References

Abaïdia, A. E., Daab, W., & Bouzid, M. A. (2020). Effects of Ramadan fasting on physical performance: A systematic review with meta-analysis. Sports Medicine, 50(6), 1009- 1026. https://doi.org/10.1007/s40279-020-01257-0

Aldobali, M., & Pal, K. (2021, July). Bioelectrical impedance analysis for evaluation of body composition: A review. In 2021 International Congress of Advanced Technology and Engineering (ICOTEN) (pp. 1-10). IEEE.

Al-Jafar, R., Wahyuni, N. S., Belhaj, K., Ersi, M. H., Boroghani, Z., Alreshidi, A., Alkhalaf, Z., Elliott, P., Tsilidis, K. K., & Dehghan, A. (2023). The impact of Ramadan intermittent fasting on anthropometric measurements and body composition: Evidence from LORANS study and a meta-analysis. Frontiers in Nutrition, 10, Article 1082217. https://doi.org/10.3389/fnut.2023.1082217

Al-Rawi, N., Madkour, M., Jahrami, H., Salahat, D., Alhasan, F., BaHammam, A., & Al- Islam Faris, M. (2023). Ramadan intermittent fasting is associated with ameliorated inflammatory markers and improved plasma sphingolipids/ceramides in subjects with obesity: Lipidomics analysis. Scientific Reports, 13(1), 43862.
https://doi.org/10.1038/s41598-023-43862-9

Al Zunaidy, N. A., Al-Khalifa, A. S., Alhussain, M. H., Althwab, S. A., Mohammed, M. A., & Faris, M. E. (2024). The effect of Ramadan intermittent fasting on anthropometric, hormonal, metabolic, inflammatory, and oxidative stress markers in pre- and post- menopausal women: A prospective cohort of Saudi women. Frontiers in Nutrition, 11, 1437169. https://doi.org/10.3389/fnut.2024.1437169

Alogaiel, D. M., Alsuwaylihi, A., Alotaibi, M. S., Macdonald, I. A., & Lobo, D. N. (2025). Effects of Ramadan intermittent fasting on hormones regulating appetite in healthy individuals: A systematic review and meta-analysis. Clinical Nutrition. https://doi.org/10.1016/j.clnu.2025.01.001

Aloui, A., Baklouti, H., Souissi, N., & Chtourou, H. (2019). Effects of Ramadan fasting on body composition in athletes: A systematic review. La Tunisie Médicale, 97(10), 1077- 1087.

Aloui, A., Chtourou, H., Briki, W., Tabben, M., Chaouachi, A., Souissi, N., & Chamari,
K. (2016). Rapid weight loss in the context of Ramadan observance: Recommendations for judokas. Biology of Sport, 33(4), 407-413.

Bahijri, S. M., Ajabnoor, G. M., & Chrousos, G. P. (2015). Effect of Ramadan fasting in Saudi Arabia on serum bone profile and immunoglobulins. Therapeutic Advances in Endocrinology and Metabolism, 6(5), 223-232.
https://doi.org/10.1177/204201881559452

Bencharif, M., Dahili, K., Benseghir, L., & Benabbas, Y. (2017). Effect of Ramadan fasting on diet and physical activity: Comparison by age and gender. Clinical Nutrition and Metabolism, 31(1), 11-17. https://doi.org/10.1016/j.nupar.2016.12.005

Bouhlel, E., Denguezli, M., Zaouali, M., Tabka, Z., & Shephard, R. J. (2008). Effect of Ramadan fasting on plasma concentrations of leptin, adiponectin and body composition in trained young men. International Journal of Sports Nutrition and Exercise Metabolism, 18(6), 617-627.

