Effects of Ramadan fasting on physical performances in soccer players: a systematic review

Effets du jeûne de Ramadan sur les performances physiques des footballeurs: revue systématique

Hamdi Chtourou[1], Khaled Trabelsi[1], Omar Boukhris[1], Achraf Ammar[1], Roy Jesse Shephard[2], Nicola Luigi Bragazzi[3*]

1-UR15JS01: Education, Motricité, Sport et Santé (EM2S), High Institute of Sport and Physical Education, University of Sfax, Tunisia
2-Faculty of Kinesiology and Physical Education, University of Toronto, Toronto, Ontario, Canada
3-Department of Health Sciences (DISSAL), Postgraduate School of Public Health, University of Genoa, Genoa 16132, Italy

RÉSUMÉ

Objective. Evaluer les effets du jeûne de Ramadan sur les performances physiques des footballeurs en utilisant une analyse systématique de la littérature.
Conception. Revue systématique.
Sources de données. Le contenue de deux bases de données: PubMed/MEDLINE et Web of Science.
Critères d'éligibilité pour la sélection des études. Les études avec conception pré-post avec et sans groupe de contrôle et cross-over publiées avant le 15 mars 2019 et évaluant l'effet du jeûne du Ramadan sur les performances physiques des footballeurs.
Évaluation de la qualité méthodologique des études. La qualité méthodologique des études retenues à été évaluée à l'aide de l'outil 'Qual-Syst'.
Résultats. Sur 18 articles retenus, 16 études ont été de bonne qualité et deux de moyenne qualité. La plupart des études ont suggéré que le jeûne du Ramadan n'a pas d'effets sur la performance maximale de courte durée (ex., détente verticale, sprint, contraction maximale volontaire, force d'agrippement et agilité). Pour le test de Wingate, la répétition de sprints et la performance de longue durée durant des exercices rectangulaires ou triangulaires, la plupart des études ont montré un effet négatif du jeûne du Ramadan même si la charge d'entraînement a été maintenue durant Ramadan. Pour la performance lors des tests spécifiques et les exercices avec balle, la plupart des études n'ont pas observé des effets significatifs du jeûne du Ramadan lorsque la charge d'entraînement a été maintenue ou légèrement diminuée durant Ramadan.
Conclusions. La poursuite de l'entraînement et le maintien de la charge d'entraînement durant Ramadan n'ont pas des effets négatifs sur la performance maximale de courte durée et la performance lors des tests spécifiques et les exercices avec balle chez des footballeurs. En revanche, les performances lors des tests de Wingate et de répétition de sprints et les exercices de longues durées (ex., triangulaire et rectangulaire) ont diminué significativement même lorsque la charge d'entraînement a été maintenue durant Ramadan.

Mots-clés
Ramadan; Performance aérobie; Performance anaérobie; Répétition de sprints; tests spécifiques; Football.

SUMMARY

Objective: To evaluate the effects of Ramadan fasting on physical performance measures in soccer players through a systematic appraisal of the literature.
Design: Systematic review
Data sources: The entire content of two databases, PubMed/MEDLINE and Web of Science. Eligibility criteria for selecting studies: Both single-group, pre-post and crossover design studies published in any language before March 15, 2019 were included. Assessments of physical performance were accepted for analysis.
Study appraisal: The methodological quality of the included studies was assessed using 'QualSyst'.
Results: Of 18 selected articles, 16 were generally of strong quality and the remaining studies (n=2) were rated as moderate, although most lacked significant details about the Ramadan fasting. Most studies showed that Ramadan fasting did not impair short-term maximal performances in soccer players (i.e., vertical jump, sprint performance, maximal voluntary contraction, hand grip, agility performance). During the 30-s Wingate test, the repeated sprint exercise (RSE) tasks, and the long-duration incremental and non-incremental exercises, most studies reported some negative effects of Ramadan fasting even when the training load was maintained. For the soccer specific skills and test with ball, most studies reported that there was no significant negative effects of the fasting month on performance when the training load was maintained or slightly reduced during the Ramadan.
Conclusions: The continuance of training during Ramadan fasting, with maintained training load, has no negative effects on short-term maximal performances and soccer specific skills and test with ball. However, performances of the 30-s Wingate test, the RSE tasks, and the long-duration incremental and non-incremental exercises were significantly impaired during Ramadan fasting even when the training load was maintained.

Key-words
Keywords. Ramadan fasting; Aerobic performance; Anaerobic performance; Repeated sprints; Specific tests; Football.

INTRODUCTION

Soccer is known to be a very demanding sport in terms of physical performances (1,2). With the exception of goalkeepers, professional soccer players cover between 10 and 13 km during a match, including frequent sprints and rapid changes of direction (3). However, a large part of the total distance is covered by low-intensity running or walking, with 80-90% of a soccer match stimulating mainly the aerobic pathway and 10-20% of actions depending principally upon the anaerobic pathway (1,2). Mohr et al. (4) reported that a midfielder, for example, covered a total distance of 12.3 km, with 3.5 km of high-intensity efforts. During a typical match, the heart rate was at 85 and 98% of the player's maximal values, reflecting an average oxygen intake (V02) of around 70% of maximal values (V02max) (1). However, in order to achieve optimal performance, a soccer player needs to develop many other physical qualities (*e.g.,* speed, agility, jumping and the ability to make repeated sprints) (1,2). The implication of physical qualities depends on the player's position and style of play, but there may be from 3 up to 27 short-term explosive actions during tackling and 1 up to 36 jumping actions (4). In general, there are a total of 150-250 short-term intensive efforts during a match (4) reflecting a requirement for a high anaerobic energy turnover in elite soccer players. In this context, biopsy analyses (5) have shown a 70% increase of muscle creatine phosphate concentrations after an intense period of a soccer game, and mean blood lactate values of 2 to 10 mmol/L (1) that could increase four-fold compared to rest during an intense period of a game (5). Muscle glycogen stores also decreased significantly from resting values of 400 to 50 mmol/kg dry weight at the end of a match (5), whereas free fatty acid concentrations increased during the second half of a soccer match. In a longer-term perspective, the performance of a soccer player also depends, on the recovery process (*e.g.,* the sleep quantity and quality), energy storage and utilization (5-7) and hydration status (8). During the Ramadan fasting, many of these parameters could be adversely affected in Muslims players (9-11).

Ramadan is the ninth month of the *Hegira* calendar during which healthy Muslims abstain from eating, drinking, smoking and sexual activities from dawn to sunset for 29-30 days (12); it falls at different periods during the year according to the Gregorian calendar. This month is one of the five pillars (*Arkan*) of Islam and, for practicing Muslims, Ramadan is a holy month; in addition to daytime fasting, there are many night-time prayers (*e.g., Tarawih*, prayer of *Laylat Al-Qadr*) and other activities (*e.g.,* reading the *Koran*) for forgiveness and for closeness to God, with a potential for these activities to impinge upon sleep-waking cycles and eating habits (12).

