The impact of Ramadan fasting on hematopoiesis, hematological inflammatory parameters, and metabolic processes among athletes

El impacto del ayuno del Ramadán en la hematopoyesis, los parámetros inflamatorios hematológicos y los procesos metabólicos entre los atletas

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Abstract

Introduction: Muslim athletes fast from dawn to sunset during the month of Ramadan, prompting research into how this fasting affects their physiology and performance.
Objective: This study aimed to evaluate the impact of Ramadan fasting on anthropometric parameters, hematological and inflammatory markers, and metabolic processes in a cohort of athletes, given the inconsistent findings from previous studies and limited focus on immune system effects.
Methodology: This research was conducted on 15 fasted Jordanian national players who maintained their regular training sessions. Anthropometry, blood elements, inflammatory parameters, lipid profiles, and kidney functions were measured the day before and the day after Ramadan fasting.
Results: Analyses showed that weight, body fat mass, neutrophils, hematological inflammatory parameters, cholesterol, triglyceride, and low-density lipoprotein were significantly lower after Ramadan fasting; body mass index, body fat percentage, lean body mass, and blood volume displayed a trend of reduction, while lymphocytes were significantly higher. There were no changes in erythrocyte indices and kidney function tests.
Conclusion: These findings indicate that Ramadan fasting leads to weight loss, improved cardiovascular health, and modification in immune response dynamics in athletes. Further studies are required to elucidate the mechanisms underlying these effects.

Keywords

Hematological inflammatory parameters; hematopoiesis; metabolic processes; sports nutrition; sports physiology.

Resumen

Introducción: Los atletas musulmanes ayunan desde el amanecer hasta el atardecer durante el mes de Ramadán, lo que impulsó la investigación sobre cómo este ayuno afecta su fisiología y rendimiento.
Objetivo: Este estudio tuvo como objetivo evaluar el impacto del ayuno de Ramadán en los parámetros antropométricos, los marcadores hematológicos e inflamatorios y los procesos metabólicos en una cohorte de atletas, dados los hallazgos inconsistentes de estudios previos y el enfoque limitado en los efectos del sistema inmunológico.
Metodología: Esta investigación se realizó en 15 jugadores nacionales jordanos en ayunas que mantuvieron sus sesiones de entrenamiento regulares. La antropometría, los elementos sanguíneos, los parámetros inflamatorios, los perfiles lipídicos y las funciones renales se midieron el día antes y el día después del ayuno de Ramadán.
Resultados: Los análisis mostraron que el peso, la masa grasa corporal, los neutrófilos, los parámetros inflamatorios hematológicos, el colesterol, los triglicéridos y las lipoproteínas de baja densidad fueron significativamente más bajos después del ayuno de Ramadán; el índice de masa corporal, el porcentaje de grasa corporal, la masa corporal magra y el volumen sanguíneo mostraron una tendencia a la reducción, mientras que los linfocitos fueron significativamente más altos. No hubo cambios en los índices de eritrocitos y las pruebas de función renal.
Conclusión: Estos hallazgos indican que el ayuno del Ramadán conduce a la pérdida de peso, mejora la salud cardiovascular y modifica la dinámica de la respuesta inmunitaria en los deportistas. Se requieren más estudios para dilucidar los mecanismos subyacentes a estos efectos.

Palabras clave

Parámetros inflamatorios hematológicos; hematopoyesis; procesos metabólicos; nutrición deportiva; fisiología deportiva.

Introduction

Millions of Muslims around the world commemorate Ramadan (29 to 30 days), a holy month during which they fast from down to sunset, abstaining from food and drink. The daily fasting period ranges from 12 to 18 hours, depending on geographical location (Osman et al., 2020). Ramadan fasting alters the schedule of food and fluid intake, as well as the composition and energy balance of the diet (Osman et al., 2020; Trabelsi et al., 2023). Ramadan fasting presents some difficulties for athletes because it necessitates modifying their training and eating schedules. Athletes continue to be interested in and concerned about how fasting affects various physiological processes.

Hematopoiesis, the formation of blood cells, is a crucial aspect of an athlete's performance. Fasting during Ramadan involves prolonged periods without nutrient intake, potentially affecting the body's ability to maintain optimal production of erythrocytes, leukocytes, and platelets (Hosseini & Hejazi, 2013). Studies investigating the impact of Ramadan fasting on hematopoiesis have shown conflicting results. Hematocrit and hemoglobin have been observed to rise (Trabelsi et al., 2011a), fall (Hosseini & Hejazi, 2013), or remain unchanged (Tayebi et al., 2010) throughout Ramadan fasting. In addition to hematopoiesis, Ramadan fasting may influence inflammatory parameters, providing insights into the athlete's immune response. Limited studies have explored the effects of fasting on inflammation markers. C-reactive protein (CRP), tumor necrosis factor-alpha (TNF-α), interleukin (IL)-1β, and IL-6 levels decreased following Ramadan fasting in healthy and diseased conditions (Adawi et al., 2017; Kurniawati et al.; 2024; Okawa et al., 2021). Understanding these changes is crucial for athletes, as alterations in inflammatory parameters may impact recovery, injury susceptibility, and overall performance.

