Chronotype, Aerobic Performance, and Sleep Quality of Young Athletes Before and During Ramadan Observance

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Background and Objective

Intermittent fasting has become a popular topic in recent years, with many people turning to this dietary approach to improve their health and manage their weight. It has also been studied for its potential impact on various aspects of health, including sleep and physical performance. This study aimed to investigate the impacts of intermittent fasting during Ramadan and chronotype on sleep quality and aerobic performance in young athletes.

Methods

This study is a prospective cohort design with repeated measurements, including 117 amateur athletes (16.86 ± 1.07 years) from Morocco. The aerobic performance was measured with the 20-m shuttle-run test. We also assessed sleep quality with the Pittsburgh Sleep Quality Index. The chronotype was assessed by the Morningness-Eveningness Questionnaire. We examined the difference in means before and during Ramadan; then, we analyzed the correlation between all variables.

Results

The current study showed that while aerobic performance and sleep quality declined during Ramadan, those with good sleep quality performed better in all periods. It also showed that chronotype is correlated with the aerobic performance before but not during Ramadan. However, the chronotype is associated with the sleep quality before and during Ramadan.

Conclusions

During Ramadan, athletes must build coping strategies to improve their sleep quality and maintain optimal physical performance.

Keywords

Chronotype; Sleep; Ramadan; Aerobic performance; Intermittent fasting.

INTRODUCTION

Fasting is a regular practice in several religions, including Christianity, Judaism, and Hinduism. Also, Muslims consider the month of Ramadan a holy month that requires fasting with high regard for faith. Indeed, fasting, as a form of intermittent fasting [1], starts at dawn to sunset during the whole month of Ramadan without interruption for 29 or 30 days [2]. The average fasting time varies according to the season and geographical location [3]. Nevertheless, in Morocco, it is around 12–18 hours. During that, people abstain from eating and drinking until dawn. Afterwards, they are free to eat until the next dawn.

The Ramadan intermittent fasting (RIF) makes some modifications, including altered eating schedules, sleep patterns, and exercise [4], that decrease the usual energy intake of the human body and alter the circadian rhythm [5]. Consequently, it puts the organism in a critical state. Notably psychological stability (e.g., motivation), physiological mechanisms, and biochemistry reactions could have detrimental effects on sports performance. Various aspects of human health and exercise performance can be affected. Moreover, the most significant repercussion is the decrease in physical activity [6]. Since most Muslim athletes con-
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According to the available research, RIF has a negative effect on peak oxygen uptake (VO₂peak) and athletic performance. Indeed, this study was conducted with 32 professional medium-distance male runners in the summer of 2019. They performed the Cooper Test before and during Ramadan. As a result, they showed that the physical performance of athletes deteriorated during Ramadan [7]. In addition, a systematic review including meta-analysis explored 28 articles (up to December 2019) and found that RIF affects maximum oxygen uptake negatively (RIF; standardized mean difference = -2.20, p < 0.001) [8]. Nevertheless, other studies showed significant increases in VO₂peak in male athletes. The participants were asked to run on the track for 30 minutes on two separate occasions (before and during Ramadan). The mean result revealed that Ramadan fasting had a small but significant impact on endurance running performance [9]. By contrast, no significant effects of RIF on aerobic performance were found when meta-analyzing pre-post data of all RIF interventions, confirming that athletes can participate in a competition in a fasting state with little impact on physical performance [10].

Muslim athletes who train during Ramadan may also cause significant changes associated with sleep disturbances and changes in sleep patterns [11]. Indeed, during fasting, athletes prefer to train in the evenings or early mornings, which affects quality and sleep duration [12]. In addition, previous studies have shown that sleep disorders significantly impact post-exercise recovery [13], fatigue [14], and circadian rhythm [15]. The last systematic review in 2020 showed that training during RIF decreases the total sleep times in athletes. However, no significant effect on other sleep characteristics was found [16]. For Moroccan young athletes at secondary school, the arrival of Ramadan poses an annual challenge. The Moroccan Ministry of National Education, Preschool and Sport changes the class schedule yearly during Ramadan, so these young athletes need more time to train during the day. As a reaction, they delay it until the evening, mainly after the first meal of the day (fasting break) or after the night prayer (Taraweeh), which will impact their own personal training rhythm. Additionally, due to the Moroccan table’s nature (carbohydrates and lipids but low in water and vegetables), that usually consumed late at night, more troubles are emerging due to gastric troubles, which can influence athletes’ sleep quality and circadian rhythm.