For soccer players, many events have been scheduled during or just after Ramadan (*e.g.,* the "Fédération Internationale de Football Association" FIFA World Cup of 2018, the "Union of European Football Associations" UEFA European Under-19 Championship of 2018, and the final of the UEFA Champions League 2018). In these competitions, players have had to decide whether to forgo or to observe fasting during training and/or match days. Farooq et al. (13) reported that 21 of 54 Muslim soccer players who participated in the London Olympic games of 2012 planned to fast during the period of the competition (*i.e.,* but not during the match day).

In view of these attitudes, it is important for sport scientists and coaches to examine the impact of Ramadan fasting upon the performance of soccer players. For instance, FIFA has organized an international conference entitled "Ramadan and Football" in Qatar in 2011 to discuss available findings concerning the impact of fasting on physical and cognitive performance and on behavior. The conclusions from this conference were published in a special issue of the *Journal of Sports Sciences* in 2012; but all manuscripts were narrative in type (14-16), and did not focus specifically on soccer players. Given the world-wide popularity of soccer, the aim of this systematic review was to evaluate the effects of Ramadan fasting on soccer players' physical performance.

METHODS

Systematic review protocol and registration

This systematic review followed the "Preferred Reporting Items for Systematic Reviews and Meta-Analysis" (PRISMA) guidelines (17).

Eligibility criteria

Single-group pre-post design with or without a control group and crossover design studies were included in the systematic review. All articles that assessed physical performance were included, with these studies comparing outcomes before and during Ramadan fasting (respectively, Bef-R and Dur-R). Samples were required to comprise soccer players who continued to train during

their Ramadan fasting. Articles written in any language and published in or accepted by peer-reviewed journals were considered. No restrictions were imposed in terms of study design, setting, country or time frame. However, articles that were strictly descriptive (*i.e.* review articles), conference proceedings, and articles referring to sedentary persons were excluded.

Information sources and search

Two electronic scholarly databases, PubMed/MEDLINE and Web of Science, were searched without time limits or filters. The last search was completed on March 15, 2019. The following combination of keywords was used when searching: [(Ramadan fasting) AND [(soccer) OR (football)] AND [(aerobic)) OR (anaerobic) OR (exercise) OR (sport) OR (performance) OR (physical)]. In addition, the reference lists of included manuscripts were checked, as well as related citations from other journals *via* Google Scholar and the authors' personal files. Specialists in the field were also contacted for information about possible pending publications, and target journals (i.e., Journal of Sports Sciences, British Journal of Sports medicine, Chronobiology International, Asian Journal of Sports Medicine, Biological Rhythm Research, among others) were hand-searched for relevant accepted studies.

Study selection

The process used for selecting articles is outlined in Figure 1. Duplicate articles were eliminated using EndNote X8.

The two first authors independently screened the titles and abstracts of all unique hits for eligibility and resolved disagreements by consensus. The full texts of the selected studies were then screened for eligibility and disagreements were again resolved by consensus. The reason for excluding an article during the full-text review was recorded.

Data collection process

The two first authors independently collected data using a pilot-tested extraction form and resolved disagreements by consensus. Data extracted included participant characteristics (number of participants, age, sex, training program, level of practice), study characteristics (country, study design, duration of daytime fasting, temperature and relative humidity), and key outcomes.

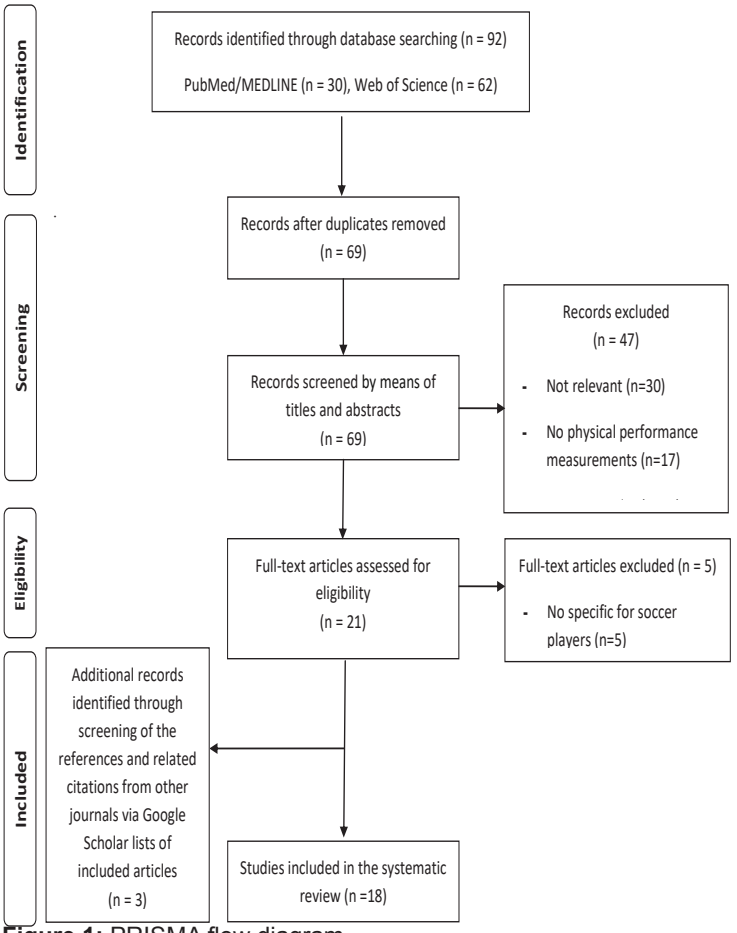

Figure 1: PRISMA flow diagram

Quality assessment

The methodological quality of each study was assessed using the quantitative assessment tool 'QualSyst' (18). QualSyst contains 14 items (Table 1) that are scored depending on the degree to which specific criteria are met (yes=2, partial=1, no=0). Items not applicable to a particular study design were marked as 'NA'. A summary score was calculated for each article by summing the total score obtained across relevant items and dividing it by the total possible score. The two first authors independently performed quality assessments, and disagreements were solved by consensus or by involving the last author. A score of ≥75% was considered to indicate a strong quality, a score of 55–75% indicated moderate quality, and a score ≤55% indicated weak quality. Additionally, the percentage of lost points in each item was calculated.

Table 1. Quality assessment of the studies.

