Effects of Ramadan fasting on athletes' hematological indices: a systematic review

Effets du jeûne de Ramadan sur les indices hématologiques des athlètes: revue systématique

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RÉSUMÉ

Objectif: Effectuer une revue systématique des données relatives à l'effet du jeûne de Ramadan sur les indices hématologiques chez des athlètes.
Conception: revue systématique
Sources de données: La recherche bibliographique a été effectuée dans les bases de données PubMed / MEDLINE et Web of Science.
Critères d'éligibilité pour la sélection des études: Les études évaluant l'effet du jeûne de Ramadan sur les indices hématologiques chez des athlètes ont été sélectionnées. Les études avec une conception pré-post avec et sans groupe de contrôle et publiées en anglais avant le 31 décembre 2018 ont été incluses.
Évaluation de la qualité méthodologique des études: La qualité méthodologique des études retenues a été évaluée à l'aide de l'outil 'Qual-Syst.
Résultats: Sur les neuf études retenues, huit étaient de qualité moyenne et une seule jugée de bonne qualité. La principale limite méthodologique est le manque de contrôle des facteurs de confusion. Comparativement à avant Ramadan, les valeurs d'hématocrite et d'hémoglobine ont augmenté dans trois études, ont diminué dans une étude et n'ont pas changé dans une étude au cours du jeûne de Ramadan. Une autre étude a montré une augmentation de l'hématocrite et une diminution de l'hémoglobine pendant le jeûne de Ramadan comparativement à avant Ramadan. Dans la plupart des études, le nombre de plaquettes sanguines et le nombre réduit de marqueurs de la fonction immunitaire utilisés à ce jour ont été inchangés.
Conclusion: Tous les changements rapportés dans les indices hématologiques sont dans la plage de référence normale du laboratoire. D'un point de vue hématologique, un entraînement régulier peut se poursuivre en toute sécurité pendant le mois de Ramadan.

Mots-clés
Sportifs; Nutrition; Sang; Fonction immunitaire; Déshydratation; Statut en fer

SUMMARY

Objective: To evaluate the effects of Ramadan fasting on hematological data in athletes 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: Ramadan-related measurements of any hematological indices in athletes were considered. Both single-group pre-post with and without a control group studies conducted in athletes and published in English language before December 31, 2018 were included.
Study appraisal: The methodological quality of the studies identified was assessed using 'QualSyst'.
Results: Of nine selected articles, eight were of moderate quality and only one was of strong quality. The main problem to date has been a lack of appropriate controls. Compared to before Ramadan, hematocrit and hemoglobin values increased in three studies, decreased in one study and did not change in one study during Ramadan fasting. Another study reported increased hematocrit and a puzzling decrease of **hemoglobin during** as compared to before Ramadan fasting. In most studies, blood platelet counts and the limited number of immune function used to date remained unchanged.
Conclusions: All reported changes in hematological indices remained within the normal reference range of the laboratory. Therefore, regular training can continue safely during Ramadan fasting from a hematological view point.

Key-words
Sportsperons; Nutrition; Blood; Immune function; Dehydration; Iron status.

INTRODUCTION

Overload is a key principle of athletic training (1). To achieve peak performance, periods of intensified training (*i.e.,* overload) are incorporated into the training season (1). However, if a high training load is combined with insufficient recovery intervals and/or concomitant stressors (*e.g.,* chronic exposure to stress, impaired sleep, disruption of the circadian rhythms, or poor nutrition), changes in hematological factors suggesting impairment of immune function and an increased risk of infection may be reported (2). The disruption in body homeostasis may induce a state of overreaching or overtraining, with a deterioration rather than an improvement of physical performance (3–5).

Regular hematologic monitoring of athletes can identify abnormal values and contribute to the selection of an optimal workload by coaches and trainers. The measurement of hemoglobin concentration (Hb), red blood cell count (RBC) and biochemical parameters such a ferritin and transferrin are useful to examine iron metabolism, optimize oxygen transportation, and detect any increased risk of infection. The hematocrit (Hct) also indicates the hydration status of an athlete (6). Moreover, some sports federations (*e.g.,* ski, cycling, athletic) used Hct and/or Hb values as a simple index of blood doping and/or erythropoietin administration (7).

The quantification of white blood cells (WBC) and their subpopulations (*i.e.,* basophils (BAS), eosinophils (EOS), lymphocytes (LY), monocytes (MO) and neutrophils (NE)) provide one simple index of an athlete's immune function. Impairment can result from a single strenuous exercise session as well as from excessively hard training programs (8–13). Dietary deficiencies in energy, protein and specific micronutrients can also impair immune function and many infections increased in prevalence and/or severity by specific nutritional deficiencies (14,15). The WBC, also, influences the susceptibility of athletes to infection during training (16).

