Does Ramadan Observance Affect Cardiorespiratory Capacity of Healthy Boys?

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Abstract
Studies raising the issue of the effects of Ramadan observance (RO) on boys’ 6-min walk test (6MWT) data are rare. The studies, which did not include control groups of non-fasters, presented contradictory results. This study aimed to compare the 6MWT data (6-min walk distance [6MWD; m, %predicted], heart rate [HR; bpm, % of maximal predicted HR]), oxy-hemoglobin saturation (Oxy-sat; %), systolic and diastolic blood pressures (SBP and DBP, respectively; mmHg) determined at rest (Rest) and at the end (End) of the test of a group of 22 healthy fasting boys (age: 12 to 15 years) with an age-matched non-fasting group (n = 10). The 6MWTs were performed during three experimental conditions (ECs): Pre-Ramadan, Mid-Ramadan, and Post-Ramadan. The two groups’ 6MWT data for each EC were compared, and repeated factorial analysis of variance (2 groups vs. 3 ECs) was performed. Both groups had similar values of 6MWD (m, %predicted), HRRest or HREnd (bpm, % of maximal predicted HR), Oxy-satRest, Oxy-satEnd, SBPRest and DBPRest during the three ECs. Compared to the non-fasting group, the fasting group had significantly higher SBPEnd (121 ± 10 vs. 130 ± 11) and DBPEnd (72 ± 6 vs. 78 ± 7) determined during the Mid-Ramadan EC. No significant interactive effects of the groups (2) vs. ECs (3) was found for the 6MWD (%predicted; p = .809), HRRest (%; p = .555), HREnd (%; p = .964), Oxy-satRest (p = .336), Oxy-satEnd (p = .389), SBPRest (p = .708), SBPEnd (p = .548), DBPRest (p = .277), and DBPEnd (p = .096). To conclude, in boys, RO does not impact the 6MWD, HR, or Oxy-sat, but it has minimal impact on the SBPEnd and DBPEnd.

Keywords
North Africa, Ramadan fasting, child, adolescent, walking test

Received November 14, 2019; revised February 20, 2020; accepted March 5, 2020

Ramadan observance (RO; i.e., abstaining from both food and fluid ingestion from dawn to sunset) concerns every healthy Muslim starting from the age of puberty (i.e., 12 to 15 years old for boys; Aslam & Wilson, 1992). In adults, RO leads to several physiological changes (e.g., sleep, alertness, meal times and eating agenda, hypohydration, body composition, metabolic and/or ventilatory responses; Aloui et al., 2019; Ben Saad, 2018; Iraki et al., 1997; Latiri et al., 2017; Roky et al., 2012; Trabelsi, El Abed, et al., 2011; Trabelsi, Rebai, et al., 2011). Altogether, the aforementioned RO-induced changes can lead to a decrease in adults’ physical activity and performance levels (Aloui et al., 2013; Aloui et al., 2018; Aziz et al., 2010; Brisswalter et al., 2011; Cherif et al., 2016; Chtourou et al., 2019; Kirkendall et al., 2008; Lessan et al., 2018; Ramadan, 2002; Ramadan et al., 1999; Ramadan & Barac-Nieto, 2000). As children/adolescents are not miniature adults (Chang, 2010), the hypothesis that the RO physiological changes reported in adults may
be extrapolated in children and adolescents is questionable and should be verified.

