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The effects of practicing resistance training in a fasted or fed state during Ramadan intermittent fasting on maximal strength and hematological parameters

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Abstract

Introduction: Muslim people often continue physical training during the month of Ramadan, not only for competing but also for recreation and health purposes. Choosing the optimal time of day for resistance training (RT) during the Ramadan intermittent fasting (RIF) would be important to avoid any negative impacts of fasting. Thus, the aim of this study is to investigate the effect of time-of-day (i.e., in a fasted state) of RT during Ramadan on muscle strength and hematological parameters.

Methods: 36 Muslim recreational weightlifters participated in this study and completed whole-body RT (12 rep × at 75–85% 1RM for 8 weeks). Participants were divided into: FAST group (n=18) training in the late afternoon before breaking fast (between 16h and 18h), and FED group (n=18) completing the RT in the late evening after breaking fast (between 20h and 22h). Maximal performance of squat ($1RM_{SQ}$), deadlift ($1RM_{DL}$) and bench press ($1RM_{BP}$), and hematological parameters were analyzed 24 h before the start of Ramadan (T0), on the 15th day of Ramadan (T1), on the 29th day of Ramadan (T2), and 21 days after Ramadan (T3).

Results: Significant group × time differences were reported for $1RM_{SQ}$ (p =.03; ES = 0.23) and $1RM_{DL}$ (p =.01; ES = 0.32). Post-hoc analyses indicated significant pre-to-post improvements in FED at T2 for $1RM_{SQ}$ (p =.03; ES= 0.27) and $1RM_{DL}$ (p =.04; ES= 0.36) when compared to T0, with no significant changes measured in FAST. No significant time x group effect was reported for hematological parameters. Additionally, no significant pre-to-post measurements were observed for hematological parameters for either group.

Conclusion: Practicing RT in a fed state seems more effective in comparison with a fasted state to improve muscle performance and prevent negative impact of the fasting period. Moreover, RIF has no adverse impact on muscle strength and hematological parameters.

Key words: dehydration, blood component, exercise, fasting

Introduction

Resistance training (RT) is a method of sport training designed in consideration of several variables (e.g., number of repetitions and sets, recovery intervals, training frequency, repetition velocity, and others) (Kraemer and Ratamess, 2004). The first objective of an RT program is to promote muscle adaptation by increasing or maintaining muscular strength and hypertrophy while the second aim is to conserve or enhance physical performance and health via anabolic mechanisms (Mcleod et al., 2019). In fact, respiratory, cardiovascular, and neuromuscular systems undergo many physiological and biochemical changes as a result of RT exercises, which places a great demand on these systems (Abrahin et al., 2014; Costa et al., 2019; Yu et al., 2016). Moreover, RT has been investigated as an efficient training method to improve hematological parameters among patients with cardiovascular diseases (Agbonlahor, 2020), sedentary yet healthy individuals (Samavati et al., 2013) and even athletes (Saran et al., 2019).

Additionally, the relationship between RT and hematological parameters is a bidirectional effect. For instance, hematological responses are related to skeletal muscle tissue repair, and subsequent recovery (Freidenreich and Volek, 2012). Generally, the cardiovascular system, including hematological components, reacts to exercise and associated physiological demands by increasing perfusion pressure, muscle pump activity, oxygen extraction and vasodilation to maintain sufficient blood flow and thus oxygen and nutrient supply (Joyner and Casey, 2015). Moreover, to investigate the effectiveness of this relation or to achieve additional adaptation effects of RT and hematological parameters, environmental conditions can also be manipulated. Therefore, RT under a fasted status has received more attention in the last two decades (Ashtary-Larky et al., 2021; Keenan et al., 2020).

Ramadan intermittent fasting (RIF) is one of several fasting strategies that has been investigated concurrent to RT (Tayebi et al., 2010; Trabelsi et al., 2013). During this holy month, Muslims abstain from food and fluids from sunrise to sunset (Azizi, 2010). Thus, dehydration is common with fluid restriction during fasting, which may affect hematological indices (Waterhouse, 2010). In fact, total plasma volume may change due to the reduction of extracellular fluid volume during water restriction (Melin et al., 1997). Additionally, blood hemoglobin concentration and

