

LETTER TO THE EDITOR

Critical analysis of the published literature about the effects of Ramadan intermittent fasting on healthy children's physical capacities

Ramadan is the month in which Muslims refrain from food and fluid intake from dawn to sunset. It is quite questionable whether pre-pubescent children should be allowed to fast while religion advises such a practice only after puberty, but it is a relatively current practice that children make their first attempt to fast the entire month while they are still pre-pubescent.

Most published studies examining the effects of Ramadan intermittent fasting (RIF) on sport performance were performed on adult subjects, and data regarding its effects on children are few. We searched MEDLINE, EMBASE, and ISI Web of Science on April 10, 2015, using the combination of the following medical subject headings: ('fasting' AND 'exercise test') AND ('child' OR 'adolescent']). Only four studies (1–4) examined the effect of RIF on children's physical performance. They were published between 2008 (2) and 2014 (1) in North Africa ($n = 2$) (1, 4) and the Middle East ($n = 2$) (2, 3). The four studies' methodologies and main results are detailed, respectively, in Tables 1 and 2. The effects of RIF on the physical capacities of children seem controversial, but there is a tendency toward a decrease in endurance performance, while a slight decrease or no significant effect on short-term explosive performance has been shown (1–4).

The sample sizes of children in these four studies varied between 12 (4) and 19 (2). Two remarks concerning this issue should be raised:

1. Only one study (1) calculated the required sample size according to a predictive equation (6). This could be a statistically crucial point since determining the optimal sample size for a study assures an adequate power to detect statistical significance and is a critical step in the design of a research protocol (6). Using too many participants in a study is expensive and exposes more subjects to procedures (6). On the other hand, if a study is underpowered, it will be statistically inconclusive and may make the whole protocol a failure (6). In the latter case, the study cannot be used to draw valid conclusions despite having exposed a number of participants to the study procedures. In the future, similar studies should include appropriate sample sizes calculated according to a predictive equation (6).

2. No study included a parallel control group of non-fasting individuals. This could be considered a serious omission because the internal validity of the findings from these studies and the changes in the variables assessed cannot be attributed solely to RIF. Nevertheless, it has to be noted that obtaining non-fasting groups in 'Muslim' countries is not easy due to understandable ethical reasons (1). Therefore, most of the studies on RIF used before-Ramadan (BR) values as baseline or control. For example, a MEDLINE search performed on April 10, 2015, using the key words 'Ramadan fasting' and 'control group' identified only 13 studies (7–18). All were performed on adults, and only six studies (7–12) were about exercise physiology. In the future, similar studies should systematically include a non-fasting control group whenever possible to reduce the possibility of learning effects skewing the results and to avoid any threat to the internal validity of the findings (1).

Other important methodological limitations leading to anecdotal comparisons of physical responses between studies were also noted:

3. Information about the geographical location and/or the season was lacking in two studies (2, 4). Ramadan lasts from 29 to 30 days based on the lunar crescent visibility. In addition, Ramadan moves ahead ~11 days each year compared to the Gregorian calendar and can occur in any season (19). Consequently, the effects of daytime fasting are powerfully influenced by climatic circumstances: Ramadan in summer at elevated latitudes presents very different features compared to Ramadan in winter at lower latitudes (19).
4. The elapsed time between dawn and sunset was not mentioned in two studies (2, 3). This parameter is of importance, as it depends on the geographical site and the season of the year. Indeed, the fasting duration can be as long as 18 h a day in the summer in temperate locations (19), and is even longer in countries situated nearer the poles, which poses a real challenge for fasting individuals (19).

Table 1. Study designs and characteristics of included subjects in published studies aiming to evaluate the effects of RIF on physical performance of male children

Region/first author(s)	Middle East Meckel et al. (2)	Middle East Girard and Farooq (3)	North Africa Aloui et al. (4)	North Africa Fenneni et al. (1)
Ramadan year	NR	2010	NR	2012
Timing	NR	13:00–14:00 h	Morning (07:00–09:00 h) and afternoon (17:00–19:00 h)	15:00–17:00 h
Elapsed fasting time	NR	NR	Dawn to sunset ~15 h	Dawn to sunset ~16 h at the beginning (20th of July) and ~15 h at the end (18th of August)
Average ambient temperature and humidity	NR	NR	NR	~25°C; 38–42%
Number of evaluation sessions	Two sessions (same time of day conducted on 2 successive days): BR Last 2 days of Ramadan	Five sessions (same time of day): 1 week BR R1 R4 AR2 AR4	Two testing phases: 1 week BR R4 2 test sessions in each period (recovery period of at least 36 h in between): 1 in the morning 1 in the afternoon	Four testing phases: 2 weeks BR R2 R4 10–12 days AR 2 test sessions in each period, with a recovery period of at least 36 h in between
Number of subjects	19	18	12	18
Age (years)	15.1 ± 0.9 ^a 14–16 ^b	12.6 ± 1.5 ^a	13.3 ± 0.4 ^a	11.9 ± 0.8 ^a [10.2–13.4] ^b (11.5–12.3) ^c
Height (cm)	166 ± 4 ^a	156 ± 13 ^a	165 ± 3 ^a	153 ± 9 ^a [149–157] ^b (136–168) ^c
Body mass (kg)	62.5 ± 7.4 ^a	45.3 ± 12.4 ^a	60.9 ± 6.5 ^a	55 ± 18 ^a [46–64] ^b (34–91) ^c
Training status	Soccer players with regular training program during Ramadan	Untrained	Soccer players (minimum of 3 years of practice) observing Ramadan fasting for the first time	Sedentary (practice of sport activity only at school) observing Ramadan fasting for the first time