Most of the published studies examining the impacts of RO on cardiorespiratory capacity were conducted on adults (Aloui et al., 2013; Aloui et al., 2018; Aziz et al., 2010; Brisswalter et al., 2011; Chaouachi et al., 2009; Cherif et al., 2016; Chtourou et al., 2019; Kirkendall et al., 2008; Lessan et al., 2018; Ramadan, 2002; Ramadan et al., 1999; Ramadan & Barac-Nieto, 2000), and the data regarding its impacts on children’s cardiorespiratory capacity are few. To the best of the authors’ knowledge, only five studies have examined the impacts of RO on the physical capacities of children/adolescents (Aloui et al., 2013; Fenneni et al., 2014, 2017; Girard & Farooq, 2012; Meckel et al., 2008). The methodologies and results of the aforementioned studies were discussed by Fenneni et al. (2015). First, several different tests were performed: vertical jump test (Fenneni et al., 2014; Meckel et al., 2008), horizontal jump test (Fenneni et al., 2014), counter movement jump (Aloui et al., 2013), squat jump (Aloui et al., 2013), 20-m sprint (Fenneni et al., 2014; Girard & Farooq, 2012), 30-m sprint (Fenneni et al., 2014), 40-m sprint (Meckel et al., 2008), 4 × 10-m run (Meckel et al., 2008), sum × 40-m run (Meckel et al., 2008), 6 × 40-m performance (Meckel et al., 2008), 3,000-m run (Meckel et al., 2008), medicine ball throw (Fenneni et al., 2014), maximal oxygen uptake (Aloui et al., 2013), and 6-min walk test (6MWT; Fenneni et al., 2014, 2017). Second, in their critical analysis of the published literature about the impacts of RO on healthy children’s physical capacities, Fenneni et al. (2015) concluded that “the impact of RO on the physical capacities of children appears controversial, but there is a penchant to a reduction in endurance performance, while a minor decrement or no significant impact on short-term explosive performance has been shown.” Third, some important methodological limitations leading to anecdotal comparisons of physical responses between studies were noted (Fenneni et al., 2015). The main limitations concerned the lack of sample sizes calculation and the lack of information about some important data (e.g., geographical location, season, duration of fasting, test timing, previous experience with RO, children’s physical activity status, average ambient temperature and relative humidity at the time of physical testing; Fenneni et al., 2015). Finally, all of the aforementioned studies did not include a parallel control group (CG) of non-fasting. The lack of a parallel CG of non-fasting explained a large part of the results’ discrepancy (Fenneni et al., 2015), since this alters the internal validity of the studies’ findings and therefore the variations in the data assessed cannot be exclusively related to RO. For this reason, Fenneni et al. (2015) strongly recommended that future similar studies should systematically include a CG of non-fasting in order to circumvent any threat to the internal strength of the results.

In children/adolescents, the assessment of the cardiorespiratory capacity via, for example, a field test data (e.g., 6MWT; American Thoracic Society [ATS] 2002; Ben Saad et al., 2009) provides valuable information to make management decisions leading to improve functional capacity (Connuck, 2005; Massin, 2014). The 6MWT, a self-paced test of walking capacity where subjects are asked to walk as far as possible in 6 min along a flat corridor (Holland et al., 2014), is very useful in both healthy and unhealthy children/adolescents (Andrade Lima et al., 2018; Cacau et al., 2016; den Boer et al., 2017; Himuro et al., 2017; Mylius et al., 2016). During the 6MWT, the following data are recorded/noted: 6-min walk distance (6MWD; the primary outcome of the 6MWT), systolic and diastolic blood pressures (SBP, DBP, respectively), heart rate (HR), and oxy-hemoglobin saturation (Oxy-sat; ATS, 2002; Holland et al., 2014). The strong relationships between the 6MWD and the measurements of exercise performance and physical activity support the conceptualization of the 6MWT as a test of functional exercise performance (Li et al., 2005). In children/adolescents, the 6MWD elicits a peak oxygen uptake that is similar to the one determined during a cardiopulmonary exercise test (Li et al., 2005). During exercise, the HR responses reflect the subjects’ physical level (Holland et al., 2014; Singh et al., 2014). The Oxy-sat and arterial blood pressure responses during exercise are important parts of exercise data interpretation (Brenner & Allemann, 2011; Sharma et al., 2012). The only study that evaluated the impact of RO on children’s/adolescents’ 6MWD concluded that “RO impairs submaximal exercise capacity” (Fenneni et al., 2014). In addition, the only study dealing with the impact of RO on children’s/adolescents’ HR and/or Oxy-sat changes concluded that “RO influences HR data but has minimal impacts on Oxy-sat” (Fenneni et al., 2017). The Oxy-sat changes were not “clinically significant” since they were lower than 5 points (Fenneni et al., 2017). To the best of the authors’ knowledge, no previous study has raised the issue of the impact of RO on children’s/adolescents’ arterial blood pressures determined during the 6MWT.

In real life, it is a relatively current practice for children to make their first attempt of RO while they are still prepubescent (i.e., from early adolescence; Deeb et al., 2017). It is quite questionable whether prepubescent children should be allowed to fast while religion requires such a practice only after puberty (Fenneni et al., 2015). The question that should be raised will be as follows: Does RO alter the cardiorespiratory capacity of children/adolescents? Taking into account the above considerations, the main aim of this quasi-experimental study performed on healthy boys aged 12–15 years was to compare the 6MWD, Oxy-sat, HR, SBP, and DBP of a fasting group with an age-matched non-fasting one. The null
hypothesis is that there is no difference between their 6MWD, Oxy-sat, HR, SBP, and DBP mean values.