	Question described	Appropriate study design	Appropriate subject selection	Characteristics described	Random allocation	Researchers blinded	Subjects blinded	Outcome measures well defined and robust to bias	Sample size appropriate	Analytic methods well described	Estimate of variance reported	Controlled for confounding	Results reported in detail	Conclusion supported by results?	Rating (%)	Study quality
Zerguini et al. (31)	Partial	Partial	Yes	Partial	NA	NA	NA	Partial	Yes	Partial	Yes	No	Yes	Yes	68.2	Moderate
Kirkendall et al. (19)	Yes	Yes	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Yes	Partial	Yes	Yes	95.5	Strong
Meckel et al. (34)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Lotfi et al. (35)	Yes	Partial	Partial	Partial	NA	NA	NA	Yes	Partial	Yes	Yes	No	Yes	Yes	72.7	Moderate
Aziz et al. (32)	Yes	Yes	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Chtourou et al. (20)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Güvenç, (36)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Chtourou et al. (21)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Partial	Partial	Yes	Yes	81.8	Strong
Hammouda et al. (22)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	86.4	Strong
Aloui et al. (25)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	86.4	Strong
Aloui et al. (26)	Yes	Partial	Partial	Partial	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	77.3	Strong
Hammouda et al. (23)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Rebai et al. (28)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Partial	Partial	Yes	Yes	86.4	Strong
Hammouda et al. (24)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	86.4	Strong
Abedelmalek et al. (29)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	86.4	Strong
Aziz et al. (33)	Yes	Yes	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	90.9	Strong
Baklouti et al. (30)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Yes	Yes	Partial	Partial	Yes	Yes	86.4	Strong
Aloui et al. (27)	Yes	Partial	Yes	Yes	NA	NA	NA	Yes	Partial	Yes	Yes	Partial	Yes	Yes	86.4	Strong
% of lost points (%)	2.8	41.7	5.6	8.3	NA	NA	NA	2.8	27.8	2.8	8.3	55.6	0	0	-	-

NA (not applicable).

RESULTS

Study selection

Study selection

The search resulted in a pool of 92 articles, 21 of which remained after duplicates had been excluded and titles and abstracts had been screened (Figure 1). Sixteen articles were eventually included; screening of their reference lists and related citations from other journals found *via* Google Scholar added due articles for a total of eighteen studies.

Study characteristics

Data from all studies published between 2007 and 2018 are presented in Table 2-10, arranged by order of publication date and measured performances. Twelve studies were conducted in Tunisia (19-30), one in Algeria (31), two in Singapore (32,33) one in Middle East (34), one in Morocco (35), and one in Turkey (36). Authors adopted either a single fasting group pre-post design (20-31,33-36; n=16) or a pre-post design with a fasting and a non-fasting control group (19, 32; n=2). In all, observations were made on 381 fasting male soccer players, with studies examining 10 to 55 players.

Included studies focused on the effects of Ramadan on short-term measures of performance (*e.g.,* sprinting, vertical jumping, the 5 jump test, agility, force of maximal voluntary contraction, force of handgrip, muscle power and fatigue during performance of the 30-s Wingate test and the repeated cycling and sprint tests) and longer-duration tests (*e.g.,* a 12 min run, the Loughbourough soccer dribbling test, the Loughbourough soccer passing test, a 20-m multistage shuttle-run test, 1000 and 3000 m runs, the Yo-Yo intermittent recovery test, and the Hoff test (37).

Quality assessment

Quality scores for the included studies ranged from 68.2% (moderate) to 95.5% (strong). Most studies (n=16) were rated as of strong quality but two were of only moderate quality (Table 1). The loss of points was higher for appropriate study design (41.7%), control of confounding factors (55.6%) and inadequate sample size (27.8%).

Vertical jump and 5-jump test performance

Six studies (19,26-28,31,34) investigated the effect of the Ramadan fasting on vertical jump performance (Table 2), with inconclusive results. Although Zerguini et al. (31) (*i.e.,* before Ramadan, Bef-R *vs.* end of Ramadan, End-R), Kirkendall et al. (19), Rebai et al. (28) (*i.e.,* Bef-R *vs.* End-R for a group maintaining the same training program as Bef-R) and Aloui et al. (27) (*i.e.,* Bef-R *vs.* after Ramadan, Aft-R), reported no significant effect of Ramadan, others observed significant decreases of vertical jump performance (End-R *vs.* Aft-R, 31; End-R *vs.* Bef-R, 35), squat jump or SJ (End-R *vs.* Bef-R, 26) and counter movement jump or CMJ (End-R *vs.* Bef-R, 26; End-R *vs.* Bef-R, 28, for a group maintaining the same training program as Bef-R). Interestingly, Rebai et al. (28) reported significant increases in SJ and CMJ during Ramadan (Dur-R) compared to Bef-R (Mid-R *vs.* Bef-R; 28; for a group who reduced their training load Dur-R compared to Bef-R).

Only one study (30) focused on the effects of Ramadan fasting on the 5-jump performance (Table 2) and no significant effects were reported in two groups who continued to train during the fasting month. However, a decreased performance was seen at End-R compared to Bef-R in a group who ceased training during Ramadan.

Sprint performance

Three studies (19,31,34) focused on the effects of Ramadan fasting on sprint performance (Table 3), with inconclusive findings. Zerguini et al. (31) (*i.e.,* for a 20-m sprint time when comparing Bef-R, End-R and Aft-R, 5-m and 10-m sprint times when comparing Bef-R to End-R, 5-m sprint time when comparing End-R to Aft-R, 10-m sprint time when comparing Bef-R to Aft-R and speed registered during a 20-m sprint when comparing End-R to Aft-R), Kirkendall et al. (19) and Meckel et al. (35) reported no significant effects of Ramadan fasting on sprint performance; but Zerguini et al. (31) noted a significant decreases in the 5-m (*i.e.,* Aft-R in comparison with Bef-R) and the 10-m (*i.e.,* Aft-R in comparison with End-R) sprint times. Additionally, Zerguini et al. (31) reported that the speed registered during a 20-m sprint decreased at End-R and Aft-R in comparison with Bef-R.

Force of maximal voluntary contraction and handgrip

Three studies (25,28,34) have focused on the effects of Ramadan on the force of maximal voluntary contraction (MVC) (Table 4), and again the results are inconclusive. Aloui et al. (25) reported that MVC, before a repeated sprint exercise, was reduced at Mid-R and End-R in comparison with Bef-R; but that it was unaffected by Ramadan fasting before and after the repeated sprint test. Similar

Table 2. Effects of Ramadan fasting on jump performance.