AR, after-the-end of-Ramadan; AR2, 2 weeks AR; AR4, 4 weeks AR; BR, before-Ramadan; h, hour; NR, not reported; RIF, Ramadan intermittent fasting; R1, 1st week of Ramadan; R2, end of the second week of Ramadan; R4, 4th week of Ramadan.

^aData are mean ± SD; ^bData are range (minimum to maximum); ^cData are 95% confidence interval.

For example, in the study by Fenneni et al. (1) performed in a North African country during the summer of 2012, the elapsed time from dawn to sunset was ~16 h at the beginning and ~15 h at the end of Ramadan. This condition could be considered as relatively challenging as fasting duration was relatively long for the young study participants (1).

5. Test timing (time of day) was not mentioned in one study (2). It is well known that test timing could affect physical performance (1). For example,

subjects in the Fenneni et al. (1) study performed the tests only about 2 h before breaking their fast. In addition, it has been clearly established that RIF led to impairment in adolescent soccer players' performance in the afternoon and consequently impacted their diurnal pattern observed BR (4).

6. Information about previous experience with RIF was omitted in two studies (2, 3). Some authors have shown that the number of years the subjects had fasted (the RIF history of the participants) could influence their adaptations and responses to

Table 2. Tests and main results of main published studies aiming to evaluate the effects of RIF on physical performance of male children

Region	Middle East	Middle East	North Africa	North Africa
first author(s)	Meckel et al. (2)	Girard and Farooq (3)	Aloui et al. (4)	Fenneni et al. (1)
Collected data	VJT height 40-m sprint time 4 × 10-m run time sum 6 × 40-m run time 6 × 40-m performance decrement (%) 3,000-m run time Body mass Skinfold measurement, caloric intake (kcal/day) % of carbohydrates Fats and proteins Intense physical activity (h/week) Sleep habits (week BR, last week of Ramadan) (h/day) Total sleeping hours Energy intake in a regular month and during Ramadan	Best time in a single sprint Cumulated sprint times Sprint decrement score Body composition (body fat%, lean mass, fat mass) Objective daily activity Estimated energy expenditure Caloric intake % of proteins Fat and carbohydrates	Squat jump CMJ heights Estimated $\dot{V}O_2$ max Perceived exertion Food intakes over a span of 3 days for each week of physical testing	6MWD VJT height HJT distance 20-m sprint time 30-m sprint time MBT distance
Test instructions	Standard warm-up procedure 15–20 min period separated the different tests on each day Each run started from a standing position	Complete all sprints as fast as possible	Players familiarized with the VJT and the multistage 20-m shuttle run test Active warm-up after 30-min rest in a seated position	Subjects familiarized with all the study tests
Test encouragement	NR	Strong verbal encouragement during all sprints	NR	Verbally encouragement during short-term exercises and during the 6MWT (5)
Physical performance results	Non-significant change in body mass Significant increase in the sum of skinfolds Reduced aerobic endurance (increased 3,000-m running time) Reduced speed endurance (increased sum of 6 × 40-m run time and performance decrement) Reduced CMJ performance Non-significant effect on the 40-m sprint time or agility performance Reduced intense physical activity Non-significant changes in sleeping hours or total caloric intake (including the relative consumption of carbohydrates, fats and proteins)	Compared to BR, cumulated sprint times lengthened during Ramadan (R1; R4) and remained elevated AR (AR2 and AR4) Initial best sprint performance and sprint decrement score did not change Body mass (but not body fat, lean mass and fat mass) was elevated at R4 and AR2 compared with BR, whereas energy expenditure remained constant	Jumping heights during the squat jump and the CMJ tests and estimated $\dot{V}O_2$ max were lower during Ramadan than BR in the afternoon, and their diurnal variations observed BR were not apparent during the fasting period	6MWD (mean or % predicted) was lower during R2 and R4 compared with BR. 6MWD (% predicted) was significantly lower during R2 and during R4 compared with AR Body mass was lower during R2 and R4 compared with AR Non-significant effect on VJT height, HJT distance, 20- and 30-m sprint time and MBT distance

Table 2 (Continued)