Population and Methods

The present study is part of a project involving two parts. The first, which was recently published, aimed to evaluate the impact of RO on spirometric data (Ben Fraj et al., 2019). The authors concluded that “RO had no interaction effect with the spirometric data of healthy boys.” The second part is the objective of this study.

Study Design

This quasi-experimental study was conducted in compliance with the World Medical Association (WMA) Declaration of Helsinki in a junior high school located in Kalaa-Sghira (Sousse, Tunisia). Approval for the study was obtained from the Farhat Hached Hospital Ethical Committee (approval number 1206/2015) and written consent was obtained from all the participants’ parents. Boys agreed verbally to participate in this study. Participation in this study was free of pressure and participants were informed that they could withdraw from the study at any time. Participants were also informed that they can stop RO at any time.

The study was conducted during Ramadan 2015 (mean elapsed time from dawn to sunset $= 16.15$ h). The means of ambient temperature and humidity during the study period (59 days) were 32.8°C and 68%, respectively. The means of ambient temperature and humidity during the Pre-Ramadan (Pre-R), Mid-Ramadan (Mid-R), and Post-Ramadan (Post-R) experimental conditions (ECs) were, 32.0, 31.6, and 34.7 °C; and 71.7, 63.8, and 73.7%, respectively.

Sample Size

The total sample size was estimated using the following formula (Maxwell et al., 2008):

$$N = \left( r + 1 \right) \left( Z_{\alpha/2} + Z_{\beta} \right)^2 \frac{\delta^2}{r d^2}$$

- $N$ is equal to $n_1 + n_2$ ($n_1$ and $n_2$ are the sample sizes for the two groups of fasters and non-fasters)
- $Z_{\alpha/2}$: normal deviate at a level of significance ($= 1.96$ for 5% level of significance)
- $Z_{\beta}$: normal deviate at 1-β% power with β% of type II error ($= 2.33$ at 99% statistical power)
- $r$ (equal to $n_1/n_2$): ratio of the sample size required for the two groups ($r = 2.5$ gives the sample size distribution as 2.5:1 for the fasting and non-fasting groups). The reason for the unequal sample size was the difficulty in finding non-fasters in this age group

- $\delta$ and $d$ are the pooled standard deviation (SD) and the difference of the 6MWD means of the two groups determined at Mid-R. These two values were obtained from a previous study having a similar hypothesis and including 18 fasting boys (mean ± SD of age and weight were $11.9 \pm 0.8$ years and $55.4 \pm 18.2$ kg, respectively; Fenneni et al., 2014). During the 2nd week of Ramadan, the fasters had a 6MWD of $635 \pm 105$ m (Fenneni et al., 2014; while the mean 6MWD predicted normal values derived from a group of healthy North African children [Ben Saad et al., 2009] was $703 \pm 54$ m) with a common $SD$ of $78.5$ m ($=(105+54)/2$).

The total sample size was 34 boys (23 fasters and 11 non-fasters). The assumption of 40% of nonattendance during the second/third testing EC gives a revised sample of 56 boys ($= 34/(1 - 0.40)$).

Study Population

Figure 1 describes the study consort flowchart. Only healthy volunteer participants aged 12 to 15 years were included. In this study, the term “boys” was used to include the following two terms: “children” (6 to 12 years old; http://www.ncbi.nlm.nih.gov/mesh/68002648; last...
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access: February 14, 2020) and “adolescents” (13 to 18 years old; http://www.ncbi.nlm.nih.gov/mesh/68000293; last access: February 14, 2020). The noninclusion criteria were smoking, chronic diseases, obesity, abnormalities of the vertebral column or thoracic cage, thoracic or abdominal surgery, chronic medication use, lack of cooperation during the spirometry test, bronchial obstruction, inability to perform the 6MWT, and 6MWT contraindications (Holland et al., 2014; HR_{Rest} ≥ 120 bpm; high SBP_{Rest} or DBP_{Rest} [Rao, 2016]). The following exclusion criteria were applied: fasting some days during Ramadan (for the non-fasting group), incomplete RO period (for the group of fasters), and absence during the second/third testing EC.

Experimental Design

The experimental design consisted of three testing ECs: 5–7 days Pre-R (23 to 25 Shabaan), 3 days Mid-R (15 to 17 Ramadan), and 10–12 days Post-R (20 to 22 Shawal). For the group of fasters, a complete RO period was defined as including 29 days.