Several studies indicated that restricted water consumption during Ramadan fasting may increase the risk of dehydration (Ibrahim et al., 2018; Osman et al., 2020; Trabelsi et al., 2023; Trabelsi et al., 2011b). Thus, there might be a change in kidney function that results in the body reabsorbing water rather than excreting it to maintain fluid balance (Ibrahim et al., 2018; Osman et al., 2020). Studies have revealed that serum osmolality generally remains normal due to homeostatic mechanisms (Ibrahim et al., 2018; Mustafa et al., 1978; Trabelsi et al., 2011b), while other indicators like hematocrit and urine osmolality suggest dehydration (Bouhlel et al., 2006; Trabelsi et al., 2011b). The hydration state is greatly affected by non-fasting hours of physical activity and water consumption patterns (Osman et al., 2020; Trabelsi et al., 2023; Trabelsi et al., 2011b). There is disagreement on whether fasting during Ramadan leads to acute or chronic dehydration, despite some evidence of inadequate fluid intake (Mustafa et al., 1978; NasrAllah & Osman, 2014). There has been conflicting evidence on the effects of Ramdan fasting on renal function. While some studies have found slight variations in serum urea, creatinine, electrolytes, and estimated glomerular filtration rate (eGFR), no long-term negative health impacts have been identified in other studies (Eldeeb et al., 2020; Mustafa et al., 1978; NasrAllah & Osman, 2014).

Metabolic processes are intricately linked to an athlete's energy levels and overall performance. During Ramadan, meal patterns and compositions change, typically reduced from three or more to two main meals: Suhoor before dawn and Iftar at sunset. These changes affect energy and nutrient intake, varying widely across cultures and geographical locations. Studies showed increased or decreased consumption of carbohydrate-rich foods, while others reported a high or low intake of fat and proteins (Osman et al., 2020; Trabelsi et al., 2023). Studies on the impact of Ramadan on body composition have yielded inconsistent findings. Some studies indicated decreases in body weight, body mass index, and body fat mass (Fernando et al., 2019; Trabelsi et al., 2023), whereas others showed no changes in body composition (Trabelsi et al., 2020). Several researchers reported a significant decrease in total cholesterol, low-density lipoprotein cholesterol (LDL-C), and triglyceride levels in individuals observing Ramadan fasting (Ajibola et al., 2021; Akhtar et al., 2020). Conversely, Chaouachi et al. (2008) showed an increase in different lipid parameters. A thorough investigation into these metabolic changes is vital for athletes to optimize training and maintain peak performance during Ramadan.

The influence of Ramadan fasting on hematological and metabolic parameters in athletes requires additional investigation due to conflicting findings in the previous studies. Furthermore, there is limited understanding of the effects of Ramadan fasting on the immune system, and previous studies have not employed hematological inflammatory parameters in this context. Hence, employing rigorous criteria for participant recruitment and monitoring, the current study sought to evaluate the impacts of Ramadan fasting on hematological and inflammatory markers and metabolic processes in a cohort of athletes.

Method

Design and participants

This observational cohort pre-post study was conducted during the month of Ramadan (March-April 2022) on a sample of healthy males who observed an average fast of 15 hours daily for 30 days. Initial recruitment targeted 23 healthy volunteers, specifically Jordanian national boxing and wrestling players, aged between 18 to 22 years. Inclusion criteria involved healthy athletes with a minimum training frequency of three times a week and training experience of at least three years. Exclusion criteria included individuals with chronic diseases (2 subjects), acute infections (1 subject), those receiving any medical treatments (2 subjects), smokers, participants who failed to complete the full month of fasting (1 subject), those who lost the initial examination (1 subject), or participants who lost to follow-up (1 subject). At the end, the study was successfully completed with a total of 15 participants, comprising 8 boxing players and 7 wrestling players. All participants continued their regular training program with three to four training sessions each week throughout the month of Ramadan. This research was conducted in accordance with the Declaration of Helsinki and received approval from the Scientific Research Ethics Committee at the University of Jordan (Number: 19/2021/310). Written informed consent was obtained from all subjects participating in this research.

Anthropometric and hemodynamic measurements

Anthropometric and hemodynamic parameters were evaluated one day before the commencement of Ramadan fasting (pre-fasting) and one day after the accomplishment of Ramadan fasting (post-fasting). Body mass was measured using a calibrated electronic scale, and body mass index (BMI) was calculated as weight (kg) / height (m2). Blood pressure and heart rate were measured using digital devices. Body fat percentage (BFP), body fat mass (BFM), and lean body mass (LBM) were calculated using the following formulas: LBM = Weight (kg) – BFM, BFM = BFP / 100 x weight (kg), and BFP = (1.20 x BMI) + (0.23 x Age) - 16.2 (Deurenberg et al., 1991).