hematocrit are two hematological parameters utilized to evaluate body water status of athletes (Oppliger and Bartok, 2002). However, conflicting results are apparent from previous studies. Some of them have reported a significant increase in hematological indices among physically active men (Trabelsi et al., 2011a) and rugby players (Bouhlel et al., 2006). Other studies have found compromised blood parameters (Hosseini and Hejazi, 2013; Maughan et al., 2008). Conversely, an investigation conducted by Chaouachi (Chaouachi et al., 2009) found no significant effect of RIF on blood parameters among 15 elite male judo athletes. A non-significant effect was also reported after practicing resistance training during RIF among male weight lifters and bodybuilders (Tayebi et al., 2010; Trabelsi et al., 2013; Trabelsi et al., 2012). These conflicting results are possibly attributed to the timing of blood samples. For instance, Aloui (Aloui et al., 2013) reported that during RIF amateur footballers were marginally less hypo-hydrated in the morning (blood collection at 7:00 A.M) than in the afternoon (5:00 P.M.). Interestingly, this work also indicated that hemoglobin and hematocrit values were better during RIF compared to beforehand.

Therefore, the general purpose of this study was to determine whether RT can be safely practiced during RIF by examining the effect of this combined intervention (RT and RIF) on hematological parameters and maximal strength. The second aim is to investigate the time of day for RT practice during RIF and comparing blood components and maximal strength between a fasted state (i.e., training before breaking the fast) and a fed state (i.e., training after breaking the fast). We hypothesized that: a) Maximal strength may be maintained during RIF with continuous RT training, b) practicing RT during RIF may have a negative effect on hematological parameters, and c) changes in blood parameters will be less affected during a fed state compared with a fasted state.

Materials and Methods

Participants

Thirty-eight Muslim recreational weightlifters, all men, were recruited for participation in the present study. Eligible participants were subsequently randomized to receive 8-weeks of resistance training (RT) at one of two time points, 1) the fasted state group (FAST, n=18, age= 24.7±4.6 y,

body mass= 78.37±3.25 kg, height= 173.3±7.2 cm, body-mass-index [BMI]= 23.76±1.25kg/m²) practicing RT in the late afternoon 1 hour before breaking fast (between 16h and 18h) -, and 2) practicing RT in the late evening after breaking the fast (between 20h and 22h) - fed state group (FED, n=18, age= 25.3±5.2 y, body mass= 81.03±2.53kg, height= 174.3±9.3 cm, body-mass-index [BMI]= 24.49±1.35 kg/m²). To be included in the study, participants had to meet the following criteria: being a healthy male aged 18 to 35 years with no metabolic or hematological problems, infections, allergies, and cardiovascular diseases; having a minimum of two years of RT experience; having no blood donation or loss of blood (>200 ml) in the last 3 months; being a non-smoker; having no consumption of supplements other than those provided during the study *(see below);* not having previously used anabolic steroids or related-ergogenic aids; partaking in no additional physical activities other than those during the period of the study; and keeping standard times for eating (Iftar between 6:30 and 7:30 PM and took their last meal (Suhur) at approximately ~3 AM and fasted from then until sunset. Individuals who did not meet the inclusion criteria was excluded.

Participants signed an informed consent form to participate in the study after receiving a thorough explanation of the study's protocol. The experimental protocol regarding the use of human participants was approved by the clinical research ethics committee of the National Center of Medicine and Sciences in Sport of Tunis.

Study Design

The study was conducted in Tunisia during Ramadan from March 3rd to April 3rd, 2021, with ~ 14 h/d of fasting, 23±4°C daytime temperatures and 65±5% of humidity. Participants visited the laboratory one week before the start of Ramadan fasting (T0) for two days separated by intervals of 48h between visits. The first one was to review and sign the informed consent form, answer the physical activity readiness questionnaire, undergo anthropometric measurements and one repetition maximum (1RM) tests. The second visit was to collect blood samples and repeat 1RM tests to determine the loads to be used for the experimental conditions and to assess the reproducibility of the tests.

During the experiment, anthropometric measurements, 1RM tests and blood samples were evaluated in 4 separate test occasions: one week before the start of Ramadan (T0), during the 2nd

week of Ramadan (T1), during the 4th week of Ramadan (T2), and 21 days after the end of Ramadan (T3).