Studies	Measured performances	Sample size	Age(years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature(°C)	Humidity(%)	Country	Effects
Zerguini et al. (31)	Vertical jump(cm)	55	Range17 to 34	Professional	NM	- Bef-R- End-R- Aft-R	~12-13 h	NM	NM	Algeria	↓ 4 % at Aft-R *vs.* End-R
Kirkendall et al. (19)	Vertical jump(cm)	Fasting (n=21)	18±1	Professional	60-80 min per sessionNumber of session : NM	- Bef-R- Mid-R- End-R	~12.5-13.5 h	Bef-R:30.7±0.9Mid-R:30.5±1.8End-R:25.2±0.4	- Bef-R:56±2-Mid-R:66±4-End-R:71±2	Tunisia	↔
		Non-fasting (n=18)									↔
Meckel et al. (34)	CMJ (cm)	19	15.1±0.9	First division youth league	6.4±0.2 h per week Bef- R and 4.5±0.1 h per week Dur-R	- Bef-R- End-R	NM	NM	NM	MiddleEast	↓ 2 % at aft-R *vs.* Bef-R
Aloui et al. (26)	SJ (cm)	12	13.3±0.4	NM	NM	- Bef-R- End-R	15 h	NM	NM	Tunisia	↓ 3 % at Dur-R *vs.* Bef-R
	CMJ (cm)										↓ 4 % at Dur-R *vs.* Bef-R
Rebai et al. (28)	SJ (cm)	Normal training group (n=10)	18.4±0.8	First league of the Tunisian National Senior League	- Normal training group:4 sets of 8 repetitions maximum in four resistance exercises.- Tapering group: 3 sets of 8 repetitions maximum in four resistance exercises.	- Bef-R- Mid-R- End-R	15–16 h	NM	NM	Tunisia	↔
		Tapering group(n=10)									↑ 11 % at Mid-R and End-R *vs.* Bef-R
	CMJ (cm)	Normal training group (n=10)									↓ 2 % at End-R *vs.* Bef-R
		Tapering group(n=10)									↑ 9 % at Mid-R and End-R *vs.* Bef-R
Baklouti et al. (30)	5-jump test distance (m)	SSG-S (n=8)	24±4	Semi-professional	Three sessions of 60 min per week of SSG training	- Bef-R- End-R	~16 h	NM	NM	Tunisia	↔
		SSG-L (n=8)									↔
		Control group (n=8)									↓ Dur-R *vs.*Bef-R
Aloui et al. (27)	CMJ (cm)	Morning training group (n=10)	22.9±1.3	Tunisian amateur league	15 sessions of 60 min in total of RSE training during Ramadan	- Bef-R- Aft-R	~15,5-16,5 h	~27	~62	Tunisia	↔
		Afternoon training group (n=10)									↔
		Control group (n=10)									↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; CMJ = Counter movement jump; Dur-R = During Ramadan; End-R = End of Ramadan; Mid-R = Middle of Ramadan; NM = not mentioned; RSE = Repeated sprint exercise; SJ = Squat jump; SSG = Small sided games; SSG-L = Long small sided games; SSG-S = Short small sided games.

Table 3. Effects of Ramadan fasting on sprint performance.

Studies	Measured performances	Sample size	Age (years; mean±SD)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature (°C)	Humidity (%)	Country	Effects
Zerguini et al. (31)	Speed in the 20 m sprint (m/s)	55	17 to 34	Professional	NM	- Bef-R - End-R - Aft-R	~12-13 h	NM	NM	Algeria	↓ 5 % at End-R and ↓ 4 % at Aft-R *vs.* Bef-R
	Time in the 5 m sprint (s)										↓ 12 % at Aft-R *vs.* Bef-R
	Time in the 10 m sprint (s)										↓ 9 % at Aft-R *vs.* End-R
	Time in the 20 m sprint (s)										↔
Kirkendall et al. (19)	Time in the 10 m sprint (s)	Fasting (n=21)	18±1	Professional	60-80 min per session Number of session : NM	- Bef-R - Mid-R - End-R	~12.5-13.5 h	- Bef-R: 30.7±0.9 - Mid-R: 30.5±1.8 - End-R: 25.2±0.4	- Bef-R: 56±2 - Mid-R: 66±4 - End-R: 71±2	Tunisia	↔
		Non-fasting (n=18)									↔
	Time in the 30 m	Fasting (n=21)									↔
		Non-fasting (n=18)									↔
	FI in the 10 m sprint (%)	Fasting (n=21)									↔
		Non-fasting (n=18)									↔
	FI in the 30 m sprint (%)	Fasting (n=21)									↔
		Non-fasting (n=18)									↔
Meckel et al. (34)	Time in the 40 m sprint (s)	19	15.1±0.9	First division youth league	6.4±0.2 h per week Bef-R and 4.5±0.1 h per week Dur-R	- Bef-R - End-R	NM	NM	NM	Middle East	↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; Dur-R = During Ramadan; End-R = End of Ramadan; FI = Fatigue index; Mid-R = Middle of Ramadan; NM = not mentioned.

results were reported by Rebai et al. (28) for a group who maintained the same training load during Ramadan. However, Rebai et al. (28) reported an increase of MVC between Bef-R and at Mid-R for a group who reduced their training load during Ramadan. In contrast, Aziz et al. (34) reported that MVC and hand grip force before and after the first, second, third and fourth bouts of the Loughborough Intermittent Shuttle Test did not differ significantly between Bef-R, End-R and Aft-R.

Agility performance

Three studies (19,31,35) focused on the effects of Ramadan fasting on agility (Table 5). Although Kirkendall et al. (19) and Meckel et al. (35) reported no change during Ramadan fasting, Zerguini et al. (31) found increased times to complete the 4-lines agility test at End-R and Aft-R compared to Bef-R.

The 30-s Wingate test

Three studies (20,21,29) focused on the effects of the Ramadan fasting on the 30-s Wingate test performance (Table 6). Significant negative effects on muscle power were observed (20,21), with decreases of both peak and mean power at Mid-R and End-R in comparison with Bef-R. Further, the fatigue index was increased at Mid-R and End-R in comparison with Bef- R. Likewise, Chtourou et al. (21) reported a significant decrease of peak and mean power and a significant increase of the fatigue index Dur-R compared to Bef-R. Abdelmalek et al. (29), also, reported that peak and mean power decreased at End-R compared to Bef-R without significant change in the fatigue index.

Repeated cycling and sprint test

Five studies (20,22,25,27,34) focused on the effects of the Ramadan fasting on performance and fatigue during repeated short-term efforts (Table 7).

For repeated cycling exercise, although Aloui et al. (25) did not see any significant effects of the Ramadan fasting on performance, significant decreases of the total work was observed at End-R by both Chtourou et al. (20) and Hammouda et al. (22). Hammouda et al. (22) reported a decrease of the total work performed between Mid-R and End-R. Chtourou et al. (20) further reported that the fatigue index (FI) was higher at End-R than Bef-R. On the other hand, Aloui et al. (25) reported that FI was significantly higher at Bef-R than Mid-R and End-R, and Hammouda et al. (22) did not observe any significant effects of Ramadan fasting on the FI during a repeated cycling exercise.

During a 6×40-m sprint exercise, Meckel et al. (35) reported that the total time to complete the sprints was increased Aft-R compared to Bef-R. Further, the decrement of performance over the 6 sprints was greater Aft-R compared to Bef-R. However, during 6×40-m shuttle sprints (20+20 m with 180° direction changes) interspersed with a 20-s, Aloui et al. (27) reported that mean repeated sprint exercise (RSE) time (*i*) was unchanged between Bef-R and Aft-R for soccer players who stopped the RSE training or who trained during the morning hours and (ii) was reduced for players who trained in the afternoon hours Dur-R.