Blood sample collection and laboratory analysis

A total of eight mL venous blood samples were collected from each participant before and after Ramadan fasting. For both sets of blood samples, participants fasted for a minimum of 10 hours overnight before the blood collection. Three mL venous blood was collected into Ethylenediaminetetraacetic acid (EDTA) for performing a complete blood count (CBC) using the Beckman Coulter (Danaher Corporation) machine in MEGALAB laboratories (Amman, Jordan) according to the standard manufacturer's guidance. CBC parameters included RBCs, red blood cells; PCV, packed cell volume; hemoglobin; MCV, mean corpuscular volume; MCHC, mean corpuscular hemoglobin concentration; MCH, mean corpuscular hemoglobin; WBCs, white blood cells; differential WBC counts; platelets; and MPV, mean platelet volume. Hematological inflammatory markers were derived from CBC parameters as follows: neutrophil-to-lymphocyte ratio (NLR); monocyte-to-lymphocyte ratio (MLR); platelet to lymphocyte ratio (PLR); systemic inflammatory index (SII), platelet × NLR; systemic inflammatory response index (SIRI), monocyte × NLR; aggregate index of systemic inflammation (AISI), neutrophil × platelet× MLR (Haybar et al., 2019; Song et al., 2023; Zhu et al., 2022). On the other hand, five mL venous blood was collected into plain tubes for performing biochemical variables, including fast blood sugar (FBS), kidney function tests (urea, creatinine, sodium (Na), potassium (K), and total protein levels) and lipid profiles (cholesterol, triglyceride, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). The biochemical panels were performed using the Cobas C303 (Roche Diagnostics) machine in MEGALAB laboratories according to the standard manufacturer's guidance. To evade day-to-day laboratory variations, all samples were analyzed in a single batch within 4 hours of blood collection. Blood osmolality (OSMc) was calculated using the formula: 1.86 (Na + K) + 1.15 (glucose / 18) + (Urea / 6) + 14 mmol/kg (Martín-Calderón et al., 2015). Estimated Glomerular Filtration Rate (eGFR) was calculated as follows: 175 x serum creatinine - 1.154 x age - 0.203 ml/min/1.73 m^2 (Mula-Abed et al., 2012). Blood volume and blood plasma volume were calculated as follows: blood volume, weight (kg) × 70 mL/kg; and blood plasma volume, blood volume (mL) × (1.0 - PCV) (Harmening, 2018).

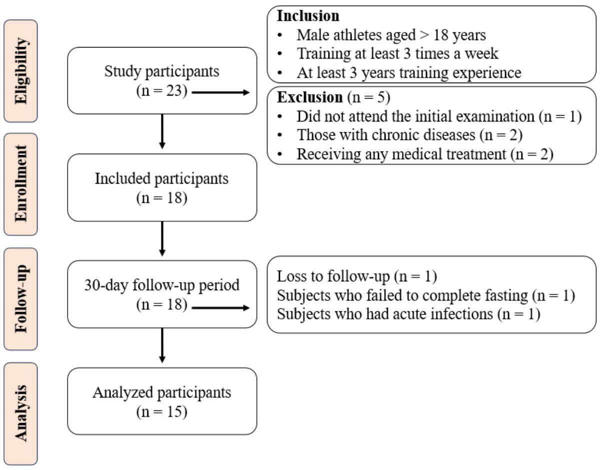
Statistical analysis

Statistical analysis was performed using Prism 9.4 software (GraphPad Software, Inc). Normality tests were performed using Anderson-Darling, Shapiro-Wilk, and D'Agostino & Pearson tests. Paired two-tailed student's t-test was used to compare pre-and post-blood samples for parametric data, and the Wilcoxon test was applied for nonparametric data. Data were presented as mean ± standard deviation (SD) for parametric data, while nonparametric data were presented as the median and interquartile range (IQR). P < 0.05 was defined as statistically significant.

Results

A total of 15 participants were early adulthood males (aged between 18 and 22 years) to reduce biological discrepancies related to gender and age. Figure 1 shows the recruitment flowchart for this study. The outcome variables were measured for all participants to identify any differences between before Ramadan fasting (one day before the first day of Ramadan) and one day after the accomplishment of Ramadan fasting (post-fasting).

Figure 1. Schematic depiction of the participant recruitment.



Effects of Ramadan fasting on anthropometric and hemodynamic parameters

Analysis revealed notable changes in various anthropometric parameters following Ramadan fasting (Table 1). Participants showed a statistically significant decrease in weight, shifting from an initial mean of 71.40 kg to a post-fasting mean of 69.80 kg (p=0.0389). A reduction in body fat mass (BFM) was also observed, with values decreasing from 9.55 kg to 8.75 kg (p=0.0247). While the decrease in body mass index (BMI), body fat percentage (BFP), and lean body mass (LBM) did not reach statistical significance (p≈0.06), there was a trend towards significance. On the other hand, there was no difference in blood pressure and heart rate. These results suggest potential alterations in body composition during Ramadan fasting, even though the observed changes in BMI, BFP, and LBM did not reach the conventional threshold for statistical significance.