For all these reasons and given the lack of literature on the effect of RIF and circadian rhythm on the performance and sleep quality of young Moroccan athletes, this study aimed to evaluate the relationship between sleep quality, circadian preferences, and aerobic performance during the holy month of Ramadan in the RIF. We hypothesized that fasting during the daytime in the holy month of Ramadan may affect the long-term maximal performance of Muslim athletes and their sleep patterns according to their circadian profile.

METHODS

Study Design and Setting

This experimental study with repeated measures in a non-random sample of volunteers was conducted during the month preceding and during Ramadan in 2022. It started on April 3 and finished on May 2. The temperature reached up to 21°. The minimum seasonal temperature is 14°. The average fasting duration was 15 hours 30 minutes. The study was conducted according to the Declaration of Helsinki and was approved by the Local Ethics Committee of Normal Higher School of Casablanca with the number No. 09-2021. All participants signed an informed consent agreeing to participate in the study. The sample performed a 20-m shuttle run test (SRT) [17] at three different time points: the first was before one week of Ramadan (BR), and the others were during the second (DR1) and last week of Ramadan (DR2). The Morningness-Eveningness Questionnaire (MEQ) [18] was completed just before Ramadan (BR), and the Pittsburgh Sleep Quality Index (PSQI) [19] was completed before and at the end of Ramadan (ER) (Fig. 1).

Fig. 1. Schematic explanation of the experimental protocol. MEQ, Morningness-Eveningness Questionnaire; SRT, 20-m shuttle run test; PSQI, Pittsburgh Sleep Quality Index.
Participants
The sample comprised 117 high school students performing in several sports (individual sport = 30, dual sports = 3, team sports = 84). The mean age of the subjects was 16.86 ± 1.07 years, with 72 females and 45 males. All subjects were non-smokers, non-drinkers, without sleep disorders, and declared that they regularly practiced at least 10 hours per week. Before starting, we described the circumstances of the protocol, including possible benefits/risks. Then, researchers obtained consent from all participants in the study project. The intervention is carried out during the physical education schedules, and all tests are programmed in the athletic area.

Assessment
Data for anthropometric variables were measured using a portable scale to the nearest 5 mm and 100 g, respectively (Seca 217, Vogel & Halke, Hamburg, Germany). The body mass index (BMI) is obtained by using the formula weight (in kg) divided by height squared (cm²).

SRT
It is widely used to predict aerobic fitness. The protocol consists of running progressively between 2 lines 20 m and following the recorded beeps, which increase gradually as the participant changes direction each time a beep is emitted. The first level corresponds typically to a speed of 7 to 8.5 km/h, increasing by 0.5 km/h at each step. When the student can no longer run following the beep, he or she has reached his or her VO₂max test. The participant’s score represented the level and quantity of shuttles (20 m) attained before losing track of the recording. The evaluators continually encouraged the participants to perform at their best [17].

MEQ
It measures the individual factors in the preferred time of activity, including circadian rhythm, sleep-wake times, and active time zones. The MEQ is a 19 item, and the scores range from 16 to 86. A score of 59 or higher indicates morningness (M-type), a score between 41–59 indicates neither type (N-type), whereas a score of 41 or lower denotes eveningness (E-type) [18]. In our study, four academics independently translated and examined the questionnaire in Arabic. Afterward, we conducted a trial study with 30 participants to determine if the questionnaire was comprehensive. The same respondents received the questionnaire under the same conditions one month later. Then, we apply the questionnaire to the study. The Cronbach’s alpha coefficient of the first and second applications were 0.77 and 0.73, respectively.