During the Pre-R EC, all the boys answered a medical questionnaire. Second, anthropometric data (age, height [cm], weight [kg], body mass index [BMI, kg/m^2]) were noted. After that, the boys performed a spirometry followed by a 6MWT. During the Mid-R and Post-R ECs, merely the anthropometric, spirometric, and 6MWT data were determined. The 6MWT of the three ECs was conducted at the same time of the day, around 5.5 to 3.5 h before sunset, when fasters are allowed to break their fast.

Collected Data, 6MWT Procedures, and Applied Definitions

Clinical data were gathered from a simplified medical questionnaire (Ferris, 1978). Questions were asked in Arabic and the subsequent data were collected: practice of regular sports activities, parents’ professions, individual medical or surgical histories, chronic treatment use, and smoking behaviors.

During every EC, each boy performed only one 6MWT. The 6MWD (m) was noted and expressed as a percentage of the predicted local norms (Ben Saad et al., 2009): 6MWD (m) = 4.63 × height (cm) - 3.53 × weight (kg) + 10.42 × age (years) + 56.32. The following data were determined at Rest and at the End of the 6MWT: Oxy-sat (%), HR_{Rest}, HR_{End}, SBP_{Rest}, SBP_{End}, DBP_{Rest}, and DBP_{End}.

The 6MWT was conducted according to the standardized protocol (ATS, 2002; Holland et al., 2014). The 6MWT was performed along a seldom traveled, flat, straight corridor (40 m long; marked every 1 m with cones) with a hard surface. To minimize intraday variability, the 6MWT was conducted at the same time of day (Chtourou & Souissi, 2012). Boys were familiarized with the 6MWT to minimize the learning effect (Morales Mestre et al., 2018). They were asked to avoid strenuous activities 24 h before each testing EC and were asked to wear comfortable clothes and appropriate walking shoes. The boys sat in a chair placed near the starting position for at least 10 min before the 6MWT started. During this time, the HR, Oxy-sat (handheld pulse oximeter, M700; Zuhai, Guangdong, China) and arterial blood pressures (electric manual blood pressure monitor with child armband, Tech Discount, France) were measured at rest. The test instructions given to the boys were those recommended by the ATS/European Respiratory Society (ATS, 2002; Holland et al., 2014). At the end of the 6MWT, the same data were remeasured.

The following data were calculated:

(i) ΔOxy-sat (=Oxy-sat_{End} - Oxy-sat_{Rest}). For each EC, a ΔOxy-sat decrease more than 5 points was defined as a “clinically significant” desaturation (Fenneni et al., 2017; Singh et al., 2014).

(ii) Percentage changes in 6MWD, Oxy-satRest, Oxy-satEnd, HR_{Rest}, HR_{End}, SBP_{Rest}, SBP_{End}, DBP_{Rest}, and DBP_{End} at Post-R compared with Pre-R:

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\%\text{change} = 100 \times \frac{(\text{Post-R value} - \text{Pre-R value})}{\text{Pre-R value}}
\]

(iii) 6MWD change (m) = Post-R 6MWD minus Pre-R 6MWD. 6MWD higher and lower than the 90% 6MWD level minimal detectable change (e.g., an arbitrary MDC90 of 48 m) was considered as “clinically significant” decrease and increase, respectively (Klepper & Muir, 2011).

Statistical Analysis

The Kolmogorov-Smirnov test was used to analyze quantitative data distributions. The quantitative data (anthropometric [age, weight, height, BMI] and 6MWT [6MWD (m, %predict, % change), HR (bpm; % of maximal predicted HR, % change), SBP (mmHg, % change), DBP (mmHg, % change), and Oxy-sat (% , % change)] data) were expressed as mean ± SD. The two groups’ quantitative data for each EC were compared using the Mann–Whitney U Test. Comparisons of the 6MWT data
were made between the three ECs via a factorial analysis of variance in order to analyze the higher order interactive effects of multiple categorical independent factors (groups [2] vs. EC [3]). Qualitative data (percentages of boys with “clinically significant” desaturation or 6MWD decrease or 6MWD increase) were expressed by relative frequency. In order to differentiate between the “statistically significant” and the “clinically significant” approaches (Yaddanapudi, 2016), the percentages of boys with “clinically significant” desaturation or 6MWD decrease or 6MWD increase were compared between the two groups (two-sided chi-squared test).

Analyses were carried out using Statistica software (Statistica Kernel version 6; StatSoft, Paris, France). Significance was set at the 0.05 level.