Table 1. Anthropometric and hemodynamic data of participants before and after Ramadan fasting

Variable	Before (n=15)	After (n=15)	*P* Value (Statistical test)
Weight (kg), mean (SD)	71.40 (12.70)	69.80 (12.04)	**0.0389** (P)
Body mass index (kg/m^2), median (IQR)	22.10 (19.5-24.7)	21.05 (19.2-24.1)	0.0617 (W)
Body fat percentage (%), median (IQR)	15.15 (12.1-18.3)	13.89 (11.6-17.6)	0.0617 (W)
Body fat mass (kg), median (IQR)	9.55 (7.6-14.8)	8.75 (6.5-13.9)	**0.0247** (W)
Lean body mass (kg), mean (SD)	59.63 (7.502)	58.70 (7.026)	0.0601 (P)
Systolic blood pressure (mmHg), median (IQR)	112.0 (106-122)	116.0 (105-120)	0.8611 (W)
Diastolic blood pressure (mmHg), mean (SD)	71.53 (4.068)	72.40 (6.104)	0.3190 (P)
Heart rate (BPM), mean (SD)	65.93 (8.787)	67.07 (7.573)	0.3087 (P)

P indicates Paired student's t-test; W, Wilcoxon test; SD, standard deviation; and IQR, interquartile range.
P < 0.05 was defined as statistically significant.
Bold values indicate statistical significance.

Effects of Ramadan fasting on hematological parameters

Analysis of hematological parameters before and after Ramadan fasting indicated that most of these measures did not exhibit statistically significant differences (Table 2). RBCs, Hemoglobin, PCV, MCH, MCHC, RDW, WBCs, platelets, and MPV demonstrated no significant changes between the pre-and post-fasting periods. However, notable alterations were observed in neutrophil and lymphocyte counts, showing statistically significant changes after Ramadan fasting. Neutrophils decreased from 3.0 to 2.5 (p=0.0423), while lymphocytes increased from 2.02 to 2.30 (p=0.0387). These findings suggest potential modifications in the immune response during the fasting period.

Table 2. Complete blood count data of participants before and after Ramadan fasting

Variable	Before (n=15)	After (n=15)	*P* Value (Statistical test)
Red blood cells (RBCs) ($10^6/\mu L$), mean (SD)	5.49 (0.4306)	5.46 (0.4019)	0.2360 (P)
Hemoglobin (g/dL), mean (SD)	15.48 (0.8858)	15.39 (0.7805)	0.2378 (P)
Packed cell volume (PCV) (%), mean (SD)	45.31 (2.225)	44.95 (2.153)	0.2016 (P)
Mean corpuscular hemoglobin (MCV) (fL), mean (SD)	83.29 (5.260)	83.01 (4.555)	0.5800 (P)
Mean corpuscular hemoglobin (MCH) (pg), mean (SD)	28.41 (2.591)	28.09 (2.643)	0.4374 (P)
Mean cell hemoglobin concentration (MCHC) (g/dL), mean (SD)	34.35 (0.7100)	34.52 (0.8825)	0.4736 (P)
RBC distribution width (RDW) (%), mean (SD)	13.69 (1.745)	13.80 (1.734)	0.9043 (P)
White blood cells (WBCs) ($10^3/\mu L$), mean (SD)	5.620 (0.9645)	5.413 (0.8935)	0.5141 (P)
Neutrophils ($10^3/\mu L$), mean (SD)	3.0 (0.8693)	2.5 (0.7048)	**0.0423** (P)
Lymphocytes ($10^3/\mu L$), mean (SD)	2.02 (0.4739)	2.30 (0.3861)	**0.0387** (P)
Monocytes ($10^3/\mu L$), mean (SD)	0.49 (0.1140)	0.43 (0.1305)	0.2835 (P)
Eosinophils ($10^3/\mu L$), mean (SD)	0.10 (0.082)	0.11 (0.058)	0.6632 (P)
Platelets ($10^3/\mu L$), median (IQR)	234.0 (201-243)	235.0 (206-251)	0.6290 (W)
Mean platelet volume (MPV) (fL), median (IQR)	8.60 (8.4-9.0)	8.60 (8.4-8.7)	0.4197 (W)

P indicates Paired student's t-test; W, Wilcoxon test; SD, standard deviation; and IQR, interquartile range.
Reference ranges: RBCs, 4.2-6.0 x 106/µL; hemoglobin, 13.5-18.0 g/dL; PCV, 40-54%; MCV, 80 – 100 fL; MCH, 26 – 32 pg; and MCHC, 32 – 36 g/dL; RDW, 11.5-14.5 %; WBCs, 3.5-11 x103/µL; neutrophils, 1.7-7.5 x 103/µL; lymphocytes, 0.1-1.3 x 103/µL; monocytes, 1.0-3.2 x 103/µL; eosinophils, 0.0-0.3 x 103/µL; platelets, 150-450 x103/µL; and MPV, 7-12 fL.
P < 0.05 was defined as statistically significant.
Bold values indicate statistical significance.