PSQI
It is an essential instrument for measuring sleep patterns in adolescents and adults. It provides two levels of sleep quality (poor or good) by measuring seven components: sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use sleep medicine, day time dysfunction, and global score over the past month. The rating of responses is based on a scale of 0 to 3, where 3 reflects the extreme negative on the Likert scale. A total score of “5” or higher indicates a “poor” sleeper. In this study, we used the Arabic version as published on 2010 [19].

Statistical Analyses
The data were reported as mean ± standard deviation (SD). We used the Shapiro-Wilk test to check the distribution of parameters. When the parameters showed a normal distribution, we performed a one-way analysis of variance (ANOVA) and the Tukey-Kramer post hoc test to compare selected characteristics between groups. The partial eta squared (η²) was performed to determine the effect size for significant results (α = 0.05) in the ANOVA. The significance level was set at p < 0.05. The Student’s t-test or Mann-Whitney U test (depending on the data distribution) was used to compare the baseline results with the other condition for each parameter. The comparisons between different time points within each group were performed using a one-way repeated-measures ANOVA and multivariate ANOVA (MANOVA) for continuous variables, then a post hoc test with Bonferroni correction. The chi-squared test was used to compare proportions when comparing the baseline with different conditions. The results were judged to be significant at the p = 0.05 level. We used Pearson’s or Spearman’s correlation index to check the correlation between parameters. Statistical analysis was performed using SPSS version 25 (IBM Corp., Armonk, NY, USA).

RESULTS
MEQ Outcomes
Based on the MEQ scores, 29 moderately morning types (24.8%: 13 males and 16 females), 7 moderately evening types (6%: 2 male and 5 females), and 81 neither types (69.2%: 30 males and 51 females) were identified (Table 1). The chi-square (χ²) tests showed no significant association between chronotype and sex (χ² = 0.855, p = 0.652). With one-way ANOVA, it was found that the MEQ does not vary significantly with the type of sport practiced (F = 0.72, p > 0.05) and with BMI (F = 1.07, p > 0.05). The correlation between the MEQ score and the VO₂peak before RIF was significant (r = 0.18, p < 0.05), but not for the other measure during RIF. Then, it was significant with PSQI global score before and at the end of Ramadan (PSQIgas: r = -0.27, p < 0.05; PSQIgas: r = -0.25, p < 0.05).

SRT Outcomes
Repeated measures ANOVA shows a significant difference in the three measurements (F = 8.951, p = 0.001). Also, one-way MANOVA showed significant difference in VO₂peak based on the
circadian profile ($F(2, 224) = 2.90, p < 0.05$; Wilk’s $\lambda = 0.861$, partial $\eta^2 = 0.72$). A Pearson correlation coefficient was computed to assess the linear relationship between $\text{VO}_2\text{peak}$ and PSQI global score (Table 2). Also, there was a negative correlation between the PSQI$_{ER}$ and $\text{VO}_2\text{peak}_{BR}$ ($r_{BR} = -0.194, p = 0.036$), and no relationship with the other measures.

**PSQI Outcomes**

A one-way repeated measures ANOVA was performed to determine if the mean PSQI in athletes differed between two times (BR, ER). A t-test revealed that RIF led to statistically significant differences in PSQI global score ($t = -10.12, p < 0.001$) (Table 3). Also, one-way MANOVA showed significant difference in sleep quality based on the circadian profile ($F(4, 226) = 3.43, p = 0.01$; Wilk’s $\lambda = 0.889$, partial $\eta^2 = 0.59$). From the linear regression, it was found that the quality of sleep at the end of Ramadan causes a reduction in $\text{VO}_2\text{peak}$ significantly ($B = -0.95$, beta $= -0.19$, $t = -2.03$, $p = 0.044$).

**DISCUSSION**

The present study aimed to investigate the impact of the circadian profile on aerobic physical performance and sleep quality in the young athletes’ Muslim community during RIF. The result showed that Vo2max and sleep quality declined during RIF. It also showed that the circadian profiles of athletes affect these variations. In addition, there was a negative correlation between the PSQI$_{ER}$ and $\text{VO}_2\text{peak}_{BR}$. Also, the positive correlation between chronotype and $\text{VO}_2\text{max}_{BR}$.