Soccer specific skills and tests with a soccer ball

Four studies (19,30,31,34) focused on the effects of Ramadan fasting on soccer specific skills and test with a soccer ball (Table 8). Kirkendall et al. (19) reported that Ramadan fasting had no effects on scores for the Loughborough Soccer Dribbling Test and the Loughborough Soccer Passing Test. However, Aziz et al. (34) noted that the mean sprint time during the fourth bouts of the 60-min (4 × 15-min with 3-min intervals) Loughborough Intermittent Shuttle Test was increased at End-R in comparison to Bef-R and Aft-R. Also, Zerguini et al. (31) reported an increase of the dribbling time at End-R and Aft-R compared to Bef-R and an increase at End-R compared to Aft-R. Using the Hoff test, Baklouti et al. (30) further reported a significant increase of the total distance Dur-R compared to Bef-R for a group who continued to train Dur-R. However, the total distance covered during the Hoff test was reduced for a group of players who ceased training Dur-R (30).

Performance during long-duration incremental exercise

Four studies (19,26,33,37) focused on the effects of Ramadan on performance and physiological parameters as estimated by a 20-m multi-stage shuttle run test (Table 9). Kirkendall et al. (19) and Aziz et al. (33) reported no significant effects of Ramadan on this measure of aerobic performance. However, Aloui et al. (26) found that the predicted VO2max decreased Dur-R in comparison with Bef-R. Güvenç (37) surprisingly found that the peak running distance during the 20-m multi-stage shuttle run test increased at End-R and first week of Ramadan (Fir-R) in comparison to Bef-R and Aft-R and Fir-R than Bef-R.

Table 4. Effects of Ramadan fasting on maximal voluntary contraction and handgrip.

Studies	Measured performances	Sample size	Age (years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature (°C)	Humidity (%)	Country	Effects
Aloui et al. (25)	MVC before RSE (N)	12	20.1±1.6	Tunisian amateur league	10.0±0.5 h per week	- Bef-R - Mid-R - End-R - Aft-R	~16 h	- Bef-R: 29 - Mid-R: 28 - End-R: 28 -Aft-R: 25	- Bef-R: 55 - Mid-R: 55 - End-R: 58 -Aft-R: 74	Tunisia	↓ 8 % at Mid-R and ↓ 8 % at End-R *vs.* Bef-R
	MVC immediately after RSE (N)										↔
	MVC at 5 min RSE (N)										↔
Rebai et al. (28)	MVC of the normal training group (N)	Normal training group (n=10)	18.4±0.8	First league of the Tunisian National Senior League	- Normal training group: 4 sets of 8 repetitions maximum in four resistance exercises. - Tapering group: 3 sets of 8 repetitions maximum in four resistance exercises.	- Bef-R - Mid-R - End-R	15–16 h	NM	NM	Tunisia	↔
	MVC of the tapering group (N)	Tapering group (n=10)									↑ at Mid-R and at End-R *vs.* Bef-R
Aziz et al. (33)	MVC of the dominant leg before the Loughborough Intermittent Shuttle Test	14	21.8±2.4	Local university football team - the second tier of the State League	3–5 session of 60-90 min per week in addition to a competitive match at the end of the week	- Bef-R - End-R - Aft-R	~14 h	28–33	62–82	Singapore	↔
	MVC of the dominant leg after the first bout the Loughborough Intermittent Shuttle Test										↔
	MVC of the dominant leg after the second bout the Loughborough Intermittent Shuttle										↔
	Test↔										
	MVC of the dominant leg after the third bout the Loughborough Intermittent Shuttle Test										↔
	MVC of the dominant leg after the fourth bout the Loughborough Intermittent Shuttle Test										↔
	Hand Grip before the Loughborough Intermittent Shuttle Test										↔
	Hand Grip after the first bout the Loughborough Intermittent Shuttle Test										↔
	Hand Grip after the second bout the Loughborough Intermittent Shuttle Test										↔
	Hand Grip after the third bout the Loughborough Intermittent Shuttle Test										↔
	Hand Grip after the fourth bout the Loughborough Intermittent Shuttle Test										↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; End-R = End of Ramadan; MVC = Maximal voluntary contraction; Mid-R = Middle of Ramadan; NM = not mentioned; RSE = Repeated sprint exercise.

Table 5. Effects of Ramadan fasting on agility performance.

Studies	Measured performances	Sample size	Age(years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature(°C)	Humidity(%)	Country	Effects
Zerguini et al. (31)	Performance during the 4-line test (s)	55	Range17 to 34	Professional	NM	- Bef-R- End-R- Aft-R	~12-13 h	NM	NM	Algeria	↑ 6 % at End- R and ↑ 5 % at Aft-R *vs.* Bef-R
Kirkendall et al. (19)	Performance during the 4-line test (s)	Fasting (n=21)	18±1	Professional	60-80 min per sessionNumber of session: NM	- Bef-R- Mid-R- End-R	~12.5-13.5 h	- Bef-R:30.7±0.9- Mid-R:30.5±1.8- End-R:25.2±0.4	- Bef-R:56±2- Mid-R:66±4- End-R:71±2	Tunisia	↔
		Non-fasting (n=18)									↔
Meckel et al. (34)	Performance during the 4×10 m agility test (s)	19	15.1±0.9	First division youth league	6.4±0.2h per week Bef-R and 4.5±0.1h per week Dur-R	- Bef-R- End-R	NM	NM	NM	MiddleEast	↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; Dur-R = During Ramadan; End-R = End of Ramadan; Mid-R = Middle of Ramadan; NM = not mentioned.

Table 6. Effect of Ramadan fasting on the 30-s Wingate test performance.

Studies	Measured performances	Sample size	Age(years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature(°C)	Humidity(%)	Country	Effects
Chtourou et al. (20)	P_{peak} (W/kg)	20	17.6±0.6	Tunisian junior football team	At least 4 × 2 h per week	- Bef-R- Mid-R- End-R	15-16 h	NM	NM	Tunisia	↓ 2 % at Mid-R and atEnd-R *vs.* Bef-R
	P_{mean} (W/kg)										↓ 2 % at Mid-R and ↓3 % at End-R *vs.* Bef- R
	FI (%)										↑ 6 % at Mid-R and ↑10 % at End-R *vs.*Bef-R
Chtourou et al. (21)	P_{peak} (W/kg)	10	17.0±0.5	Tunisian junior football team	At least 4 × 2 h per week	- Bef-R- Mid-R- End-R	15-16 h	20.4±1.1	NM	Tunisia	↓ at Mid-R and ↓ atEnd-R *vs.* Bef-R
	P_{mean} (W/kg)										↓ at Mid-R and ↓ atEnd-R *vs.* Bef-R
	FI (%)										↑ at Mid-R and ↑ atEnd-R *vs.* Bef-R
Abdelmalek et al. (29)	P_{peak} (W/kg)	11	22.1±1.3	Tunisian league	Three sessions per week	- Bef-R- Fir-R- End-R	~ 15 h	29-30	64-67	Tunisia	↓ at End-R *vs.* Bef-R
	P_{mean} (W/kg)										↓ at End-R *vs.* Bef-R
	FI (%)										↔

Abbreviations: Bef-R = Before Ramadan; End-R = End of Ramadan; FI = Fatigue index; Mid-R = Middle of Ramadan; NM = not mentioned; Pmean = Mean power; Ppeak = Peak power.