Impacts of Ramadan fasting on hematological inflammatory markers

Hematological inflammatory parameters are calculated easily from CBC indices, including the neutrophil/ lymphocyte ratio (NLR), monocyte/lymphocyte ratio (MLR), platelet/lymphocyte ratio (PLR), systemic inflammatory index (SII), systemic inflammatory response index (SIRI), and aggregate index of systemic inflammation (AISI), and provide prognostic values for systemic inflammation (Haybar et al., 2019; Song et al., 2023; Zhu et al., 2022). As expected, analysis of hematological inflammatory markers before and after Ramadan fasting revealed significant differences in multiple parameters (Table 3). Compared to the pre-fasting data, the post-fasting data showed a lower value of NLR (1.05 vs 1.65, p=0.0151), MLR (0.19 vs 0.25, p=0.0039), PLR (96.17 vs 112.60, p=0.0260), SII (224.2 vs 311.4, p=0.0413), SIRI (0.45 vs 0.85, p=0.0054), and AISI (109.2 vs 177.2, p=0.0215). These results indicate that Ramadan fasting may have a role in the regulation of systemic inflammation.

Table 3. Changes in hematological inflammatory parameters before and after Ramadan fasting

Variable	Before (n=15)	After (n=15)	*P* Value (Statistical test)
Neutrophil lymphocyte ratio (NLR), median (IQR)	1.65 (1.12-1.79)	1.05 (0.89-1.37)	**0.0151** (W)
Monocyte lymphocyte ratio (MLR), mean (SD)	0.25 (0.063)	0.19 (0.056)	**0.0039** (P)
Platelet lymphocyte ratio (PLR), mean (SD)	112.60 (27.53)	96.17 (23.79)	**0.0260** (P)
Systemic inflammatory index (SII) (x 10^9/L), median (IQR)	311.4 (250.3-411.8)	224.2 (136.8-299.1)	**0.0413** (W)
Systemic inflammatory response index (SIRI) (x 10^9/L), median (IQR)	0.85 (0.61-0.98)	0.45 (0.36-0.55)	**0.0054** (W)
Aggregate index of systemic inflammation (AISI) (x $10^{18}/L^2$), median (IQR)	177.2 (107.2-352.6)	109.2 (42.0-134.6)	**0.0215** (W)

P indicates Paired student's t-test; W, Wilcoxon test; SD, standard deviation; and IQR, interquartile range.
P < 0.05 was defined as statistically significant.
Bold values indicate statistical significance.

Impacts of Ramadan fasting on kidney function and hydration status

We next assessed the kidney function tests and hydration status before and after Ramadan fasting. Table 4 summarizes the laboratory tests related to kidney function and hydration status among the study group. Analysis revealed a statistically significant difference in total protein levels before (7.8 g/dL) and after (7.5 g/dL) Ramadan fasting, with a p-value of 0.0120. On the other hand, there were no differences in serum fast blood sugar, urea, creatinine, sodium, potassium, osmolality, estimated glomerular filtration rate (eGFR), and blood plasma volume. Although pre-post-fasting data didn't show a significant difference in total blood volume, the blood volume after fasting (4410 mL) was lower than the reference ranges (45000-6000 mL). Together, these results suggest that the fasting period has no significant impact on kidney function tests, with a subtle effect on hydration status.

Table 4. Changes in metabolic parameters before and after Ramadan fasting

Variable	Before (n=15)	After (n=15)	*P* Value (Statistical test)
Fast blood sugar (FBS)(mg/dL), mean (SD)	86.4 (5.37)	86.20 (4.51)	0.8076 (P)
Urea, serum (mg/dL), mean (SD)	29.0 (7.06)	28.78 (6.63)	0.8650 (P)
Creatinine, serum (mg/dL), mean (SD)	0.89 (0.14)	0.91 (0.16)	0.1189 (P)
Total protein, serum (g/dL), median (IQR)	7.8 (7.7-8.1)	7.5 (7.4-7.9)	**0.0120** (W)
Sodium, serum (mmol/L), mean (SD)	139.6 (2.77)	139.1 (3.67)	0.4843 (P)
Potassium, serum (mmol/L), median (IQR)	4.5 (4.0-4.7)	4.2 (3.9-4.6)	0.3345 (W)
eGFR (mL/min/ 1.73 m^2), mean (SD)	110.8 (18.66)	109.1 (20.21)	0.1847 (P)
Osmolality, serum (OSMc) (mmol/kg), mean (SD)	292.1 (5.23)	290.9 (6.86)	0.4068 (P)
Blood volume (mL), median (IQR)	4900 (4270-5530)	4410 (4270-5530)	0.0537 (W)
Blood plasma volume (mL), mean (SD)	2731 (477.3)	2693 (491.3)	0.2113 (P)

P indicates Paired student's t-test; W, Wilcoxon test; SD, standard deviation; IQR, interquartile range; and eGFR, estimated glomerular filtration rate.
Reference ranges: FBS, 70-100 mg/dL; urea, 20-50 mg/dL; creatinine, 0.7-1.2 mg/dL; total protein, 6.0-8.0 g/dL; sodium, 135-145 mmol/L, potassium, 3.5-5.0 mmol/L; eGFR, 90-120 mL/min/1.73 m^2; OSMc, 275-295 mmol/kg; blood volume, 45000-6000 mL; and plasma volume, 25000-3200 mL.
P < 0.05 was defined as statistically significant.
Bold values indicate statistical significance.