Region first author(s)	Middle East Meckel et al. (2)	Middle East Girard and Farooq (3)	North Africa Aloui et al. (4)	North Africa Fenneni et al. (1)
Sleep loss	No significant change in sleeping hours BR and during Ramadan	NR	NR	NR
Caloric intake	No significant change in total caloric intake, or in the relative consumption of carbohydrates, fat, and protein BR and during Ramadan Non-significant increase in fat consumption Decrease in carbohydrate and protein intake during Ramadan	NR	No significant change in the daily total caloric, or in the relative consumption of carbohydrates, fat, and protein before and during Ramadan	NR
Conclusions	RIF reduces physical work capacity of adolescent soccer players The timing of meals during the day and the relative contribution of macro-nutrients (e.g. carbohydrates) rather than the total caloric intake, serve as the main nutrient causes for the decrease in physical capacity Decreased physical activity and disturbed sleeping patterns may also contribute to the significant decrease in athletic performance	Mean sprint performance during repeated sprinting is compromised toward the end of Ramadan This effect persisted AR2 Fatigue resistance was not affected	Diurnal variations of short-term maximal performances and endurance performance were affected by RIF Dehydration, disturbances of the sleep- wake cycle by changed food and fluid intakes and/or alterations in circadian rhythms, and fatigue due to sleep loss may explain performance impairment observed during Ramadan in adolescent soccer players	RIF showed no significant effect upon short-term explosive efforts but reduced endurance efforts' performance and body mass

CMJ, counter movement jump; HJT, horizontal jump test; MBT, medicine ball throw; NR, not reported; $\dot{V}O_2$ max, maximal oxygen uptake; VJT, vertical jump test; 6MWD, 6-min walk distance. For other abbreviations, see Table 1.

- exercise testing (20). Direct communication with Girard and Farooq (3) showed that the subjects in their study all had fasted at least one Ramadan month before the study was conducted (1). In two studies (1, 4), the subjects were fasting for the first time, and this particular condition may present a challenge for them (1, 4).
7. Information about the children's physical activity status was omitted in one study (3). In two others (2, 4), the participants' physical activity status was qualified as 'athletes' [soccer players with a minimum of 3 years of previous practice (4) or with regular training program during Ramadan (2)]. In one study (1), the boys were 'healthy untrained' (they never participated in any sporting activity elsewhere than at school where they habitually practice for a maximum of 2 h/week). The physical activity status of the participants should be recognized, as it may interfere with the independent effects of RIF on physical capacity (1, 2).
 8. Two studies lacked acute after-Ramadan (AR) control data (2, 4). In this case, it is still unknown whether the sleep cycle alterations and/or diurnal nutrition imposed by Ramadan led to momentary performance adaptations and/or persistent effects a few weeks AR (21).
 9. The average ambient temperature and relative humidity at the time of physical testing were lacking in three studies (2–4). This is a serious methodological limitation since high climatic heat stress may affect children's performance (22). In the Fenneni et al.'s (1) study, the medium testing temperature was $\sim 25^{\circ}\text{C}$ and the humidity ranged from 38 to 42%. These circumstances could be considered somewhat challenging, as temperature was relatively warm (1).
 10. The mean ages of the subjects ranged from 11.9 ± 0.8 years (1) to 15.1 ± 0.9 years (2) and from 10.2 years (1) to 16.0 years (2). Height varied between studies by up to 12 cm (153 ± 9 cm¹ to 166 ± 4 cm²) and body mass varied by up to 17 kg (45.3 ± 12.4 kg³ to 62.5 ± 7.4 kg²). This makes comparisons between studies difficult. In addition, as several physical capacities depend on anthropometric values, they should be expressed as percentage of predicted reference values (such as for the 6-min walk distance, 6MWD) (5).
 11. The number of testing periods varied from two (2, 4) to five (3). In addition, testing periods were not defined in the same way in all studies. 'BR' was defined as one (2–4) or two (1) weeks BR. 'During Ramadan' was defined as the first week of Ramadan (R1) (3), the end of the second week of Ramadan (R2) (1), or the last 2 days of Ramadan (2) as the end of the fourth week of Ramadan (R4) (1, 3, 4). 'AR' was defined as 10–12 days AR (AR2) (1), 2 weeks AR (AR2) (1), or 4 weeks AR (AR4) (3).
 12. The nature of the repeated sprint test (e.g. sprint number/duration, recovery time) is known to affect the physical performance (i.e. task dependency of the Ramadan effects) and, therefore, leads to anecdotal comparisons of physical responses between studies (3). In addition, data about encouragement during tests were lacking in two studies (2, 3). This is a very important point because encouragement can modify the outcome, e.g. of the 6MWD (5). Another limitation is that body temperature was not measured in some studies (23).
 13. Using inappropriate terms [such as 'anaerobic' exercise (24)] can be a source of confusion. For example, Meckel et al. (2) used the term 'anaerobic capacity' to refer to speed endurance (sum 6×40 m run time).
- In conclusion, future studies should be made more rigorous by taking into account the various factors discussed here. They should also focus on the effects of RIF on young international-caliber athletes, young female athletes, cognitive function, circadian rhythms (body temperature, metabolism, hormones, etc.), and changes in physiological functions (spirometry, heart rate, oxy-hemoglobin saturation, blood lactate concentration, and urinary excretion).

Authors' contributions

MAF, IL, and AA performed PubMed research, collected published papers, and helped to draft the manuscript. SR helped to draft the manuscript. KC and BSH helped to draft the manuscript and approved the final version. All authors read and approved the final manuscript.

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