Training program

During the 8-week intervention period (T0 to T3), a full body RT program was conducted 4 times per week (Monday, Tuesday, Thursday, Friday) at a different time of day for each group. RT was practiced in the late afternoon during Ramadan (between 16h and 18h) among FAST group; however, it was practiced in the evening (between 20h and 22h) 1–2 hours after breaking the fast among FED group. The following exercises were used in each training session: Mondays/Thursdays: inclined leg press, parallel squat, deadlifts, calf raise and cable crunches; Tuesdays/Fridays: bench press, shoulder press, lateral pull-down, barbell curl and oblique raises. Each session started with a general warm-up and cool-down periods of 5–10 min of low-intensity aerobic and dynamic stretching exercises. The total volume training was fixed at 75–85% 1RM (intensity) x 8 (repetitions)x 3 (sets) with 2min rest between sets and exercises. A progressive overload training was conducted during sessions, RT protocol was started by performing 75% 1RM x12 repetitions x3 sets during the first week and progressed to 85%1RM x12 repetitions x3 sets during week 6. All training sessions were supervised by an experienced exercise training researcher to ensure that proper techniques and progression were used in each exercise.

Body Composition Testing

Anthropometric measurements were assessed in the morning after a 12-hour fasting at T0, T1, T2 and T3 by the same evaluator. Height was measured to the nearest 5 mm using a stadiometer. Body mass was measured to the nearest 10 g using a calibrated electronic scale (MEDISANA®, Neuss, Germany), BMI was then calculated by dividing weight by height squared. Body fat percentage was calculated using the 4 skinfolds protocol (i.e., biceps, triceps, subscapular and suprailium) with a calibrated Harpenden skinfold (Baty International, England) using a previously published algorithm (Durnin and Rahaman, 1967). Lean body mass (LBM) was calculated as body mass minus body fat mass.

Hematological Parameters

Venous blood samples (~5 ml) were taken from an antecubital vein into a plain Vacutainer tube in a seated position at T0, T1, T2 and T3 before RT session. The blood samples were collected in a

sterile tube for vacuum blood collection containing anticoagulant (EDTA) and were analyzed using an automated analyzer (Beckman Coulter, UK) according to the manufacturer's protocol for the determination of blood count (e.g., red blood cells, platelets, hemoglobin, hematocrit). The variation in plasma volume during the different periods of the experiment was determined using the Dill and Costill method (1974) as follows:

$$\boldsymbol{PVV}\ (\%) = 100 \times \frac{Hb\ (n)}{Hb\ (n+1)} \left(\times \frac{(1 - Ht\ (n+1) \times 10^{-2})}{(1 - Ht\ (n)\ \times\ 10^{-2})} \right) - 100$$

PVV: plasma volume variation expressed in % PVV, ***n*:** value measured at one of the measurement periods, ***n* + 1:** value following the previous period, **Ht:** hematocrit (%), **Hb:** hemoglobin (g / dl).

Afterwards, the remainder of blood was allowed to clot, centrifuged at a speed of 3,500 rpm for 5 min, and then stored in a refrigerator at a temperature of 4 °C to later measure concentrations of biochemical parameters. Blood glucose was determined using an enzymatic colorimetric method (Biomérieux, France). Urea was determined using an enzymatic method (Biomaghreb, Tunisia). Sodium concentration was determined by flame photometry method using flame photometer unit

$$\text{Plasma osmolarity(mOsm/1)} = 2 \times [\text{sodium}](\text{mmol/1}) + [\text{urea}](\text{mmol/1}) + [\text{glucose}](\text{mmol/1})$$

(GDV, Italy and U.S.) by potentiometry, and plasma osmolarity was then calculated using the following equation:

The remaining blood was then stored in a refrigerator at a temperature of -20°C for future analyses.

One-Repetition Maximum

To measure muscular strength, one repetition maximum testing (1RM) was conducted for the following exercises: parallel squat, bench press, and deadlift. The tests were performed at T0, T1, T2 and T3 and before the first weekly training session to maintain the relative intensity of each exercise during the experiment. Participants first performed 10 repetitions without any extra load on the equipment (Lacerda et al., 2019; Lacerda et al., 2016). Values for 1RM were determined in

a concentric mode with a maximum of 6 attempts, with 5-minute rest periods between each attempt (Lacerda et al., 2016). In addition, a 3-minute rest period was provided between the 1RM test for each exercise.

Dietary habits

Subjects were instructed to record all food and beverages consumed using a nutritional tracking application (http://www.myfitnesspal.com) and the food-composition tables of the National Institute of Statistics of Tunis (1978). Data were collected for at least four days a week to offer a reliable estimate of food intake for the entire week during the experiment. Total water intake was defined as the fluid volume of consumed beverages plus the water content of consumed foods. Participants consumed a supplement containing 24 g protein and 1 g carbohydrate before sleeping (Iso100 Hydrolyzed Whey Protein Isolate; Dymatize Nutrition, Dallas, TX) on training days as prescribed by research staff and with some participants receiving phone call reminders. ***Table 1*** presents the nutrients consumed by participants during the study. There were no significant differences found between groups, and no changes were detected across the experimental period.