Effects of Ramadan fasting on lipid profile

Compared to the control group, the after-fasting data showed significantly lower levels of serum total cholesterol (158.5 vs 165.5, p=0.0276), triglyceride (65.0 vs 86.0, p=0.0121), LDL (87.73 vs 92.6, p=0.0196), and cholesterol/HDL ratio (3.46 vs 3.52, p=<0.0001) (Table 5). In addition, there was no difference in HDL levels. These findings collectively suggest a comprehensive impact of Ramadan fasting on lipid metabolism, leading to a notable decrease in total cholesterol, LDL, and triglycerides.

Table 5. Changes in lipid profile data before and after Ramadan fasting

Variable	Before (n=15)	After (n=15)	P Value (Statistical test)
Cholesterol total, serum (mg/dL), mean (SD)	165.5 (15.53)	158.5 (20.39)	**0.0276** (P)
Triglyceride, serum (mg/dL), median (IQR)	86.0 (60.0-127.0)	65.0 (57.0-92.0)	**0.0121** (W)
High-density lipoprotein (HDL) (mg/dL), median (IQR)	47.0 (46.0-51.0)	45.0 (41.0-53.0)	0.5904 (W)
Low-density lipoprotein (LDL) (mg/dL), mean (SD)	92.6 (4.66)	87.73 (9.80)	**0.0196** (P)
Cholesterol/HDL Ratio (CHR), median (IQR)	3.52 (3.51-3.53)	3.46 (3.38-3.49)	**<0.0001** (W)

P indicates Paired student's t-test; W, Wilcoxon test; SD, standard deviation; and IQR, interquartile range.
Reference ranges: Cholesterol, 150-200 mg/dL; triglyceride, 50-150 mg/dL; HDL, 35-55 mg/dL; LDL, up to 130 mg/dL; and CHR, 3.5-5.0. *P* < 0.05 was defined as statistically significant.
Bold values indicate statistical significance.

Discussion

Muslims abstain from food, drink, and smoke from dawn until after sunset for about 30 days during the holy month of Ramadan, ranging from 12 to 18 hours per day based on geographical location (Osman et al., 2020). Medical and sports researchers have been paying much more attention in recent years to how energy constraints and fasting during the Ramadan period affect normal body functions and athletic performance. Previous studies have shown conflicting results about the effect of Ramadan fasting on hematological and metabolic parameters. The reasons behind the variations in the findings of different research might be attributed to the geographic characteristics, length of fasting, type of diets, and genetic background of Muslim athletes. Thus, this study aimed to evaluate the impact of Ramadan fasting on anthropometric and hemodynamic measures, complete blood count data, hematological inflammatory parameters, kidney functions and hydration status, and lipid profiles of Jordanian national boxing and wrestling players.

In the present study, Ramadan fasting decreased body weight and body fat mass (BFM), whereas body mass index (BMI), body fat percentage (BFP) and lean body mass (LBM) showed a trend toward reduction after Ramadan fasting. The effect of Ramadan fasting on weight loss, BFP, LBM, and total proteins was reported by a meta-analysis study that found that adult athletes who continue training throughout Ramadan fasting (at least twice a week) showed a reduction in body mass, BFP, and total proteins, but not LBM by the end of the fasting month (Trabelsi et al., 2023). Conversely, another meta-analysis study showed continuous training (at least three times a week) during Ramadan fasting had no impact on body mass, BFM, LBM, and total proteins (Trabelsi et al., 2020). Additionally, a meta-analysis of data for non-athlete adults showed a reduction in weight, BFM, BFP, and LBM after Ramadan fasting (Fernando et al., 2019). The contradiction of previous findings may be attributed to many factors such as age, gender, quantity and quality of food, and scheduled training sessions (before or after breaking the fast). Our findings further support the idea of decreased body weight due to a reduction in BFM, as evidenced by low levels of cholesterol, triglyceride, and LDL after Ramadan fasting. Another possible mechanism is that a reduction in LBM due to the continuance of training during fasting has adverse consequences on muscle protein metabolism, as evidenced by decreased serum total proteins after fasting.