During the ninth lunar month of the Islamic calendar ("Ramadan"), healthy adult Muslims abstain from drinking and eating from sunrise to sunset for 29 or 30 days (17). Ramadan fasting can induce behavioral changes including impaired sleep (18), decreased alertness (19) and changes in meal composition and eating schedule (20,21). Physiological changes can include dehydration (22), metabolic responses (22,23) and shifts in the circadian rhythms of body temperature, cortisol and melatonin (24,25). All of these changes tend to be exacerbated in fasting athletes who maintain their full training program, with a potential for disruption of hematological and immunological indices (26).

Given that the stability of hematological indices is critical to health and performance (27–31), their monitoring in athletes who fasted during Ramadan is warranted.

To the best of the authors' knowledge, no previous systematic review has synthesized information concerning the impact of Ramadan observance on athletes' hematological indices. The present review was, thus, undertaken to meet this need.

METHODS

Protocol

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (32).

2.2 Eligibility criteria

Articles written in English language and published or accepted for publication in peer- reviewed journals evaluating the effect of Ramadan fasting on hematological indices in athletes were considered. No restrictions were applied in terms of study design, setting, country or time frame; but all accepted articles concerned athletes who continued to train during Ramadan fasting, with data on their hematological and/or immunological profile.

Descriptive or review articles, conference proceedings, abstracts and articles carried on sedentary, patients or physically active subjects were excluded. Both single-group pre-post with or without a control group studies were accepted, with all of these comparing findings before and during Ramadan fasting.

Information sources and search

Two electronic databases, PubMed/MEDLINE and Web of Science, were searched without applying any time limits or filters; the final search was completed on December 31th, 2018. The following combination of keywords was used: [(Ramadan) OR (Ramadan fasting)] AND [(Athletes) OR (Amateur) OR (Professional) OR (Player)] AND [(Hematological) OR (Haematological) OR (Hydration) OR (Dehydration) OR (Fluid balance) OR (Immunity) OR (Immune system) OR (Iron status)].

In addition, the reference lists of included articles were checked, as well as related citations from other journals identified *via* Google Scholar and a search of personal files. Specialists in the field were, also, contacted for information on possible upcoming studies.

Study selection

The process of article selection is outlined in Figure 1. Duplicate articles were eliminated using End-Note X9. Two authors (KT and HC) then independently screened titles and abstracts for eligibility and resolved disagreements by consensus. The full texts of the selected studies were next screened, and disagreements concerning eligibility were again resolved by consensus; reasons for excluding an article during the full-text screening were recorded.

Data collection process

The two reviewers (KT and HC) independently collected data, using a pilot-tested extraction form and resolved disagreements by consensus. Data extracted included participant characteristics (*i.e.,* number of participants, age, sex, sport practiced, type of training program, level of competition), study characteristics (*i.e.,* country, temperature, relative humidity, year of study, timing of blood sampling, the mean duration of the daytime fasting, measurement period), and key outcomes.

Quality assessment

The quality of each individual article was assessed using the 'QualSyst' (33) instrument. This rates 14 items (see Table 1) on a three point scale (yes = 2, partial = 1, no = 0), based on specific criteria. Items not applicable to a particular study were marked as 'NA'. A summary score was based on the total score for relevant items, divided by the total possible score for that study. Two reviewers (KT and HC) independently assessed studies, and disagreements in ratings were resolved by discussion, or by the intervention of a third reviewer (AH) as necessary. Studies with a score ≥75% were considered as of strong quality, those rated at 55–
75% as of moderate quality, and a score ≤55% was judged as of weak quality. The percentage of lost points for each item was also calculated.

RESULTS

Study selection

The search process yielded 101 articles; 36 remained after duplicates were excluded and their titles and abstracts were screened (Figure 1). Six articles were eventually accepted; screening of their reference lists and related citations from other journals *via* Google Scholar resulted in the inclusion of three additional articles and for a total of nine included articles.

Study characteristics

Table 2 and 3 show the detailed characteristics of Tunisian and Iranian studies, respectively.