< INSERT TABLE 1 NEAR HERE>

Statistical analyses

Descriptive statistics (mean ± SD) were calculated for all variables. Statistical analyses of the data were carried out using a 2 x 4 repeated measures ANOVA for groups (FAST, FED) and time (T0, T1, T2, T3). Post-hoc testing to identify specific differences was accomplished using the Bonferroni method. Effect sizes (ES) were determined from the output of ANOVA by converting partial eta-squared to Cohen's d. In addition, within-group ES were computed using the following equation: ES = (mean post—mean pre)/SD. ES were classified as trivial (<0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2, 0) and very large (2.0-4.0) (Hopkins et al., 2009). Differences were considered significant at the level of $p < .05$. The data were analyzed using SPSS (SPSS Inc., Chicago, IL) version 16.

Results

All study participants completed all sessions with good discipline. No training- or test-related injuries were recorded. No significant between-group differences were observed for any anthropometric, strength, and hematological parameters at baseline.

Anthropometric tests

Anthropometric parameters of participants are presented in **Table 2**. No significant group x time effect was reported for any outcome. However, both groups showed a significant effect of time; reductions for body mass, BMI, and body fat percentage during Ramadan were found in comparison with baseline. The effect of time was as follows: body mass (p=.001; ES= 0.42), BMI (p =.001; ES = 0.63) and body fat percentage (p =.001; ES= 0.84). No changes in lean body mass for both groups was reported (p >.05).

<u>< INSERT TABLE 2 NEAR HERE></u>

Maximal strength

The group × time effect for maximal strength is reported in **Figure 1**. A significant group × time effect for $1RM_{SQ}$ (p=.03; ES= 0.23) and $1RM_{DL}$ (p =.01; ES= 0.32) was observed. Post-hoc test indicated that the FED group reported significant increases in $1RM_{SQ}$ and $1RM_{DL}$ at T2 compared to T0 (p =.03; ES= 0.27 and p =.04; ES= 0.36). No significant group × time effects was recorded for 1 RM_{BP} (p =.39; ES= 0.10).

<u>< INSERT FIGURE 1 NEAR HERE></u>

Hematological parameters

Data are presented as (Mean ± SD) in **Table 3**. No significant group x time effect was observed for all hematological parameters; group × time tests were not significant for hematocrit (p=.84; ES= 0.004), hemoglobin (p=.34; ES= 0.11), red blood cells (p=.46; ES= 0.02), platelets (p=.99; ES= 0.003), plasma osmolarity (p=.57; ES= 0.02) and plasma volume variation (p=.39; ES= 0.05).

< INSERT TABLE 3 NEAR HERE>

Correlations

The inter-relationships between anthropometric measurements, maximal strength, and hematological parameters during the experiment among FAST and FED groups are shown in **Table 4** and **Table 5**. According to these results, the FAST group presented significant associations between body mass and lean body mass (r = 0.862, p = .001), 1 RM_{BP} (r = -0.584, p = .022) and red cell (r = -0.584, p = .022). There were significant correlations between BMI and hemoglobin, and BMI with PVV respectively (r = 0.643, p = .010 and r = -0.719, p = .003). Body fat was also correlated with 1 RM_{BP} (r = -0.668, p = .006) and osmolarity (r = -0.550, p = .034); lean body mass was correlated only with 1 RM_{BP} (r = -0.564, p = .028) and $1RM_{DL}$ only with red cells (r = 0.610, p = .016). The FED group also had significant correlations between body mass and BMI (r = 0.852, p = .001), between body fat and red cells (r = -0.554, p = .032) and between body fat and hematocrit (r = -0.560, p = .167). 1 RM_{BP} also showed a significant correlation with osmolarity (r = 0.574, p = .025) and hematocrit (r = 0.578, p = .024), while hemoglobin was correlated with hematocrit (r = -0.524, p = .045) and PVV (r = -0.884, p = .001).

< INSERT TABLES 4 AND 5 NEAR HERE>

Discussion

The propose of this study was to investigate the effects of practicing RT during the month of Ramadan on strength and hematological parameters among recreational weightlifters. We also aimed to discover the best time of day to practice RT during RIF: either during fasting (training before breaking fast) or a non-fasting state (training after breaking fast). According to the current results, a significant improvement of $1RM_{SQ}$ and $1RM_{DL}$ was observed only for FED state group. Furthermore, there was no significant change recorded for all hematological parameters across the study and between both groups.