Chaouachi, A., Coutts, A. J., Chamari, K., Wong, D. P., Chaouachi, M., Chtara, M., Roky, R., & Amri, M. (2009). Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. Journal of Strength and Conditioning Research, 23(9), 2702-2709.
https://doi.org/10.1519/JSC.0b013e3181bc17fc

Chaouachi, A., Leiper, J. B., Chtourou, H., Aziz, A. R., & Chamari, K. (2012). The effects of Ramadan intermittent fasting on athletic performance: Recommendations for the maintenance of physical fitness. Journal of Sports Sciences, 30(Suppl 1), S53-S73. https://doi.org/10.1080/02640414.2012.698297

Chennaoui, M., Desgorces, F., Drogou, C., Boudjemaa, B., Tomaszewski, A., Depiesse, F., & Gomez-Merino, D. (2009). Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. Applied Physiology, Nutrition, and Metabolism, 34(4), 587-594.

Chtourou, H., Hammouda, O., Souissi, H., Chamari, K., Chaouachi, A., & Souissi, N. (2012). The effect of time-of-day and Ramadan fasting on anaerobic performances. International Journal of Sports Medicine, 33(2), 142-147. https://doi.org/10.1055/s- 0031-1286250

Cienfuegos, S., Corapi, S., Gabel, K., Ezpeleta, M., Kalam, F., Lin, S., Pavlou, V., & Varady, K. A. (2022). Effect of intermittent fasting on reproductive hormone levels in females and males: A review of human trials. Nutrients, 14(11), 2343.
https://doi.org/10.3390/nu14112343

Correia, J. M., Pezarat-Correia, P., Minderico, C., Infante, J., & Mendonca, G. V. (2024). Effects of time-restricted eating on aerobic capacity, body composition, and markers of metabolic health in healthy male recreational runners: A randomized crossover trial. Journal of the Academy of Nutrition and Dietetics, 124(8), 1041-1050.
https://doi.org/10.1016/j.jand.2024.01.005

Correia, J. M., Santos, I., Pezarat-Correia, P., Silva, A. M., & Mendonça, G. V. (2021). Effects of Ramadan and non-Ramadan intermittent fasting on body composition: A systematic review and meta-analysis. Frontiers in Nutrition, 7, Article 625240.
https://doi.org/10.3389/fnut.2020.625240
Faris, M., Jahrami, H. A., Alsibai, J., & Obaideen, A. A. (2019). Impact of Ramadan diurnal intermittent fasting on metabolic syndrome components in healthy, non-athletic Muslim people aged over 15 years: A systematic review and meta-analysis. British Journal of Nutrition, 122(10), 1-22. https://doi.org/10.1017/S000711451900254X
Fenni, Y., Ikiouane, M., Redjal, M., Remini, H., Allam, A., & Zaabar, S. (2025). The effects of Ramadan fasting on various physiological and biochemical parameters on Muslim soccer players. Apunts Sports Medicine, 60(225), 100467.
https://doi.org/10.1016/j.apunsm.2024.100467
Fernando, H. A., Zibellini, J., Harris, R. A., Seimon, R. V., & Sainsbury, A. (2019). Effect of Ramadan fasting on weight and body composition in healthy non-athlete adults: A systematic review and meta-analysis. Nutrients, 11(2), 478.
https://doi.org/10.3390/nu11020478
Gagnon, D., & Kenny, G. P. (2012). Sex differences in thermoeffector responses during exercise at fixed requirements for heat loss. Journal of Applied Physiology, 113(5), 746- 757. https://doi.org/10.1152/japplphysiol.00637.2012
Hamouda, O., Chtourou, H., Farjallah, M. A., & Souissi, N. (2019). The effect of Ramadan fasting on body composition and performance in professional soccer players. Biology of Sport, 36(4), 317-324.
Horowitz, J. F. (2007). Exercise-induced alterations in muscle lipid metabolism improve insulin sensitivity. Exercise and Sport Sciences Reviews, 35(4), 192-196.
https://doi.org/10.1097/jes.0b013e318156e084
Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Gómez, J. M., &
Pichard, C. (2004). Bioelectrical impedance analysis-Part I: Review of principles and methods. Clinical Nutrition, 23(5), 1226-1243.
https://doi.org/10.1016/j.clnu.2004.06.004
Liao, Y. S., Li, H. C., Lu, H. K., Lai, C. L., Wang, Y. S., & Hsieh, K. C. (2020).
Comparison of bioelectrical impedance analysis and dual energy X-ray absorptiometry for total and segmental bone mineral content with a three-compartment model. International Journal of Environmental Research and Public Health, 17(7), 2595.
https://doi.org/10.3390/ijerph17072595
Ling, C. H., de Craen, A. J., Slagboom, P. E., Gunn, D. A., Stokkel, M. P., Westendorp,
R. G., & Maier, A. B. (2011). Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in a middle-aged adult population. Clinical Nutrition, 30(5), 610-615.
https://doi.org/10.1016/j.clnu.2011.04.001
Martínez-Rodríguez, A., Rubio-Arias, J. A., García-De Frutos, J. M., Vicente-Martínez, M., & Gunnarsson, T. P. (2021). Effect of high-intensity interval training and intermittent fasting on body composition and physical performance in active women. International Journal of Environmental Research and Public Health, 18(12), 6431.
https://doi.org/10.3390/ijerph18126431
Maughan, R. J., Fallah, J., & Coyle, E. F. (2010). The effects of fasting on metabolism and performance. British Journal of Sports Medicine, 44(7), 490-494.
https://doi.org/10.1136/bjsm.2010.072181
Maughan, R. J., & Shirreffs, S. M. (2010). Dehydration and rehydration in competitive sport. Scandinavian Journal of Medicine & Science in Sports, 20(Suppl 3), 40-47.
McLester, C. N., Nickerson, B. S., Kliszczewicz, B. M., & McLester, J. R. (2020). Reliability and agreement of various InBody body composition analyzers as compared to dual-energy X-ray absorptiometry in healthy men and women. Journal of Clinical Densitometry, 23(3), 443-450.
Meckel, Y., Ismaeel, A., & Eliakim, A. (2008). The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. European Journal of Applied Physiology, 102(5), 651-657. https://doi.org/10.1007/s00421-007-0633-2