The current study found that the sleep quality deteriorated during Ramadan. These results support previous research which links sleep patterns and RIF. Indeed, sleep quality is negatively

### Table 1. Descriptive statistics for all variables

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value (n = 117)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>16.86 ± 1.07</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>72 (61.5)</td>
</tr>
<tr>
<td>Male</td>
<td>45 (38.5)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.59 ± 3.3</td>
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<tr>
<td>Type of exercise</td>
<td></td>
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<tr>
<td>Individual sports</td>
<td>30 (25.6)</td>
</tr>
<tr>
<td>Dual sports</td>
<td>3 (2.6)</td>
</tr>
<tr>
<td>Team sports</td>
<td>84 (71.8)</td>
</tr>
<tr>
<td>Chronotype</td>
<td></td>
</tr>
<tr>
<td>M-type</td>
<td>29 (24.8)</td>
</tr>
<tr>
<td>N-type</td>
<td>81 (69.2)</td>
</tr>
<tr>
<td>E-type</td>
<td>7 (6.0)</td>
</tr>
<tr>
<td>PSQI BR</td>
<td>5.35 ± 2.44</td>
</tr>
<tr>
<td>PSQI ER</td>
<td>7.64 ± 2.43</td>
</tr>
<tr>
<td>$\text{VO}_2\text{peak}$ (mL/kg/min)</td>
<td></td>
</tr>
<tr>
<td>1 week before Ramadan</td>
<td>47.45 ± 11.83</td>
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<tr>
<td>1st week of Ramadan</td>
<td>44.83 ± 13.05</td>
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<tr>
<td>3rd week of Ramadan</td>
<td>42.14 ± 11.47</td>
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</table>

Values are presented as mean ± standard deviation or number (%). BMI, body mass index; M-type, morning-type; N-type, neither-type; E-type, evening-type; PSQI, Pittsburgh Sleep Quality Index; BR, before Ramadan; ER, end of Ramadan; $\text{VO}_2\text{peak}$, maximal oxygen uptake.

### Table 2. Correlations between variables

<table>
<thead>
<tr>
<th></th>
<th>1. BMI</th>
<th>2. $\text{VO}<em>2\text{peak}</em>{BR}$</th>
<th>3. $\text{VO}<em>2\text{peak}</em>{DR1}$</th>
<th>4. $\text{VO}<em>2\text{peak}</em>{DR2}$</th>
<th>5. MEQ</th>
<th>6. PSQI BR</th>
<th>7. PSQI ER</th>
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<td>1</td>
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<td>2</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.065</td>
<td>0.838†</td>
<td>1.000</td>
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<td>0.944†</td>
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<tr>
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<td>0.181*</td>
<td>0.029</td>
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<tr>
<td>6</td>
<td>-0.178</td>
<td>0.049</td>
<td>-0.028</td>
<td>-0.017</td>
<td>-0.266*</td>
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<tr>
<td>7</td>
<td>-0.110</td>
<td>-0.194*</td>
<td>-0.158</td>
<td>-0.156</td>
<td>-0.246*</td>
<td>0.463†</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*a$p < 0.05$; †$p < 0.001$.