The current data find that practicing RT in a fed state is more effective to improve physical strength. Aziz and colleagues (Aziz et al., 2012) reported that the optimal time of day to practice an acute high-intensity exercise session during RIF is after breaking fast, and by achieving the

same nutrition and hydration status in comparison with before RIF. Moreover, the timing of nutriment ingestion (especially carbohydrate and protein) is important for activating anabolic pathways in skeletal muscle tissue. Previous studies have showed that protein ingestion before and during exercise also increases muscle protein synthesis rates during RT and contributes to improved muscular strength (Beelen et al., 2008; Tipton et al., 2001). Compared to the FAST group, the FED group consumed their protein supplement in the same time period as practicing RT, contributing to a greater improvement in strength. Additionally, Cribb and Hayes (Cribb and Hayes, 2006) observed that the ingestion of protein inside the pre-post workout period is better than outside of this time frame.

Aside from the effect of time of day (i.e., fasted or fed) for practicing RT on strength, no significant differences were observed for any hematological parameters between groups and across the experimental period. Only one study has investigated the effect of RT and RIF on hematological parameters, which reported the same results (Tayebi et al., 2010). There were no significant changes in red blood cell counts, hematocrit or hemoglobin among participants doing RT (3sessions/week, 90min/session) during RIF. Likewise, there were no differences by timing of training.

Interestingly, our results conflict with those of Trabelsi and colleagues (Trabelsi et al., 2011b), who observed a significant increase in hematocrit, hemoglobin and plasma osmolarity among rugby players before and after matches, while plasma volume decreased. These findings were explained by dehydration during fasting. In fact, increases in plasma osmolarity and hematological parameters may be the result of the cumulative effect of sustained losses of fluid and electrolytes, linked to abstinence from fluids while maintaining exercise (Fall et al., 2007). Additionally, Aloui (Aloui et al., 2013) reported that hematocrit and hemoglobin were higher during Ramadan than before this period among soccer players. However, this was true only for the afternoon session, while no changes were observed in morning sessions. These data were also explained by the hypohydration of players during the afternoon after a long period of fasting, in contrast to morning conditions.

It is likely our contradictory results can be explained by the type of exercise practiced during water and food restriction. Previous studies examined aerobic types of exercise (e.g., soccer and rugby

matches) and reported significant increases in hemoglobin, hematocrit and plasma osmolarity resulting from training under a hypohydrated status (Aloui et al., 2013; Bouhlel et al., 2006; Trabelsi et al., 2011b). The current study investigated a resistance training method, which is a type of anaerobic exercise, ostensibly less dependent on water intake in comparison with aerobic exercises, but possibly more dependent on protein and carbohydrate supplementation (Yoshida et al., 2002).

Conclusion

In conclusion, to prevent fasting from impacting strength performance during Ramadan intermittent fasting (RIF), it is better to practice RT after breaking fast, which provides a better nutritional condition in comparison with a fasted state. However, RIF has no impact on variation in hematological parameters, despite water restriction. Likewise, timing of training in relation to fasting appears to have no impact on these parameters.

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Table 1. Estimated daily dietary intake (mean ± SD) for the FAST and FED groups measured 1 week before the start of Ramadan (T0), on the 15th day of Ramadan (T1), the day after the end of Ramadan (T2) and 21 days after the end of Ramadan (T3) (n=20 per group).