Memari, A. H., Kordi, R., Panahi, N., Nikookar, L. R., Abdollahi, M., & Akbarnejad, A. (2011). Effect of Ramadan fasting on body composition and physical performance in female athletes. Asian Journal of Sports Medicine, 2(3), 161-166. https://doi.org/10.5812/asjsm.34754

Merrigan, J., Stute, N., Eckerle, J., Mackowski, N., Walters, J., O'Connor, M., & Hagen, J. (2022). Reliability and validity of contemporary bioelectrical impedance analysis devices for body composition assessment. Journal of Exercise and Nutrition, 5(4).

Mitchell, J. H., Tate, C., Raven, P., Cobb, F., Kraus, W., Moreadith, R., & Wenger, N. (1992). Acute response and chronic adaptation to exercise in women. Medicine & Science in Sports & Exercise, 24(6), 258-265.

Nachvak, S. M., Pasdar, Y., Pirsaheb, S., Darbandi, M., Niazi, P., & Moghaddam, R. (2019). Effects of Ramadan on food intake, glucose homeostasis, lipid profiles and body composition. European Journal of Clinical Nutrition, 73(4), 594-600. https://doi.org/10.1038/s41430-018-0189-8

Norouzy, A., Salehi, M., Philippou, E., Arabi, H., Shiva, F., Mehrnoosh, S., ... & Nematy, M. (2016). Effect of fasting in Ramadan on body composition and nutritional intake: A prospective study. Journal of Human Nutrition and Dietetics, 29(3), 395-403. https://doi.org/10.1111/jhn.12357

Ribeiro, A. S., Avelar, A., Schoenfeld, B. J., Ritti Dias, R. M., Altimari, L. R., & Cyrino, E. S. (2014). Resistance training promotes increase in intracellular hydration in men and women. European Journal of Sport Science, 14(6), 578-585. https://doi.org/10.1080/17461391.2014.880192

Saleh, S. A., Elsharouni, S. A., Cherian, B., & Mourou, M. (2005). Effects of Ramadan fasting on waist circumference, blood pressure, lipid profile, and blood sugar on a sample of healthy Kuwaiti men and women. Malaysian Journal of Nutrition, 11(2), 143-150.