Results

Among the initial sample of 60 boys, only 36 were retained (26 fasters and 10 non-fasters; Figure 1). The fasting and non-fasting groups had similar mean ± SD ages (13.3 ± 0.8 vs. 12.9 ± 0.5 years; p = .1974), weights (46.8 ± 9.2 vs. 41.7 ± 12.6 kg; p = .1288), and BMIs (18.4 ± 2. vs. 18.3 ± 4.1 kg/m²; p = .5601). The fasters were significantly taller than the non-fasters (159 ± 9 vs. 150 ± 9 cm; p = .0273, respectively).

Impact of RO on 6MWD

There was no significant difference between the two groups’ mean 6MWD data (expressed in m or as % of predicted) for each EC (Table 1). No significant interactive effect of the groups (2) vs. ECs (3) was found.

Impact of RO on HR

There was no significant difference between the two groups’ mean HR data (expressed in bpm or % of maximal predicted HR) for each EC (Table 2). No significant interactive effect of the groups (2) vs. ECs (3) was found.

Impact of RO on Arterial Blood Pressures

The two groups had similar values of SBP Rest and DBP Rest for each EC and similar values of SBP End and DBP End during the Pre-R and Post-R ECs (Table 3). However, compared to the non-fasting group, the fasting group had higher values of SBP End and DBP End during the Mid-R EC. No significant interactive effect of the groups (2) vs. ECs (3) was found.

Impact of RO on Oxy-Sat

The two groups had similar Oxy-sat values for each EC (Table 4). No significant interactive effect of the groups (2) vs. ECs (3) was found. During the three ECs, no boy presented a “clinically significant” desaturation.

6MWT Data Changes Between the Two Groups

The two groups had similar percentage changes in 6MWT data (6MWD, Oxy-sat Rest, Oxy-sat End, HR Rest, HR End, SBP Rest, SBP End, DBP Rest, DBP End) at Post-R compared with Pre-R (Table 5).

Discussion

Values of 6MWD, HR, Oxy-sat, and arterial blood pressure of the healthy 26 fasters and 10 non-fasters boys aged 12 to 15 years with similar ages, weights, and BMIs were compared during the three ECs. It appears that RO had no impact on the 6MWD, HR, Oxy-sat, and resting arterial blood pressures. However, during the Mid-R EC, the fasting group, compared to the non-fasting one, had significantly higher

Table 1. Six-Minute Walk Distance (6MWD) Values During the Three Experimental Conditions: Fasters (n = 26) and Non-Fasters (n = 10) Groups.

|                  | Pre-R | Mid-R | Post-R | Factorial ANOVA |
|------------------|-------|-------|--------|-----------------|
| 6MWD (m)         |       |       |        |                 |
| Fasters          | 680 ± 76 | 679 ± 98 | 652 ± 68 | F(2,102) = 0.196; p = .822 |
| Non-fasters      | 635 ± 60 | 619 ± 69 | 618 ± 69 |                 |
| p                | .120 | .066 | .120 |                 |
| 6MWD (%)         |       |       |        |                 |
| Fasters          | 89 ± 9 | 88 ± 11 | 85 ± 8 | F(2,102) = 0.213; p = .809 |
| Non-fasters      | 86 ± 9 | 84 ± 10 | 84 ± 9 |                 |
| p                | .368 | .237 | .537 |                 |

Note. Data were mean ± SD. ANOVA = analysis of variance; R = Ramadan.

Factorial ANOVA: between the three experimental conditions for the two groups.
p: Mann–Whitney U test between the two groups for the same experimental condition.
SBPEnd by ~9 mmHg and DBPEnd by ~6 mmHg. The null hypothesis that there is no difference between the two groups’ SBPEnd and DBPEnd mean values is rejected.

To the best of the authors’ knowledge, only two studies (Fenneni et al., 2014, 2017), belonging to the same project, examined the impact of RO on the boys’ 6MWT data. The methodology of the project and the two studies’ main results are largely described in Table 6.