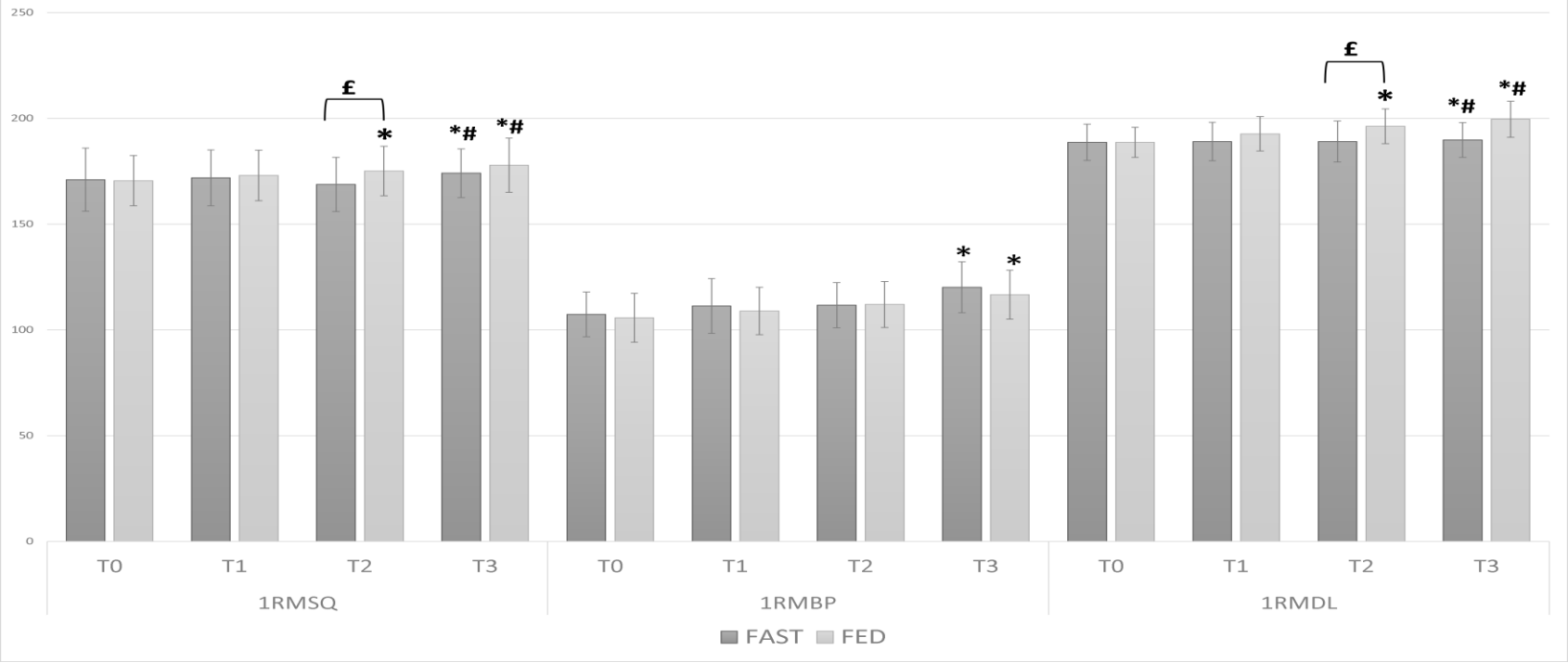
	Group	Time				*p*-values (ES)		
		T0	T1	T2	T3	Time	Group	Group × Time
Protein (% kcal)	FAST	18 ± 8	19 ± 1	18 ± 7	18 ± 7	**0.08 (0.37)**	**0.06 (0.45)**	**0.1 (0.57)**
	FED	18 ± 6	18 ± 2	18 ± 9	18 ± 6			
Carbohydrate (% kcal)	FAST	47 ± 5	45 ± 8	46 ± 3	47 ± 1	**0.1 (0.46)**	**0.08 (0.54)**	**0.07 (0.55)**
	FED	47 ± 3	46 ± 5	45 ± 9	46 ± 7			
Fat (% kcal)	FAST	35 ± 8	36 ± 5	36 ± 4	35 ± 7	**0.09 (0.45)**	**0.08 (0.38)**	**0.08 (0.58)**
	FED	35 ± 9	36 ± 3	37 ± 2	36 ± 4			
Energy (kcal/day)	FAST	3472 ± 245	3436 ± 249	3425 ± 283	3482 ± 275	**0.2 (0.37)**	**0.08 (0.45)**	**0.09 (0.51)**
	FED	3496 ± 368	3432 ± 237	3465 ± 232	3472 ± 254			
Total water intake (L/day)	FAST	4.3 ± 0.5	4.1 ± 0.4	4.2 ± 0.3	4.1 ± 0.7	**0.06 (0.57)**	**0.08 (0.35)**	**0.2 (0.41)**
	FED	4.2 ± 0.4	4.3 ± 0.6	4.2 ± 0.3	4.1 ± 0.4			

Table 2. Anthropometric and body composition characteristics (means ± SD) of the FAST and FED groups measured 1 week before the start of Ramadan (T0), on the 15th day of Ramadan (T1), the day after the end of Ramadan (T2) and 21 days after the end of Ramadan (T3) (n=20 per group)