Scarbrough, C. (2023). The effects of intermittent fasting on female athletes: A systematic review. Mississippi State University.

Shapses, S. A., & Sukumar, D. (2012). Bone metabolism in obesity and weight loss. Annual Review of Nutrition, 32, 287-309. https://doi.org/10.1146/annurev.nutr.012809.104655

Shirreffs, S. M., & Sawka, M. N. (2011). Fluid and electrolyte needs for training, competition, and recovery. Journal of Sports Sciences, 29(S1), S39-S46. https://doi.org/10.1080/02640414.2011.614269

Smith, G. I., Yoshino, J., Reeds, D. N., Bradley, D., Burrows, R. E., Heisey, H. D., Moseley, A. C., & Mittendorfer, B. (2020). Testosterone and progesterone, but not estradiol, stimulate muscle protein synthesis in postmenopausal women. The Journal of Clinical Endocrinology & Metabolism, 99(1), 256-265. https://doi.org/10.1210/jc.2013- 2835

Stellingwerff, T., Morton, J. P., & Burke, L. M. (2019). A framework for periodized nutrition for athletics. International Journal of Sport Nutrition and Exercise Metabolism, 29(2), 141-151.

Taniguchi, M., Yamada, Y., & Ichihashi, N. (2020). Acute effect of multiple sets of fatiguing resistance exercise on muscle thickness, echo intensity, and extracellular-to- intracellular water ratio. Applied Physiology, Nutrition, and Metabolism, 45(2), 213-219. https://doi.org/10.1139/apnm-2018-0813

Trabelsi, K., Ammar, A., Boukhris, O., Glenn, J. M., Clark, C. C. T., Stannard, S. R., ... & Chtourou, H. (2020). Dietary intake and body composition during Ramadan in athletes: A systematic review and meta-analysis with meta-regression. Journal of the American College of Nutrition, 39(5), 457-473. https://doi.org/10.1080/07315724.2020.1715317

Trabelsi, K., El-Abed, K., & Hakim, A. (2012). Effects of Ramadan fasting on body water status markers after a rugby sevens match. Asian Journal of Sports Medicine, 2(3), 186-194. https://doi.org/10.5812/asjsm.34748

Trabelsi, K., Ammar, A., Boukhris, O., Glenn, J. M., Bott, N., Stannard, S. R., ... & Chtourou, H. (2024). Ramadan intermittent fasting and its association with health-related indices and exercise test performance in athletes and physically active individuals: An overview of systematic reviews. British Journal of Sports Medicine, 58(3), 136-143. https://doi.org/10.1136/bjsports-2023-107355

Weaver, C. M., Gordon, C. M., Janz, K. F., Kalkwarf, H. J., Lappe, J. M., Lewis, R., ... & Zemel, B. (2016). The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: A systematic review and implementation recommendations. Osteoporosis International, 27(4), 1281-1386.https://doi.org/10.1007/s00198-015-3440-3

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Appendix Table A1. Anthropometric Measurements and Derived Ratios

ANNEX: TABLES

Note: Each annex table lists pre- and post-values (mean ± SD), Cohen's d (or r), and 95 % CI for all parameters described above.