**Impact of RO on 6MWD**

The 6MWD was not affected by RO (Table 1). This result was inconsistent with the one previously observed by Fenneni et al. (2014) where the 6MWD was 85 m shorter during the 4th week of Ramadan compared to Pre-R (Table 6). According to Fenneni et al. (2014), the 85-m difference was higher than the arbitrary MDC90 of 48 m used to determine whether the change in the 6MWD following intervention (i.e., RO) is “clinically significant” (Klepper & Muir, 2011). The aforementioned finding is not sustained by this study since the two groups of fasters and non-fasters included similar percentages of boys with a “clinically significant” 6MWD decrease (57.69% vs. 30.00%, respectively). The present study result is not surprising since the respiratory system adapts normally during RO (Ben Fraj et al., 2019). A
recent study concluded that “RO had no interaction effect with the spirometric data of healthy boys” (Ben Fraj et al., 2019). For example, during the Pre-R, Mid-R, and Post-R ECs, there was no significant difference between the fasters and non-fasters groups’ mean forced expiratory volume in 1 s (101 ± 13 vs. 96 ± 16; 98 ± 11 vs. 97 ± 16; 101 ± 10 vs. 98 ± 16%, respectively; Ben Fraj et al., 2019). It is important to highlight that while RO impairs the adolescents’/children’s performance during maximal and endurance exercises with higher intensities (e.g., increased 3,000-m running time; Fenneni et al., 2015; Meckel et al., 2008), it has no impact on the short-term explosive performance (e.g., vertical and horizontal jump tests, 20-m and 30-m sprints, and medicine ball throw; Fenneni et al., 2014).

Impact of RO on HR

RO had no significant impact on the HR (Table 2). Similar to this study finding, Fenneni et al. (2014) found similar HR_{rest} values during the four ECs of their protocol (Table 6). Contrary to this study finding, Fenneni et al. (2014) found that HR_{end} values determined during the 4th week of Ramadan were lower than those of Post-R (Table 6). The findings of this study with regard to HR are in line with some results of the studies conducted on adults (Aziz et al., 2010; Brisswalter et al., 2011; Chaouachi et al., 2009), but opposite to others conducted also on adults (Husain et al., 1987; Ramadan & Barac-Nieto, 2000).

Impact of RO on Arterial Blood Pressures

RO seems to have a “statistically significant” impact on arterial blood pressures: Compared to non-fasters, fasters had higher values of SBP_{end} and DBP_{end} during the Mid-R EC. To the best of the authors’ knowledge, this study is the first to examine the impact of RO on healthy boys’ arterial blood pressures. This study results, especially with regard to DBP changes, are unclear. It seems

Table 4. Oxy-Hemoglobin Saturation (Oxy-Sat, %) During the Three Experimental Conditions: Fasters (n = 26) and Non-Fasters (n = 10) Groups.

|                | Fasters       | Mid-R         | Post-R        | Factorial ANOVA |
|----------------|---------------|---------------|---------------|-----------------|
| Oxy-sat_{rest}|               |               |               |                 |
| Fasters        | 95.8 ± 1.8    | 97.7 ± 0.8    | 96.9 ± 0.6    |                 |
| Non-fasters    | 96.8 ± 1.3    | 97.9 ± 0.9    | 97.1 ± 1.0    |                 |
| p              | .104          | .514          | .387          |                 |
| Oxy-sat_{end}  |               |               |               |                 |
| Fasters        | 97.0 ± 1.4    | 97.4 ± 0.9    | 97.7 ± 0.7    |                 |
| Non-fasters    | 96.7 ± 0.7    | 97.7 ± 0.7    | 97.3 ± 0.9    |                 |
| p              | .323          | .377          | .469          |                 |

Note. Data were mean ± SD. ANOVA = analysis of variance. R = Ramadan. Factorial ANOVA: between the three experimental conditions for the two groups. p: Mann–Whitney U test between the two groups for the same experimental condition.

Table 5. Six-Min Walk Test Data Changes\(^*\).

|                | Fasters (n = 26) | Non-fasters (n = 10) | p     |
|----------------|------------------|----------------------|-------|
| 6-min walk distance |                  |                      |       |
| m              | –3.61 ± 9.66     | –2.41 ± 9.23         | .986  |
| %              | –3.38 ± 9.58     | –1.57 ± 9.46         | .876  |
| Oxyhemoglobin saturation (%) |          |                      |       |
| Rest           | 1.20 ± 2.07      | 0.33 ± 1.85          | .177  |
| End            | 0.66 ± 1.61      | 0.61 ± 0.99          | .715  |
| Systolic blood pressure (mmHg) |            |                      |       |
| Rest           | –4.36 ± 10.42    | –2.33 ± 7.04         | .958  |
| End            | –1.12 ± 11.66    | 0.02 ± 8.13          | .876  |
| Diastolic blood pressure (mmHg) |          |                      |       |
| Rest           | –4.83 ± 13.17    | –0.57 ± 16.26        | .689  |
| End            | –1.86 ± 11.08    | –2.40 ± 13.47        | .639  |
| Heart rate_{rest} |              |                      |       |
| bpm            | 3.86 ± 11.30     | –1.59 ± 10.81        | .542  |
| %              | 3.91 ± 11.31     | –1.54 ± 10.82        | .542  |
| Heart rate_{end} |              |                      |       |
| bpm            | –7.16 ± 13.80    | –5.91 ± 13.63        | .794  |
| %              | –7.11 ± 13.80    | –5.86 ± 13.63        | .794  |