Studies used either a single-group pre-post design without a control group (34–40) or a pre- test post-test design with a control group (41,42). Most studies (n=6) were conducted in Tunisia (34–37,40,41) and the remaining studies (n=3) were from Iran (38,39,42). Temperature and relative humidity during Ramadan were reported in only two studies (36,40), and none indicated the access of subjects to air-conditioning. Participants (a total of
216) were all male, with mean ages ranging from 16 to 24 years; individual sample size varied from 9 to 48 in these investigations. Athletic disciplines included soccer (37,38,41), judo (34,35), weight-lifting (42), wrestling (39), rugby union (36) and rugby sevens (40). Levels of competition ranged from elite (34–36), to professional (39) or amateur (37,40,41), with some articles not indicating the level of involvement (38,39,42).

Quality assessment

Quality assessment rated one article as of strong quality; but the remainder were of only moderate quality (Table 1). The highest percentage of lost points were due to a lack of control for confounding factors (50%), an inappropriate sample size (44.4%) and a lack of outcome measures that were well defined and robust to bias (33.3%) (Table 1).

Hematological indices of iron and hydration status

The reported results of the effects of Ramadan observance on iron and hydration status have been inconsistent. Bouhlel et al. (36) reported that the resting Hct and Hb concentrations of nine rugby union players were significantly higher at the end of Ramadan (End-R) compared to control measurements made before Ramadan (Bef-R). Increases of Hct and Hb were, also, reported in 12 rugby sevens players during Ramadan (40). On the other hand, Hosseini and Hejazi (38) observed decreases of

Table 1. Quality assessment of the included studies

Study	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
Bouhlel et al. (36)	2	1	2	2	NA	NA	NA	2	1	2	2	1	2	2	72	Moderate
Maughan et al. (41)	2	2	2	2	NA	NA	NA	2	2	2	2	1	2	2	84	Strong
Chaouachi et al. (34)	2	1	2	2	NA	NA	NA	1	1	2	2	1	2	2	72	Moderate
Chaouachi et al. (35)	2	1	2	2	NA	NA	NA	1	1	2	2	1	2	2	72	Moderate
Tayebi et al. (42)	2	2	1	1	NA	NA	NA	1	1	1	2	1	2	2	64	Moderate
Trabelsi et al. (40)	2	2	1	2	NA	NA	NA	1	1	2	2	1	2	2	72	Moderate
Aloui et al. (37)	2	1	2	2	NA	NA	NA	2	1	2	2	1	2	2	72	Moderate
Hosseini and Hejazi (38)	2	1	1	1	NA	NA	NA	1	1	1	2	1	2	2	60	Moderate
Hosseini et al. (39)	2	1	1	1	NA	NA	NA	1	1	1	2	1	2	2	60	Moderate
% of lost points	0.0	33.3	22.2	16.7	-	-	-	33.3	44.4	16.7	0.0	50	0.0	0.0		

NA= not applicable

Table 2. Summary of included Tunisian studies.

Study	Subjects	Age (years)	Sex	Activity	Level of practice	Training program	Year of the experimental protocol	The mean duration of fasting	Temperature (°C)	Relative humidity (%)	Measurement period	Timing of blood sampling	Hematology indices	Effect
Bouhlel et al. (36)	9	19 ± 2	Male	Rugby union	Tunisian national team	Five two-hour training sessions/ we ek			22-24°C	76%	One week Bef-R, at the end of the W1R and during the W4R	In the afternoon (14.00 – 16.30 h)	Hb	Increased
													Hct	Increased
Chaouachi et al. (34)	15	18 ± 1	Male	Judo	Tunisian national team	6 days per week and at least 2 training hours per day	2005	12h			4 days Bef-R, the W1R, the W3R and the W4R and 21 days After-R	In the morning (8.00-10.00 AM)	Hb	Decreased at the W3R then recovered After-R
													Hct	Increased at the W1R and the W4R
Maughan et al. (41)	Fasting players tested in the morning (n=28)	16–19	Male	Soccer	National first and third leagues	6–8 training sessions/week, with each session normally lasting about 90 min, including about 15 min of warm-up and 15 min	2006	12h			Bef-R, the W2R and the W4R and After-R	In the morning (9.00h)	Hb	Decreased in the W2R and increased After-R in comparison with Bef-R
													Hct	Decreased at the End-R compared to Bef-R
						of post training cool-down							Leucocytes	Not change
	Fasting players tested in the afternoon (n=20)											In the afternoon (13.30h)	Hb	Decreased
													Hct	Decreased at the End-R and After-R compared to Bef-R
													Leucocytes	Decreased during Ramadan compared to Bef-R
	Non-fasting players tested in the morning (n=16)											In the morning (9.00h)	Hb	Decreased at the W2R compared to Bef-R
													Hct	Not change
													Leucocytes	Not change
	Non-fasting players											In the afternoon (13.30h)	Hb	Decreased during Ramadan compared to