Parameter	Sex	Before Ramadan	End of Ramadan	p	Effect Size	95 % CI
Weight (kg)	M	63.84 ± 6.94	63.55 ± 7.06	.045	−0.32	[−0.58, −0.06]
	F	57.47 ± 6.79	56.97 ± 6.60	.006	−0.48	[−0.79, −0.17]
BMI (kg/m^2)	M	20.11 ± 1.72	20.02 ± 1.88	.801	−0.02	[−0.31, 0.26]
	F	20.87 ± 2.44	20.75 ± 2.44	.002	−0.42	[−0.72, −0.12]
Body Fat Mass (kg)	M	7.07 ± 2.78	6.78 ± 2.78	.031	−0.45	[−0.78, −0.12]
	F	15.71 ± 4.81	15.65 ± 5.09	.577	−0.03	[−0.44, 0.39]
Fat-Free Mass (kg)	M	56.39 ± 5.98	56.38 ± 6.08	.936	−0.01	[−0.33, 0.31]
	F	41.76 ± 3.47	41.35 ± 3.24	.022	−0.50	[−0.82, −0.17]
Percent Body Fat (%)	M	11.07 ± 3.84	10.66 ± 4.25	.566	−0.11	[−0.42, 0.20]
	F	26.88 ± 5.78	26.87 ± 6.24	.962	−0.003	[−0.33, 0.33]
Fat Mass Index (kg/m^2)	M	2.23 ± 0.87	2.14 ± 0.85	.030	−0.43	[−0.76, −0.11]
	F	5.72 ± 1.78	5.69 ± 1.87	.583	−0.02	[−0.32, 0.28]
Visceral Fat Area (cm^2)	M	26.01 ± 16.10	25.03 ± 16.63	.152	−0.10	[−0.41, 0.21]
	F	67.05 ± 24.33	68.77 ± 27.13	.149	−0.09	[−0.40, 0.22]
Waist-Hip Ratio (WHR)	M	0.8009 ± 0.03	0.7952 ± 0.03	.025	−0.33	[−0.60, −0.06]
	F	0.8500 ± 0.04	0.8407 ± 0.04	< .001	−0.55	[−0.82, −0.28]
Arm Circumference (cm)	M	28.21 ± 1.94	28.02 ± 1.96	.120	−0.14	[−0.43, 0.15]
	F	27.22 ± 1.98	27.10 ± 2.04	.011	−0.29	[−0.54, −0.04]
Arm Muscle Circumference (cm)	M	25.83 ± 1.50	25.95 ± 1.74	.248	+0.10	[−0.19, 0.39]
	F	23.39 ± 1.31	23.33 ± 1.31	.239	−0.11	[−0.40, 0.18]
Neck Circumference (cm)	M	35.28 ± 1.48	35.45 ± 1.66	.014	+0.30	[0.01, 0.59]
	F	31.76 ± 1.37	31.83 ± 1.45	.325	+0.05	[−0.26, 0.36]
Chest Circumference (cm)	M	91.86 ± 4.35	91.79 ± 4.83	.774	−0.02	[−0.32, 0.28]
	F	85.82 ± 4.15	85.28 ± 4.20	< .001	−0.40	[−0.66, −0.14]
Abdominal Circumference (cm)	M	73.79 ± 4.01	73.40 ± 4.34	.064	−0.18	[−0.48, 0.12]
	F	78.06 ± 6.38	77.22 ± 6.29	< .001	−0.43	[−0.69, −0.17]
Hip Circumference (cm)	M	92.74 ± 3.60	92.52 ± 3.58	.018	−0.27	[−0.52, −0.02]
	F	91.19 ± 3.88	91.04 ± 3.99	.022	−0.26	[−0.51, −0.01]
Right Arm Circumference (cm)	M	28.28 ± 1.97	28.18 ± 2.03	.127	−0.12	[−0.42, 0.18]
	F	27.31 ± 1.97	27.19 ± 2.04	.011	−0.29	[−0.54, −0.04]
Left Arm Circumference (cm)	M	28.21 ± 1.94	28.13 ± 2.01	.171	−0.10	[−0.40, 0.20]
	F	27.22 ± 1.98	27.10 ± 2.04	.011	−0.29	[−0.54, −0.04]
Right Thigh Circumference (cm)	M	49.84 ± 2.67	49.65 ± 2.59	.024	−0.34	[−0.60, −0.08]
	F	49.09 ± 2.65	49.03 ± 2.78	.459	−0.04	[−0.32, 0.24]
Left Thigh Circumference (cm)	M	49.74 ± 2.63	49.57 ± 2.56	.028	−0.32	[−0.58, −0.06]
	F	48.98 ± 2.59	48.93 ± 2.74	.504	−0.03	[−0.31, 0.25]

Appendix Table A2. Segmental Fat-Free Mass (FFM) and Fluid Compartments (Right/Left Leg, Right/Left Arm, Trunk)