		T0	T1	T2	T3	Time	Group	Group x Time
Body mass (kg)	FAST	78.87±4.01	75.72±3.41*	73.94±3.24*#	76.62±4.67**$**	**0.001 (0.118)**	**0.040 (0.142)**	**0.589 (0.022)**
	FED	79.87±3.78	79.33±3.18*	75.86±3.19*	79.73±2.67 **$**			
BMI (kg/m^2)	FAST	24.20±1.24	23.77±1.21*	22.40±1.20*#	23.73±1.02**$**	**0.001 (0.656)**	**0.314 (0.036)**	**0.125 (0.195)**
	FED	24.52±1.50	23.94±1.07	23.37±1.13*	24.23±1.10**$**			
Body fat (%)	FAST	16.70±1.19	15.54±1.54*	13.96±1.50*#	14.95±1.39*$	**0.001 (0.601)**	**0.941 (0.00)**	**0.455 (0.024)**
	FED	16.27±0.50	15.54±1.54*	14.10±1.60*#	15.08±1.44*$			
LBM (kg)	FAST	66.34±2.69	64.78±2.94	64.34±3.03	64.82±3.46	**0.461 (0.093)**	**0.025 (0.168)**	**0.551 (0.076)**
	FED	66.98±2.08	67.03±2.52	66.37±2.79	67.98±2.48			

BMI: body mass index; **LBM:** lean body mass; *: ***p***< 0.05 compared to T0; **#:** *p*< 0.05 compared to T1; **$:** *p*<0.05 compared to T2.

Figure 1: Maximal strength (1RM) (means ± SD) of the FAST and FED groups measured 1 week before the start of Ramadan (T0), on the 15th day of Ramadan (T1), the day after the end of Ramadan (T2) and 21 days after the end of Ramadan (T3) (n=18 per group).



1RM: one-repetition maximum; **SQ:** squat; **BP:** bench press; **DL:** deadlift; *: $p < 0.05$ compared to T0; **#:** $p < 0.05$ compared to T1; **£:** *Significant group x time effect*.

Table 3: Hematological parameters (means ± SD) of the FAST and FED groups measured 1 week before the start of Ramadan (T0), on the 15th day of Ramadan (T1), the day after the end of Ramadan (T2) and 21 days after the end of Ramadan (T3) (n=18 per group).

Variable	Group	Phases				P values (ES)		
		T0	T1	T2	T3	Time	Group	Group x Time
Ht (%)	FAST	48.18±2.81	48.07±2.78	48.04±2.75	48.49±2.65	**0.364 (0.027)**	**0.536 (0.014)**	**0.848 (0.004)**
	FED	48.83±2.57	48.69±2.47	48.68±2.43	49.05±2.53			
[Hb] (g· (100 mL) $^{-1}$)	FAST	16.52±1.30	16.38±1.35	16.48±1.35	16.48±1.27	**0.739 (0.046)**	**0.861 (0.001)**	**0.348 (0.117)**
	FED	16.45±1.30	16.51±1.32	16.59±1.30	16.57±1.20			
Red blood cells (10^12/L)	FAST	4.98±0.74	5.03±0.70	5.01±0.65	5.03±0.70	**0.746 (0.008)**	**0.647 (0.008)**	**0.467 (0.025)**
	FED	5.15±0.59	5.06±0.59	5.14±0.56	5.13±0.62			
Platelets (10^9/L)	FAST	255.00±43.32	254.67±41.17	255.00±40.37	255.00±41.71	**0.994 (0.003)**	**0.963 (0.001)**	**0.994 (0.003)**
	FED	255.67±44.00	255.67±42.18	255.67±41.02	255.67±42.34			
Plasma osmolarity (mOsmol/Kg)	FAST	274.67±29.69	273.33±31.87	276.00±32.77	274.67±32.27	**0.812 (0.008)**	**0.253 (0.046)**	**0.578 (0.020)**
	FED	288.67±26.55	288.33±32.64	287.67±32.19	288.33±30.09			
		T0-T1		T1-T2	T2-T3			
ΔPV (%)	FAST	1.14±2.57		-0.07±0.33	-1.34±2.60	**0.094 (0.085)**	**0.361 (0.030)**	**0.362 (0.035)**
	FED	-0.05±1.50		-0.41±2.26	-0.63±2.83			

T0: 24 hours before the start of Ramadan (basal measurements); **T1:** 15th day of Ramadan; **T2 :** The day after the end of Ramadan; **T3 :** 21 days after the end of Ramadan; **ΔPV:** plasma volume variation; **[Hb]:** hemoglobin concentration; **Ht:** hematocrit; **ES:** Effect size; ***** :** P <0.001; **** :** P <0.01; *** :** P <0.05.