Note. Data were mean ± SD. \(^*\)Change (%) = 100 × ([Post-Ramadan – Pre-Ramadan]/Pre-Ramadan]. bpm = beats per minute. \(^a\)Percentage of predicted 6-min walk distance. \(^b\)Percentage of predicted maximal heart rate. \(^p\) (Mann–Whitney U test) < .05: fasters versus non-fasters.
### Table 6. Study Designs, Characteristics of Adolescents, and Main Results of the Two Studies Aiming to Evaluate the Impacts of Ramadan Observance (RO) on the Boys’ 6-Min Walk Test (6MWT) Data.

**Methodology of the Two Studies**

| Study Design | Ramadan year | Timing | Elapsed fasting time | Ambient temperature | Average humidity | Number of experimental conditions | Number of children | Control group | Age (years) | Height (cm) | Weight (kg) | Training status | 6MWT familiarization | 6MWT instructions | 6MWT encouragement | 6MWT Collected Data and Main Results |
|--------------|--------------|--------|----------------------|---------------------|-----------------|-----------------------------------|--------------------|---------------|-------------|-------------|-------------|------------------|------------------------|-------------------|------------------|----------------------------------|
|              | 2012         | 15:00–17:00 h | Dawn to sunset: ~16 h at the beginning (20th of July) and ~15 h at the end (18th of August) | ~25°C | 38%–42% | Four experimental conditions: 2 weeks Pre-R, R2, R4, and 10–12 days Post-R (two tests in each period (with a recovery period of at least 36 h in between)) | 18 boys observing Ramadan fasting for the first time | No | 11.9 ± 0.8° [10.2–13.4]° (11.5–12.3)° | 153 ± 9° [149–157]° (136–168)° | 55 ± 18° [46–64]° (34–91)° | Sedentary (practice of sport activity only at school) | Yes | American Thoracic Society guidelines (ATS, 2002) | Verbal encouragement | 6MWT (m) | HR (%predicted maximal HR; Tanaka et al., 2001): rest, 1st, 2nd, 3rd, 4th, 5th, and 6th min | Oxy-sat (%): rest, 1st, 2nd, 3rd, 4th, 5th, and 6th min | 6MWD × 6th min Oxy-sat (m) |

**Impact of RO on 6MWD**

- 6MWD (m) was lower during R2 (635 ± 105°) and R4 (601 ± 122°) compared to Pre-R (686 ± 98°) but returned to baseline values Post-R (687 ± 97°)

**Impact of RO on HR (%)**

- No significant experimental condition effect in resting or 3rd min values
- R2 values were lower than those of Post-R (2nd min)
- R4 (1st, 2nd min)
- Post-R (1st, 2nd, 4th, 5th, 6th min)

**Impacts of RO on Oxy-sat (%)**

- No significant experimental condition effect in resting, 1st, 2nd, 4th, and 6th min values
- R2 values were higher than those of Pre-R (3rd min)
- Post-R (5th min)
- Post-R values were lower than those of Pre-R and R4 (5th min)
- Oxy-sat changes were not clinically significant (difference <5 points)

**Impacts of RO on 6MWD × Oxy-sat (m)**

- Significant experimental condition effect Pre-R value (67573 ± 7514°) was higher than R4 (56224 ± 12274°) one

**Main conclusion**

- RO reduced submaximal aerobic capacity
- RO influenced HR data but had a minimal effect on Oxy-sat values

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Note. 6MWD: 6-min walk distance; HR = heart rate; Oxy-sat = oxy-hemoglobin saturation; R = Ramadan; R1 = 1st week of R; R2 = end of the 2nd week of R; R4 = 4th week of R. Data were °mean ± SD. °Range (minimum–maximum). °95% confidence interval.
that the increases of $SBP_{\text{End}}$ by $\sim 9$ mmHg and $DBP_{\text{End}}$ by $\sim 6$ mmHg are not “clinically significant” in healthy boys. First, the Mid-R $SBP_{\text{End}}$ values of the fasters and non-fasters ($130 \pm 11$ and $121 \pm 10$ mmHg, respectively) were closer to those previously reported for healthy boys aged 12–13 years ($126 \pm 22$ mmHg) or 14–15 years ($129 \pm 21$ mmHg; Ben Saad et al., 2009). Second, the Mid-R $DBP_{\text{End}}$ values of the fasters and non-fasters ($78 \pm 6$ and $72 \pm 6$ mmHg, respectively) were also closer to those previously reported for healthy boys aged 12–13 years ($70 \pm 11$ mmHg) or 14–15 years (68 $\pm 9$ mmHg; Ben Saad et al., 2009). Additional future studies preferably with a continuous arterial blood pressure measurement (e.g., each min of the 6MWT) are necessary.