Parameter	Sex	Before Ramadan	End of Ramadan	p	Effect Size	95 % CI
FFM Right Leg (kg)	M	8.99 ± 0.99	9.03 ± 0.96	< .001	0.45	[0.18, 0.72]
	F	6.53 ± 0.66	6.58 ± 0.66	.001	0.44	[0.17, 0.71]
FFM Left Leg (kg)	M	8.92 ± 0.90	9.01 ± 0.96	< .001	0.47	[0.20, 0.74]
	F	6.53 ± 0.67	6.59 ± 0.66	.000	0.46	[0.19, 0.73]
FFM Left Arm (kg)	M	2.94 ± 0.42	2.95 ± 0.44	.011	0.41	[0.12, 0.70]
	F	1.89 ± 0.25	1.86 ± 0.25	.011	−0.29	[−0.54, −0.04]
FFM Trunk (kg)	M	24.20 ± 2.45	24.24 ± 2.52	.008	0.38	[0.10, 0.66]
	F	18.08 ± 1.53	17.93 ± 1.56	.008	−0.30	[−0.55, −0.05]
TBW Right Leg (L)	M	6.93 ± 0.71	7.00 ± 0.75	.016	0.31	[0.05, 0.57]
	F	5.08 ± 0.51	5.12 ± 0.51	.000	0.51	[0.25, 0.77]
TBW Left Leg (L)	M	6.92 ± 0.70	6.996 ± 0.75	.011	0.33	[0.07, 0.59]
	F	5.08 ± 0.52	5.14 ± 0.52	.000	0.53	[0.27, 0.79]
ICW Right Leg (L)	M	4.40 ± 0.48	4.43 ± 0.51	.043	0.29	[0.03, 0.55]
	F	3.16 ± 0.31	3.18 ± 0.31	.039	0.27	[0.01, 0.53]
ICW Left Leg (L)	M	4.36 ± 0.44	4.39 ± 0.47	.028	0.30	[0.04, 0.56]
	F	3.16 ± 0.32	3.18 ± 0.32	.002	0.51	[0.25, 0.77]
ECW Right Leg (L)	M	2.57 ± 0.29	2.61 ± 0.30	.005	0.37	[0.10, 0.64]
	F	1.92 ± 0.20	1.95 ± 0.20	.000	0.54	[0.28, 0.80]
ECW Left Leg (L)	M	2.57 ± 0.26	2.61 ± 0.29	.004	0.38	[0.11, 0.65]
	F	1.92 ± 0.21	1.96 ± 0.20	.000	0.56	[0.30, 0.82]
ECW/TBW Right Leg	M	0.3690 ± 0.01	0.3709 ± 0.01	.003	0.36	[0.09, 0.63]
	F	0.380 ± 0.01	0.380 ± 0.01	.000	0.58	[0.32, 0.84]
ECW/TBW Left Leg	M	0.3714 ± 0.01	0.3727 ± 0.01	.102	0.18	[−0.08, 0.44]
	F	0.379 ± 0.00	0.379 ± 0.00	.000	0.55	[0.29, 0.81]
TBW Right Arm (L)	M	2.29 ± 0.33	2.30 ± 0.34	.514	0.08	[−0.18, 0.34]
	F	1.49 ± 0.18	1.47 ± 0.18	.063	−0.28	[−0.54, −0.02]
TBW Left Arm (L)	M	2.25 ± 0.29	2.28 ± 0.32	.135	0.19	[−0.07, 0.45]
	F	1.47 ± 0.19	1.44 ± 0.19	.008	−0.31	[−0.57, −0.05]
TBW Trunk (L)	M	18.79 ± 1.89	18.83 ± 1.95	.466	0.07	[−0.19, 0.33]
	F	14.08 ± 1.19	13.92 ± 1.13	.015	−0.28	[−0.54, −0.02]
ICW Right Arm (L)	M	1.44 ± 0.21	1.44 ± 0.21	.734	0.05	[−0.21, 0.31]
	F	0.93 ± 0.12	0.92 ± 0.12	.045	−0.22	[−0.48, 0.04]
ICW Left Arm (L)	M	1.43 ± 0.21	1.44 ± 0.21	.411	0.10	[−0.16, 0.36]
	F	0.91 ± 0.12	0.90 ± 0.12	.006	−0.26	[−0.52, −0.00]
ICW Trunk (L)	M	11.80 ± 1.22	11.82 ± 1.26	.663	0.04	[−0.22, 0.30]
	F	8.70 ± 0.70	8.61 ± 0.72	.003	−0.28	[−0.54, −0.02]
ECW Right Arm (L)	M	0.86 ± 0.13	0.86 ± 0.14	.242	0.15	[−0.11, 0.41]
	F	0.57 ± 0.08	0.56 ± 0.07	.032	−0.27	[−0.53, −0.01]
ECW Left Arm (L)	M	0.85 ± 0.12	0.87 ± 0.14	.120	0.20	[−0.06, 0.46]
	F	0.56 ± 0.07	0.54 ± 0.07	.004	−0.32	[−0.58, −0.06]
ECW Trunk (L)	M	6.98 ± 0.68	7.05 ± 0.76	.156	0.27	[−0.01, 0.53]
	F	5.35 ± 0.45	5.32 ± 0.43	.148	−0.07	[−0.33, 0.19]
ECW/TBW Right Arm	M	0.3735 ± 0.00	0.3741 ± 0.00	.147	0.12	[−0.14, 0.38]
	F	0.38 ± 0.00	0.38 ± 0.00	.964	0.01	[−0.25, 0.27]
ECW/TBW Left Arm	M	0.3735 ± 0.00	0.3739 ± 0.00	.357	0.08	[−0.18, 0.34]
	F	0.38 ± 0.00	0.38 ± 0.00	.837	0.00	[−0.26, 0.26]
ECW/TBW Trunk	M	0.3721 ± 0.00	0.3725 ± 0.01	.390	0.10	[−0.16, 0.36]
	F	0.38 ± 0.00	0.38 ± 0.00	.000	0.58	[0.32, 0.84]