Table 4: Correlation between anthropometric measurements, maximal strength and hematological parameters during the experiment among FAST.

	BM	BMI	BF	LBM	1 RM_{SQ}	1 RM_{BP}	1 RM_{DL}	Platelets	P.os	Red cells	Hb	HT	ΔPV
BM	**1**												
BMI	**.259**	**1**											
BF	**.344**	**.173**	**1**										
LBM	**,862****	**-.003**	**.289**	**1**									
1 RMSQ	**-.477**	**-.404**	**-.220**	**-.376**	**1**								
1 RMBP	**-,584***	**-.215**	**-,668****	**-,564***	**.272**	**1**							
1 RMDL	**-.028**	**.037**	**.443**	**.189**	**-.221**	**-.043**	**1**						
Platelets	**.217**	**.041**	**-.435**	**.022**	**-.190**	**.019**	**-.482**	**1**					
Osmolarity	**-.011**	**.054**	**-,550***	**-.064**	**-.389**	**.339**	**-.043**	**.474**	**1**				
Red cells	**-,584***	**-.276**	**.024**	**-.295**	**.025**	**.258**	**,610***	**-.429**	**.120**	**1**			
Hemoglobin	**.091**	**,643****	**.200**	**.050**	**-.183**	**-.148**	**.175**	**-.456**	**-.352**	**.068**	**1**		
Hematocrit	**.386**	**.195**	**.072**	**.354**	**-.013**	**-.305**	**-.134**	**.027**	**.072**	**-.511**	**-.152**	**1**	
PVV	**-.292**	**-,719****	**-.229**	**-.235**	**.188**	**.303**	**-.083**	**.401**	**.302**	**.202**	**-,875****	**-.342**	**1**

BM: Body mass**; BMI:** body mass index; **LBM:** lean body mass; **BF:** Fat mass; **1RM:** one-repetition maximum; **SQ:** squat; **BP:** bench press; **DL:** deadlift; **ΔPV:** plasma volume variation; **Hb:** hemoglobin concentration; **Ht:** hematocrit**; P.os:** Plasma osmolarity ; ****:** The correlation is significant at the 0.01 level (bilateral); *** :** The correlation is significant at the 0.05 level (bilateral).

Table 5: Correlation between anthropometric measurements, maximal strength and hematological parameters during the experiment among FED.

	BM	BMI	BF	LBM	1 RM_{SQ}	1 RM_{BP}	1 RM_{DL}	Platelets	P.os	Red cells	Hb	HT	ΔPV
BM	**1**												
BMI	**,852****	**1**											
BF	**-.278**	**-.239**	**1**										
LBM	**.448**	**.218**	**-.087**	**1**									
1 RMSQ	**.176**	**-.178**	**-.200**	**-.029**	**1**								
1 RMBP	**-.300**	**-.332**	**-.117**	**.137**	**.124**	**1**							
1 RMDL	**-.080**	**-.282**	**.017**	**-.149**	**.107**	**-.028**	**1**						
Platelets	**.165**	**.054**	**-.355**	**.130**	**-.091**	**-.139**	**.066**	**1**					
Osmolarity	**.097**	**.269**	**-.231**	**.086**	**-.223**	**,574***	**-.452**	**.057**	**1**				
Red cells	**.025**	**.084**	**-,554***	**-.390**	**.451**	**-.029**	**-.355**	**-.187**	**.103**	**1**			
Hemoglobin	**-.328**	**-.378**	**.489**	**-.076**	**-.010**	**-.001**	**-.170**	**-.387**	**.036**	**-.186**	**1**		
Hematocrit	**-.056**	**.072**	**-,560***	**.167**	**.037**	**,578***	**-.101**	**.029**	**.431**	**.247**	**-,524***	**1**	
PVV	**.434**	**.414**	**-.248**	**.010**	**.005**	**-.290**	**.244**	**.445**	**-.251**	**.069**	**-,884****	**.069**	**1**

BM: Body mass**; BMI:** body mass index; **LBM:** lean body mass; **BF:** Fat mass; **1RM:** one-repetition maximum; **SQ:** squat; **BP:** bench press; **DL:** deadlift; **ΔPV:** plasma volume variation; **Hb:** hemoglobin concentration; **Ht:** hematocrit**; P.os:** Plasma osmolarity ; ****:** The correlation is significant at the 0.01 level (bilateral); *** :** The correlation is significant at the 0.05 level (bilateral).