Table 7. Effects of Ramadan fasting on repeated cycling and sprint exercise performance.

Studies	Measured performances	Sample size	Age(years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature(°C)	Humidity(%)	Countr y	Effects
Meckel et al. (34)	Totat distance during 6×40 m sprint (s)	19	15.1±0.9	First division youth league	6.4±0.2 h per week Bef-R and4.5±0.1 h per week Dur-R	- Bef-R- End-R	NM	NM	NM	MiddleEast	↑ 1 % at End-R *vs.* Bef-R
	Performance6×40 m sprint (%)										↑ 5 % at End-R *vs.* Bef-R
Chtourou et al. (20)	Total work duringRSE (W/kg)	20	17.6±0.6	Tunisian junior	At least 4 × 2 h per week	- Bef-R- Mid-R- End-R	15-16 h	NM	NM	Tunisia	↓ 4 % at End-R *vs.* Bef-R
	Performance decrement during RSE (%)										↑ 34 % at End-R *vs.* Bef- R
Hammouda et al. (22)	Total work duringRSE (W/kg)	10	17.3±0.48	First division of the Tunisian National League	At least 4 × 2 h per week	- Bef-R- Mid-R- End-R	15-16 h	20.4±1.1	NM	Tunisia	↓ 6 % at End-R *vs.* Bef-R↓ 6 % at Mid-R *vs.* End-R
	Performance decrement during RSE (%)										↔
Aloui et al. (25)	Total work duringRSE (W/kg)	12	20.1±1.6	Tunisian amateur league	10.0±0.5 h per week	- Bef-R- Mid-R- End-R- Aft-R	~16 h	- Bef-R: 29- Mid-R: 28- End-R: 28- Aft-R: 25	- Bef-R: 55- Mid-R: 55- End-R: 58- Aft-R: 74	Tunisia	↔
	Performance decrement during RSE (%)										↓ 4 % at Mid-R and End- R *vs.* Bef-R
Aloui et al. (27)	Mean time duringRSE (s)	Morning training group (n=10)	22.9±1.3	Tunisian amateur league	15 sessions of 60 min in total of RSE training during Ramadan	- Bef-R- Aft-R	~15,5-16,5 h	~27	~62	Tunisia	↔
		Afternoon training group (n=10)									↓ at Aft-R *vs.* Bef-R
		Control group (n=10)									↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; Dur-R = During Ramadan; End-R = End of Ramadan; Mid-R = Middle of Ramadan; NM = not mentioned; RSE = Repeated sprint exercise.

Table 8. Effects of Ramadan fasting on soccer specific skills and test with ball performance.

Studies	Measured performances	Sample size	Age(years; mean±S D)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature(°C)	Humidity(%)	Country	Effects
Zerguini et al. (31)	Dribbling over a distance of 50 m (s)	55	Range17 to 34	Professional	NM	- Bef-R- End-R- Aft-R	~12-13 h	NM	NM	Algeria	↑ 9 % atEnd-R and ↑ 2 % at Aft-R *vs.* Bef-R↑ 6 % at End-R *vs.* Aft-R
Kirkendall et al. (19)	Loughborough SoccerDribbling Test (s)	Fasting (n=21)	18±1	Professional	60-80 min per sessionNumber of session : NM	- Bef-R- Mid-R- End-R	~12.5-13.5 h	- Bef-R:30.7±0.9- Mid-R:30.5±1.8- End-R:25.2±0.4	- Bef-R:56±2- Mid-R:66±4- End-R:71±2	Tunisia	↔
		Non-fasting (n=18)									↔
	Loughborough SoccerPassing Test (s)	Fasting (n=21)									↔
		Non-fasting (n=18)									↔
Aziz et al. (33)	Mean sprint time during the first bout of the 60-min (4 × 15-min with 3-min intervals) Loughborough Intermittent Shuttle Test(s)	14	21.8±2.4	Local university football team - the second tier of the State League	3–5 session of 60-90 min per week in addition to a competitive match at the end of the week	- Bef-R- End-R- Aft-R	~14 h	28–33	62–82	Singapore	↑ at End- R *vs.* Bef- R and Aft- R
	Mean sprint time during the second bout of the 60- min (4 × 15-min with 3-min intervals) Loughborough Intermittent Shuttle Test(s)										↑ at E nd- R *vs.* Bef- R and Aft- R
	Mean sprint time during the third bout of the 60-min (4 × 15-min with 3-min intervals) Loughborough Intermittent Shuttle Test(s)										↑ at End- R *vs.* Bef- R and Aft- R
	Mean sprint time during the fourth bout of the 60-										↑ at End- R *vs.* Bef-
	min (4 × 15-min with 3-min intervals) LoughboroughIntermittent Shuttle Test(s)										R and Aft- R
Baklouti et al. (30)	Hoff test distance (m)	SSG-S (n=8)	24±4	Semi-professional	Three sessions of60 min per week ofSSG training.	- Bef-R- End-R	~16 h	NM	NM	Tunisia	↑ End-Rvs. Bef-R
		SSG-L (n=8)									↑ End-Rvs. Bef-R
		Control group(n=8)									↓ End-Rvs. Bef-R

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; End-R = End of Ramadan; Mid-R = Middle of Ramadan; NM = not mentioned; SSG = Small sided games; SSG-L = Long small sided games; SSG-S = Short small sided games.

Table 9. Effects of Ramadan fasting on performance during incremental exercise.

Studies	Measured performances	Sample size	Age (years; mean±SD)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature (°C)	Humidity (%)	Country	Effects
Kirkendall et al. (19)	Distance during the 20- m multistage shuttle test (m)	Fasting (n=21)	18±1	Professional	60-80 min per session Number of session: NM	- Bef-R - Mid-R - End-R	~12.5-13.5 h	- Bef-R: 30.7±0.9 - Mid-R: 30.5±1.8 - End-R: 25.2±0.4	- Bef-R: 56±2 - Mid-R: 66±4 - End-R: 71±2	Tunisia	↔
		Non-fasting (n=18)									↔
Aziz et al. (32)	The number of shuttles completed during the 20-m multistage shuttle test	Fasting (n=10)	18.0±0.7	International level for at least three years	Four times per week	- Bef-R - Aft-R	13.5 h	27-32	59-66	Singapore	↔
		Non-fasting (n=8)	17.9±0.7								↔
Güvenç (36)	Peak running distance during the 20-m multistage shuttle test (m)	16	17.4±1.2	Amateur soccer league	Three training years with three sessions of 2 h per week	- Bef-R - Fir-R - End-R - Aft-R	NM	24 to 27	52 to 57	Turkey	↑ 9 % at End- R and Fir-R *vs.* Bef-R ↑ 12 % Aft-R and Fir-R *vs.* Bef-R
	Peak running time during the 20-m multistage shuttle test (min)										↑ 8 % at End- R *vs.* Fir-R ↑ 10 % at Aft- R *vs.* Fir-R and Bef-R
	Peak running velocity during the 20-m multistage shuttle test (km/h)										↑ 3 % at End- R *vs.* Fir-R ↑ 4 % at Aft-R *vs.* Fir-R and Bef-R
	Running velocity at 4.0 mmol/L lactate concentration during the 20-m multistage shuttle test (km/h)										↑ 2 % at End- R *vs.* Fir-R ↑ 4 % at Aft-R *vs.* Fir-R and Bef-R
Aloui et al. (26)	O_{2max} predicted from the 20-m multistage shuttle test (ml/min/kg)	12	13.3±0.4	NM	NM	- Bef-R - End-R	15 h	NM	NM	Tunisia	↓ 3 % at End- R *vs.* Bef-R