Appendix Table A3. Lean Body Mass (SLM) and Skeletal Muscle Mass (SMM) Variations

Parameter	Sex	Before Ramadan	End of Ramadan	p	Effect Size	95 % CI
Soft Lean Mass (kg)	M	53.10 ± 5.63	53.61 ± 5.74	.816	−0.03	[−0.35, 0.29]
	F	39.16 ± 3.25	38.81 ± 3.05	.022	−0.50	[−0.82, −0.17]
Skeletal Muscle Mass (kg)	M	31.81 ± 3.66	31.19 ± 3.71	.801	−0.04	[−0.36, 0.28]
	F	22.69 ± 2.05	22.42 ± 1.95	.008	−0.52	[−0.86, −0.18]

Appendix Table A4. Metabolic Parameters and Tissue Composition

Parameter	Sex	Before Ramadan	End of Ramadan	p	Effect Size	95 % CI
Protein (kg)	M	11.20 ± 1.21	11.19 ± 1.23	.784	−0.02	[−0.28, 0.24]
	F	8.18 ± 0.68	8.11 ± 0.68	.008	−0.37	[−0.64, −0.10]
Minerals (kg)	M	3.97 ± 0.45	3.91 ± 0.46	.004	−0.41	[−0.68, −0.14]
	F	3.09 ± 0.27	3.01 ± 0.21	< .001	−0.48	[−0.75, −0.21]
BMR (kcal/d)	M	1,588.04 ± 129.29	1,587.92 ± 131.19	.974	−0.01	[−0.27, 0.25]
	F	1,271.88 ± 74.95	1,264.61 ± 70.91	.017	−0.31	[−0.58, −0.04]
BCM (kg)	M	37.13 ± 4.02	37.11 ± 4.07	.815	−0.01	[−0.27, 0.25]
	F	27.10 ± 2.25	26.81 ± 2.14	.012	−0.35	[−0.62, −0.08]
BMC (kg)	M	3.29 ± 0.38	3.24 ± 0.37	.004	−0.39	[−0.66, −0.12]
	F	2.58 ± 0.23	2.54 ± 0.21	.001	−0.43	[−0.70, −0.16]

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