The arterial blood pressures increase during RO could be explained in one possible way. Fluctuations in lifestyle during Ramadan may impact the agenda of food intake (pre-fast meal before dawn, fast-breaking meal at sunset, then unlimited food intake and hydration are allowed till dawn) and the quality of foods (e.g., increase of protein intake, of vitamin A-rich fruits and other fruits, and of milk and milk products; decrease in the consumption of foods from tubers and roots, nuts and legumes, and dark green leafy vegetables; Khaled Trabelsi & Chtournou, 2019), which could impact blood pressures (Maughan et al., 2010). The validity of the above justification should be demonstrated in children/adolescents. In fact, in adults, fasting has been associated with catecholamine inhibition and a reduced venous return, causing a decrease in the sympathetic tone, thus leading to a decrease in blood pressures (Husain et al., 1987).

**Impact of RO on Oxy-Sat**

RO had no impact on the Oxy-sat (Table 4). Similar to this study result, Fenneni et al. (2017) found similar values of $Oxy\text{-sat}_{\text{test}}$ and $Oxy\text{-sat}_{\text{end}}$ during the four ECs (Table 6). Similar to our results, in which no boy presented a “clinically significant” desaturation, in Fenneni et al.’s study (2017), the Oxy-sat significant changes between the ECs were considered as “clinically insignificant” (i.e., they were <5 points; Singh et al., 2014).

**Methodology Discussion**

Discussion of the sample size, the study design, the 6MWT choice, and the applied procedures was previously detailed (Ben Fraj et al., 2019; Fenneni et al., 2015, 2014, 2017). The two main strongpoints of this study, compared to the five similar ones related to the impacts of RO on the healthy children’s/adolescents’ physical performances (Aloui et al., 2013; Fenneni et al., 2014, 2017; Girard & Farooq, 2012; Meckel et al., 2008), were the inclusion of a non-fasting CG and the quasi-experimental design. The inclusion of a CG eliminates some bias and outside influence that could alter the results of the experiment (Fenneni et al., 2014, 2015). The CG allows researchers to focus on the phenomena (i.e., RO) they’re trying to test (Azarian, 2011). The benefits of a quasi-experimental research (Harris et al., 2006; e.g., more feasible, reduce the time and resources required) were previously highlighted (Ben Fraj et al., 2019).

This study presents three limitations. The first concerns the convenience sampling, which is considered as a confounding factor. All boys were aware of the study goals, which might increase concern about religious prejudice and then might stimulate fasters to collaborate during the 6MWTs. The second limitation concerns the lack of control for diet and it was preferable to evaluate the dietary intake of included boys. Eating patterns and the quality of foods during Ramadan month are different from those during other months of the year. For example, some authors (Farooq et al., 2015) reported that protein intake of sedentary teenagers ($n=9$, age: 13 to 15 years) increased significantly during Mid-R compared to Pre-R; perhaps because of increased protein-rich foods during the holy month. The third limitation concerns the high rate of “lost to follow-up” (40% = 24/60; Uhlig, 2018). This induces bias and reduces the study power, which affects the generalizability of the results (Uhlig, 2018).

In conclusion, RO performed by healthy boys aged 12 to 15 years does not impact the 6MWD, the HR, or the Oxy-sat. It has minimal impacts on SBP and DBP. Yet, this finding cannot be generalized to boys with chronic cardiorespiratory and/or metabolic diseases who want to observe Ramadan.

**Acknowledgments**

The authors wish to express their sincere gratitude to all boys for their cooperation. The authors wish also to thank Professors Samir BOUKATTAYA and Béchir SAADAOUI for their invaluable contribution in the improvement of the quality of the writing in the present paper.

**Authors’ Contributions**

SBF, AM, IL, and HBS: Literature search, data collection, study design, analysis of data, Manuscript preparation and review of manuscript.

All authors read and approved the final manuscript.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: HBS reports personal fees from AstraZeneca, Saiph, Teriak, and Chiesi.
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