Chtourou et al. (20)	Total distance during the Yo-Yo intermittent recovery test (m)	20	17.6±0.6	Tunisian junior football team	At least 4 × 2 h per week	- Bef-R - Mid-R - End-R	15-16 h	NM	NM	Tunisia	↓ 12 % at End-R *vs.* Bef-R
	MAV during the Yo-Yo intermittent recovery test (km/h)										↓ 4 % at End-R *vs.* Bef-R
Hammouda et al. (22)	Total distance during the Yo-Yo intermittent recovery test (m)	10	17.3±0.48	First division of the Tunisian national League	At least 4 × 2 h per week	- Bef-R - Mid-R - End-R	15-16 h	20.4±1.1	NM	Tunisia	↓ 14 % at Mid-R and ↓ 20 at End-R *vs.* Bef-R
Hammouda et al. (23)	Total distance during the Yo-Yo intermittent recovery test (m)	15	17.3±0.3	The first division of the Tunisian football league	At least 4 × 2 h per week	- Bef-R - Mid-R - End-R	15-16 h	NM	NM	Tunisia	↓ 14 % at Mid-R and ↓ 20 % at End- R *vs.* Bef-R
Hammouda et al. (24)	Total distance during the Yo-Yo intermittent recovery test (m)	12	17.52±0.2	Tunisian first professional league	At least 4 × 2 h per week in addition to the weekend match	- Bef-R - Mid-R - End-R	~16 h	NM	NM	Tunisia	↓ 8 % at Mid- R and ↓ 15 % at End-R *vs.* Bef-R
Aloui et al. (27)	Total distance during the Yo-Yo intermittent recovery test (m)	Morning training group (n=10)	22.9±1.3	Tunisian amateur league	15 sessions of 60 min in total of RSE training during Ramadan	- Bef-R - Aft-R	~15,5-16,5 h	~27	~62	Tunisia	↑ at Aft-R *vs.* Bef-R
		Afternoon training group (n=10)									↑ at Aft-R *vs.* Bef-R
		Control group (n=10)									↔

Abbreviations: Aft-R = After Ramadan; Bef-R = Before Ramadan; Dur-R = During Ramadan; End-R = End of Ramadan; Fir-R = First week of Ramadan; MAV = Maximal aerobic velocity; Mid-R = Middle of Ramadan; NM = not mentioned; O2 = Oxygen uptake.

Table 10. Effects of Ramadan fasting on performance during non-incremental exercise.

Studies	Measured performances	Sample size	Age(years; mean±SD)	Level of practice	Training program	Periods of measurements	Fasting period	Temperature (°C)	Humidity	Country	Effects
Zerguini et al. (31)	Total distance during12 min run (m)	55	Range 17 to 34	Professional	NM	- Bef-R- End-R- Aft-R	~12-13 h	NM	NM	Algeria	↓ at End-R and ↓ atAft-R *vs.* Bef-R↓ at End-R *vs.* Aft-R
Meckel et al. (34)	Time of the realization of 3000 m run (s)	19	15.1±0.9	First division youth league	6.4±0.2 h per week Bef-R and 4.5±0.1 h per week Dur-R	- Bef-R- End-R	NM	NM	NM	MiddleEast	↑ 1 % at Aft-R *vs.*Bef-R
Lotfi et al. (35)	Time of the realization of 1000 m (s)	11	20.45±1.65	NM	NM	-Bef-R- Fir-R- Mid-R- Aft-R	~13-14 h	NM	NM	Morocco	↑ 8 % at Fir-R, ↑ 5% at Mid-R and ↑ 2% at End-R *vs.* Bef- R

Abrevations: Aft-R = After Ramadan; Bef-R = Before Ramadan; Dur-R = During Ramadan; End-R = End of Ramadan; Fir-R = First week of Ramadan; Mid-R = Middle of Ramadan; NM = not mentioned.

In this study, the peak running time increased at End-R in comparison to Fir-R and Aft-R compared to Fir-R and Bef-R, and the peak running velocity increased at End-R in comparison to Fir-R and Aft-R compared to Fir-R and Bef-R. Further, the running velocity at 4.0 mmol/L lactate concentration increased at End-R compared to Fir-R and Aft-R.

Five studies (20,22-24,27) have focused on the effects of the Ramadan fasting on performance during the Yo-Yo intermittent recovery test (Table 9). The total covered distance decreased at Mid-R and End-R in comparison with Bef-R (22,23). Hammouda et al. (24) also reported decreases of total distance at Mid-R and End-R in comparison with Bef-R, and Chtourou et al. (20) reported significant decreases of the total distance and the maximal aerobic velocity (MAV) during the Yo-Yo intermittent recovery test at End-R in comparison with Bef-R. However, Aloui et al. (27) reported that total distance covered during the Yo-Yo intermittent recovery test was (*i*) unchanged for a group who did not perform RSE training Dur-R and (*ii*) was increased for two groups (*i.e.,* afternoon training group and morning training group) who performed RSE training Dur-R.

One study (32) focused on the effects of Ramadan fasting on performance and physiological responses during an incremental cycling test (Table 9). There was no-significant difference between Bef-R and End-R for power and VO2max whether recorded at rest, at the first ventilator threshold, or at the end of the exercise. In addition, no significant Ramadan effects were observed for the total duration of exercise (32). However, the time to reach the ventilator threshold was longer at End-R compared to Bef-R (32).

Long-duration non-incremental exercise

Three studies (31,35,36) focused on the effects of Ramadan fasting on long-duration non- incremental exercise and VO2max (Table 10). Zerguini et al. (31) showed that the distance covered during a 12 min run decreased at End-R and Aft-R than Bef-R and at End-R than Aft- R. Meckel et al. (35) reported that the time to complete a 3000 m run increased Aft-R compared to Bef-R. Also, Lotfi et al. (36) found that the time to complete a 1000 m run increased during Fir-R, End-R and Aft-R in comparison with Bef-R.