It has been proposed that there was a reduction in the intake of carbohydrates during the fasting month of Ramadan, leading to a decrease in the oxidation of carbohydrates and an increase in the oxidation of fat (Trabelsi et al., 2012a; Trabelsi et al., 2012b). It is important to note that the oxidation of fatty acids as a fuel during exercise may be enhanced by engaging in physical activity before breaking the fast, resulting in an increased reliance on fat stores for energy during the fasting period compared to fed exercising conditions (Trabelsi et al., 2012a; Trabelsi et al., 2012b). The mechanisms underlying these changes in lipid metabolism during Ramadan fasting are multifaceted. A possible explanation for these results may be that fasting increases the basal lipolysis of adipose tissues by increasing the levels of catabolic hormones such as catecholamines, growth hormone, and glucagon (Bai et al., 2020; Trabelsi et al., 2012a; Trabelsi et al., 2012b). Interestingly, in addition to overall changes in lipid profiles, our data showed a significant decrease in cholesterol/ high-density lipoprotein (HDL) ratio after Ramadan fasting, further supporting the beneficial effects of fasting on cardiovascular health. Athletes can meet their energy and nutrient requirements during Ramadan fasting by planning a rich-carbohydrate and protein diet, which results in reduced fat consumption. Thus, a nutritional strategy is required for training and competition schedules to avert undesired alterations in body composition.

Another possible explanation for decreased body mass is that accumulative fluid shortage from daylight exercise training during Ramadan fasting may potentially result in hypo-hydration and a possible loss of body mass. Some authors have speculated that decreased body mass was associated with a state of dehydration (Bouhlel et al., 2006; Trabelsi et al., 2023; Trabelsi et al., 2011a; Trabelsi et al., 2011b). According to a meta-analysis study, people drank considerably less water overall during Ramadan fasting, which supports the idea that dehydration causes weight loss (Trabelsi et al., 2023). Trabelsi et al. (2011b) reported that a hot Ramadan month could cause dehydration, indicated by elevated blood hematocrit, serum electrolytes, and some renal function markers. Bouhlel et al. (2006) and Trabelsi et al. (2011b) demonstrated an increased level of blood hematocrit and plasma osmolarity, indicating a fall in plasma volume during Ramadan fasting and ultimately leading to a state of dehydration. In contrast to earlier findings, other studies showed either decreases or no changes in levels of hematocrit and electrolytes in weightlifters and soccer players (Maughan et al., 2008; Mustafa et al., 1978; Tayebi et al., 2010). Consistent with the overhead findings that support the correlation between fasting and hypo-hydration, our data showed an insignificant reduction in total blood volume and plasma volume after Ramadan fasting, with lower blood volume than the reference ranges. However, the present findings showed normal levels of hematocrit and kidney function tests, indicated by normal levels of serum urea, creatinine, electrolytes (sodium, potassium, and chloride), osmolality, and estimated glomerular filtration rate (eGFR). These inconsistent findings could be explained by variations in exercise regimens, climate, and duration of daytime fasting. Together with previous data, our findings suggest that Ramadan fasting can alter the body water status due to the reduction of fluid intake without altering the kidney functions. Thus, our data suggest that the reduced body weight might be attributed to reduced body fat and protein stores, evidenced by low BFM and LBM, and a cumulative fluid shortage throughout the fasting period.

Several hematological parameters were examined in our study about the effects of Ramadan fasting, such as RBCs, Hemoglobin, hematocrit (PCV), MCV, MCHC, MCH, RDW, platelets, MPV, WBCs, and leukocyte differential counts (neutrophils, lymphocytes, monocytes, and eosinophils). Analysis showed no alterations in most of these parameters between the pre-and-post-fasting periods, except for notable alterations in neutrophil and lymphocyte counts, suggesting that hematopoiesis, a process of blood cell formation, was stable during the Ramadan fasting. Previous studies have shown conflicting results about the impact of Ramadan fasting on hematological parameters. Different authors reported increased hemoglobin levels after fasting in swimmers and rugby players (Bouhlel et al., 2006; Trabelsi et al., 2011a; Trabelsi et al., 2011b). Other studies showed no changes in hemoglobin levels following fasting (Maughan et al., 2008; Tayebi et al., 2010; Trabelsi, et al., 2012b). Conversely, Hosseini and Hejazi (2013) showed a reduction in hemoglobin and RBCs in football players after fasting. Another study demonstrated a reduction in RBCs, an increase in WBCs and platelets, and no changes in hemoglobin following fasting (Hosseini et al., 2014). Chaouachi et al. (2009) reported no differences in total WBCs after Ramadan fasting in judo athletes. Similarly, Trabelsi et al. (2012b) reported no changes in WBCs, neutrophils, lymphocytes, and monocytes after fasting in bodybuilders. Tayebi et al. (2010) showed that RBC indices (MCV, MCH, and MCHC) were comparable between before and after fasting in weightlifters.