BMI, body mass index; $\text{VO}_2\text{peak}$, maximal oxygen consumption; MEQ, Morningness-Eveningness Questionnaire; PSQI, Pittsburgh Sleep Quality Index; BR, before Ramadan; DR, during the 2nd week of Ramadan; DR2, during the last week of Ramadan; ER, end of Ramadan.
impacted during Ramadan [20] and at the end of the Ramadan [21]. Other studies showed that while training was maintained at least twice weekly, only the overall amount of sleep was reduced during RIF [22]. Our result showed a negative correlation between the PSQI_{eq} and VO_{peak, BR}. The present findings disagree with earlier data showing that sleep deprivation does not affect anaerobic performance [23]. But, according to prior research, longer sleep duration and better sleep quality are associated with higher performance and competitive success in athletes [24]. One interesting finding is that aerobic performance was affected negatively by the RIF. Indeed, empirical studies suggest that Ramadan observance has little impact on aerobic function [25] and on the maximal oxygen intake of athletes [8]. One possible explanation for these findings is that the dehydration associated with Ramadan may lower blood volume, maximal cardiac output, and muscle glycogen reserves, which may impact maximal oxygen uptake [8]. However, our results differ from other studies that worked on short-term fasting (7 days). They found no effect on aerobic performance, walking efficiency, or maximum oxygen uptake [26]. A possible explanation might be that the body's mechanisms can still support and adapt to this fast intermittent fasting. Moreover, an additional study is required to examine the relationship between Ramadan fasting and changes in aerobic exercise, using designs that control the daily uptake and the level of physical activity during RIF, to verify if the results are independent of it. In the current study, sex is not associated to the chronotype. Many previous studies involving adolescents did not find sex differences in the frequency of morning or evening types [27]. But other study showed that biological sex has significant interactions with circadian processes [28]. In particular, it reported that females tend to be “early birds” and have faster internal clocks than men [29]. One interesting finding is that the circadian profiles of athletes correlated positively with aerobic performance before but not during RIF. Our results seem consistent with other research, which failed to show any circadian or diurnal rhythmicity effect on long-duration exercise performance during Ramadan [30]. In contrast, other studies reported significant changes in aerobic performance for the full marathon [11], 2000-m rowing sprint [31], and 200-m swimming trial [32]; or when the exercise is done in the evening [33]. Furthermore, the E-type athletes had better values of VO_{peak} [34]. Previous studies have indicated that high caloric consumption can alter the clock genes in the brain [35]. Given these considerations, the available scientific data appear to be equivocal. We need more research to define the effect of Ramadan on circadian typology during aerobic exercise to propose the best program training for young athletes and avoid the decline in performance in Ramadan fasting. The present findings suggest a significant difference of sleep quality based on chronotype. This result is inconsistent with other research, which showed that biological clock markers, daytime sleepiness, or sleep characteristics did not change across the whole diurnal intermittent fasting of Ramadan [36]. However, this result is consistent with other research, which showed that late-night-dinner eating and sleeping with a full stomach could negatively affect the circadian rhythm [36] and quality of sleep [37]. Indeed, it has been demonstrated repeatedly that Ramadan fasting is generally associated with changes in sleep, habitude intake [38], and mood states [39]. All this hypothesis may explain the sleep quality during Ramadan [20]. For this reason, our results need to be interpreted with caution. To other Arab nations, the changes cannot be generalized. Several of the reported changes also reflect regionally specific cultural and lifestyle changes.

The study presents some limitations. The anthropometric data were measured only before Ramadan, not during and after Ramadan. Since the study was limited to assessing the chronotype only during Ramadan, it was possible to find more changes in circadian rhythms during or after Ramadan. Thus, it is highly recommended to take more than one measure. It is unfortunate that the study did not include an objective method for the measurement of sleep and the circadian typology. The use of electronic devices is very recommended. The most important limitation lies in the fact that we cannot find a control group that did not observe Ramadan. Indeed, finding a sample that satisfied our inclusion criteria and that did not fast during Ramadan was a challenge. The only people who did not fast were athletes who were sick or women athletes who were on their menstrual period. Finally, the study did not check the motivation level of the participants during the physical test. It is possible that not all participants have the same preference for the endurance tests.

The main goal of the current study was to evaluate the effect of circadian preferences and sleep patterns on aerobic performance during the intermittent fasting of the holy month of Ramadan. We hypothesized that intermittent fasting may affect the long-term maximal performance and sleep quality but not the circadian type. The research showed that VO_{max} and sleep quality declined during RIF. It also showed that the circadian profiles of athletes affect these variations. In addition, there was a negative correlation between the PSQI_{eq} and VO_{peak, BR}. Also, the positive correlation between chronotype and VO_{max, BR}. Given the above considerations, the choice of practice time during Ramadan should not be arbitrary. It is recommended to check the individual circadian preferences and other sleep patterns before suggesting the best training program. Further investigations are needed to reveal athletes' strategies to cope with the negative effects of changing sleep habits and circadian rhythms during official athletic competitions.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Author Contributions


Conflicts of Interest
The authors have no potential conflicts of interest to disclose.

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None

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