DISCUSSION

The studies selected for this review support the following conclusions: (*i*) jumping, sprinting, muscle force, agility and performance during specific soccer exercises were well maintained Dur-R compared to Bef-R if soccer players continue to train during Ramadan, but were reduced if training ceased Dur-R and (*ii*) performance during the 30-s Wingate test, repeated cycling and sprint exercises and long-duration incremental and non-incremental exercises were generally impaired Dur-R.

Performance during short-term maximal exercise

Three studies have reported that the vertical jump

performance was reduced by 2% to 4% between Dur-R and Bef-R and/or Aft-R (26,31,35). However, in most studies, when soccer players continued to train Dur-R, Kirkendall et al. (19) reported that fasting and non- fasting groups maintained similar levels of performance at Bef-R, Mid-R and End-R. Similar results have been noted by Rebaï et al. (28) and Aloui et al. (27) for the vertical jump and Baklouti et al. (30) in a fasting group. However, Rebaï et al. (28) reported an increase of 2 to 9 % if the training load was reduced during the first two weeks of Ramadan. Similar to the results for jumping exercise, sprinting (19,35), maximal voluntary contraction (25,28,34), handgrip force (34) and agility (19,35) were unchanged between Bef-R, Dur-R and Aft-R if soccer players maintained their training program.

The 4 % reduction of performance during short-term maximal exercise could be related to a training cessation effect (*i.e.* detraining effect). In this context, Neufer et al. (39) reported that muscle power was reduced by ~10% after ceasing training for two weeks and Izquierdo et al. (40) observed a 3% reduction of CMJ after four weeks of training cessation.

Most studies reported that short-term maximal performance was well maintained Dur- R compared to Bef-R or Aft-R (19,25,27,30,34,35). This could reflect the very short-duration of these tasks, with little opportunity for development of fatigue (28). Also, previous studies have suggested that there are no negative effects on such tasks if the training intensity and volume are maintained and the daily energy intake is maintained (25,27,34).

On the other hand, Rebaï et al. (28) reported that SJ and CMJ performance and MVC increased Dur-R, probably due to a tapering effect. Mujika (41) argued that in team sports, a tapering period could improve muscle strength and power and vertical jump performance between 0.5% and 6%.

Performance during the 30-s Wingate test and repeated short-term maximal exercise

During the 30-s Wingate test, three studies reported that peak and mean power were reduced by 2% and 3% and the FI was increased by 6% to 10% at Mid-R and End-R compared to Bef-R (20,21,29). Aloui et al. (25,27) reported that total work and mean sprint time on the RSE test were unaffected by the Ramadan fasting, but three studies reported reductions of 1% to 6% at the End-R compared to Bef-R (20,22,35). However, for soccer players who performed RSE training Dur-R in the afternoon, mean sprint times were lower Aft-R compared to Bef-R (27).

It could be concluded that performance during the 30-s Wingate test and the RSE tasks were reduced Dur-R compared to Bef-R, possibly due to a change in sleep patterns and/or hypohydration. Aloui et al. (25) found that sleep duration was reduced Dur-R compared to Bef-R, in part because of a shift of meal times to the night hours; this would tend to increase core temperatures and increase sleep latency (25). Also, Aloui et al. (25) reported evidence of hypohydration increases of hematocrit and hemoglobin concentration Dur-R compared to Bef-R. Edwards and Noakes (42) reported that a moderate dehydration (*i.e.,* >2% loss of body-mass) decreased performance during RSE tests.

Performance during soccer specific skill exercises and tests with a soccer ball

If training was maintained Dur-R, the performance of soccer specific skills and tests with a soccer ball were unchanged (19) or even increased (30). However, Aziz et al. (34) reported that performance during the 60 min Loughborough Intermittent Shuttle Test was lower at the End-R compared to Bef-R and Aft-R, and Zerguini et al. (31) and Baklouti et al. (30) both observed that performance of soccer specific skills and tests with a soccer ball were reduced by 2% to 9% Dur-R compared to Bef-R if players ceased training Dur-R.

Detraining could contribute to the reduction of performance, and these tasks also require cognitive input, sustained in players who continue to train; but not in those who cease training. In this context, Tian et al. (43) reported that performance of some cognitive tasks, was maintained Dur-R.

Performance during long-duration incremental and non-incremental exercise

Most studies of long duration incremental (20,22-24,26,37) or non-incremental (31,35,36) exercise support the hypothesis that performance was negatively affected by Ramadan fasting. However, Kirkendall et al. (19), Aziz et al. (33) and Aloui et al. (27) reported that performance during the 20-m shuttle run test was unaffected. On the other hand, Aloui et al. (27) showed that for soccer players who performed RSE training Dur-R, the total distance covered during the Yo-Yo intermittent recovery test was increased Aft-R compared to Bef-R.

The poorer long-duration performance Dur-R could be related to dehydration. The moderate fluid losses incurred during a soccer match can negatively affect both psychological and physiological factors important to game performance (42). In this context, Amstrong et al. (44) reported that a loss of 2% of body mass significantly impaired endurance running performance. Nevertheless, further tests are needed, including observations during long distance events such as triathlon, marathon and ultra-marathon runs, \where impairment of fluid balance can be a problem even in the absence of Ramadan fasting.

Strengths and weaknesses

To the authors' knowledge, this is the first systematic review evaluating the effects of Ramadan fasting on physical performance measures in soccer players. The strengths of this study include comprehensive coverage of the literature and the careful appraisal of study quality. However, meta-analysis was not attempted due to the diversity of tests used and the limited number of studies. Although many of the studies were well-designed overall, crucial pieces of information were often lacking such as the average hours of daylight and typical environmental conditions when Ramadan was celebrated, the time of day when experimental measurements were made, availability of opportunities to rest or nap in air-conditioned facilities, the sharing of living quarters with other teams that were not observing Ramadan, the timing of meals relative to training sessions, and advice offered by coaches to minimize disruptions of training and sleep during Ramadan and pre-load with fluids in the morning. The inclusion of such details would greatly facilitate the interpretation of future research. Further, there is an obvious need to extend observations to female soccer players.

CONCLUSION

Ramadan fasting did not affect short-term maximal performances in soccer players (*i.e.,* vertical jump, sprint performance, maximal voluntary contraction, agility performance) when the training load was maintained or slightly reduced during the fasting month. However, when players stopped their training program during Ramadan, these performances could be reduced by between 2% and 12%.

During the 30-s Wingate test, the RSE tasks, and the long-duration incremental and non-incremental exercises, most studies reported negative effects of Ramadan fasting even when the training load was maintained. However, more studies are needed to explain causes of performance decrements.

For the soccer specific skills and test with ball, most studies reported that there were no significant negative effects of the fasting month on performance when the training load was maintained or slightly reduced during Ramadan fasting. However, when players stopped their training program during Ramadan, these performances could be reduced by between 2% and 9%.

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