Given that the effect of Ramadan fasting on the immune system is yet unclear, one unanticipated finding of the present study was alterations in WBC differential counts, in which decreased neutrophils and increased lymphocytes were observed following Ramadan fasting. Hematological inflammatory parameters have been recently proposed as prognostic and diagnostic factors for systemic inflammation, such as neutrophil/ lymphocyte ratio (NLR), monocyte/lymphocyte ratio (MLR), platelet/lymphocyte ratio (PLR), systemic inflammatory index (SII), systemic inflammatory response index (SIRI), and aggregate index of systemic inflammation (AISI), and provide prognostic values for systemic inflammation (Haybar et al., 2019; Song et al., 2023; Zhu et al., 2022). Given that no previous study has investigated the impact of Ramadan fasting on these inflammatory parameters, our results showed a significant decrease in values of NLR, MLR, PLR, SII, SIRI, and AISI following Ramadan fasting. NLR measures the ratio between neutrophils (innate immunity) and lymphocytes (adaptive immunity); MLR, monocytes (innate immunity) and lymphocytes; and PLR, platelets and lymphocytes. Elevated levels of these inflammatory markers are linked to inflammatory disorders, hematological malignancies, bacterial infections, coronary heart diseases, stroke, and elevated mortality rates in the general population (Haybar et al., 2019; Song et al., 2023; Zhu et al., 2022).

Based on the dynamic interaction between immune function and fasting, these results point to potential modifications in the immune response. Previous research has demonstrated that intensity, endurance, and length of exercise can raise the inflammatory marker IL-6 (Cerqueira et al., 2020). Fasting is known to have anti-inflammatory effects, characterized by reductions in pro-inflammatory cytokines and markers of inflammation, such as C-reactive protein (CRP), interleukin 1β (IL-1β), interleukin 6 (IL-6), and tumor necrosis factor (TNF) (Adawi et al., 2017; Kurniawati et al., 2024; Okawa et al., 2021). The decrease in neutrophils may be related to the suppression of inflammatory pathways, leading to decreased neutrophil recruitment and production (Adawi et al., 2017; Okawa et al., 2021). Moreover, fasting induces alterations in hormonal profiles, including changes in cortisol, insulin, and growth hormone levels (Adawi et al., 2017; Okawa et al., 2021). These hormonal changes can influence hematopoiesis and immune cell dynamics, potentially leading to a shift in lymphocyte and neutrophil populations. Fasting triggers metabolic adaptations aimed at conserving energy and maintaining homeostasis. These metabolic changes may impact immune cell metabolism and function, influencing the balance between lymphocytes and neutrophils in the circulation (Adawi et al., 2017; Okawa et al., 2021). Fasting can also modulate the composition and activity of the gut microbiota, which plays a crucial role in immune regulation. Changes in gut microbiota composition may influence immune cell populations and their interactions, contributing to the observed alterations in lymphocytes and neutrophils (Saglam et al., 2023). Overall, the decrease in NLR, MLR, PLR, SII, SIRI, and AISI inflammatory parameters after Ramadan fasting results likely from a combination of immunomodulatory, anti-inflammatory, hormonal, metabolic, oxidative, and microbiota-related effects, indicating that the current findings demonstrate the positive relationship between the management of systemic inflammation in athletes and the advantages of fasting during Ramadan.

Limitations and implications for future research

A few important limitations need to be considered. First, the study's sample size may be a limitation, and the generalizability of the findings may be influenced by the homogeneity of the participant group. Future research should aim for larger and more diverse samples to enhance the external validity of the results. Second, the study's duration of observation may limit the understanding of long-term effects. Follow-up assessment in subsequent Ramadan periods could provide insights into sustained impacts on hematological and metabolic parameters. Third, the study did not explore the interaction between Ramadan fasting and variations in training load. Investigating how different training intensities may influence the observed outcomes can provide a more comprehensive insights into athletic performance. Lastly, since we found alterations in the immune responses after fasting, future research should delve into the underlying mechanisms behind the observed changes.

Conclusions

Previous studies have shown conflicting results about the effects of Ramadan fasting on various physiological processes. The present study aimed to determine the effects of Ramadan fasting on anthropometric and hemodynamic measures, hematological inflammatory parameters, and metabolic processes. While the fasting period may induce alterations in some biomarkers, overall, it appears to be well-tolerated and may provide potential health benefits, particularly in terms of anthropometric and hemodynamic measurements, hematological inflammatory parameters, kidney functions, and lipid profiles. These are evidenced by a reduction in total cholesterol, low-density lipoprotein, triglyceride, body fat mass, hematological inflammatory markers (NLR, MLR, PLR, SII, SIRI, and AISI), and trends towards reductions in body mass index, body fat percentage, and lean body mass. There were no changes in blood pressure, blood sugar, urea, creatinine, sodium, potassium, osmolality, or estimated glomerular filtration rate, with a subtle effect on hydration status evidenced by a trend towards reduced blood plasma volume and total blood volume. Overall, the evidence from this study suggests that Ramadan fasting can lead to weight loss, improved cardiovascular health, and modification in immune response dynamics in athletes. Further studies are needed to elucidate the mechanisms underlying these effects and their long-term implications. To avoid unwanted changes in body composition, athletes should adjust their training and competition schedules according to the duration of the fast, controlling training variables like intensity, duration, and frequency, and organizing their nutritional strategies accordingly.

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