	players tested in the afternoon (n=14)												Bef- R	
													Hct	Decreased at the End-R and After-R compared to Bef- R
													Leucocytes	Decreased at the W2R compared to Bef-R
Chaouachi et al. (35)	15	18 ± 1	Male	Judo	Tunisian national team	6 days/week and 2h/day	2005	12h			4 days Bef-R, the W1R, the W3R and the W4R and 21	In the morning (8-10 AM)	Leucocytes	Not change
													Neutrophils	Not change
													lymphocytes	Not change
											days After- R		Monocytes	Not change
Trabelsi et al. (40)	12	23.8±4	Male	Rugby sevens	Amateur		2008	13h	35°C Bef-R and 29.4°C during Ramadan	41% Bef- R and 67.9% during Ramadan	Bef-R, the W1R and the W4R		Hct	Increased during Ramadan compared to Bef-R
													Hb	Increased at the W4R compared to Bef-R
													BV	Increased at the W1R compared to Bef-R before the match; no change after the match
Aloui et al. (37)	12	20.1±1.6	Male	Soccer	Tunisian amateur league	10.0 ± 0.5 h/ week			Bef-R: between 25-29%. During Ramadan: between 26-28°C	Bef-R: between 55-65%. During Ramadan : between 55% and 74%	First week Bef-R, the W2R and W4R and 2 weeks After-R	In the morning (7–9 AM)	Hct	Afternoon values were higher during Ramadan than Bef-R; and the afternoon values were higher than the morning values during Ramadan
												In the afternoon (5–7 PM)		
												In the morning (7–9 AM)	Hb	
												In the afternoon (5–7 PM)		

Abbreviations: NM=not mentioned; Hct= hematocrit; Hb=hemoglobin; RBC= red blood cells; BV= blood volume; MCV= mean corpuscular volume; MCH= mean corpuscular hemoglobin; MCHC= mean corpuscular hemoglobin concentration; RDW= red cell distribution width; RCV= red cell volume; Bef-R=Before Ramadan; After- R=After Ramadan; End-R=End of Ramadan; W1R=First week of Ramadan; W2R=Second week of Ramadan; W3R=Third week of Ramadan; W4R=Fourth week of Ramadan.

Hct, Hb and RBC in young soccer players after Ramadan (After-R) compared to Bef-R. Hosseini et al. (39) further noted a decrease in the RBC of wrestlers during Ramadan; although their Hct and Hb values remained unchanged (39). Chaouachi et al. (34) reported that the Hct of judokas increased (<1%) at the middle (Mid-R) and at the End-R; however, Hb concentrations decreased at the Mid-R; but recovered After-R. Tayebi et al. (42) evaluated the effects of three sessions per week of resistance training program on weightlifters. They identified no-changes in Hct, Hb, RBC, mean corpuscular volume, mean corpuscular Hb or mean corpuscular Hb concentration relative to data measured Bef-R.

Several investigators made comparisons between morning and afternoon data. Maughan et al. (41) reported acute changes (<2%) in Hct of soccer players during Ramadan, whether samples were collected in the morning (09:00 a.m.) or in the afternoon (13:30 p.m.). Additionally, Hb concentrations decreased significantly at the End-R only in the group of soccer players who were tested in the afternoon (41). In contrast, Aloui et al. (37) reported that the Hct and Hb values of twelve amateur soccer players were higher during Ramadan compared to Bef-R, irrespective of whether samples were collected in the morning (07:00 a.m.) or in the afternoon (05:00 p.m.); however, as might be expected values were higher in the afternoon than in the morning during Ramadan (37).

Blood platelet count

Three studies evaluated the effect of Ramadan fasting on blood platelet counts. Values increased during Ramadan fasting in wrestlers (39); but not in soccer players (38) or weightlifters (42).

White blood cells profile

Three studies evaluated the effect of Ramadan fasting on simple measures of white cell count; but none looked at more sophisticated indices such as natural killer cell counts and activity or immunoglobulin levels. Chaouachi et al. (34) reported no-change in WBC, NE, LY and MO counts of judokas during Ramadan when compared to Bef-R. Likewise, WBC values remained unchanged in soccer players (38). Compared to Bef-R, Maughan et al. (41) observed some decrease of WBC of soccer players during Ramadan when blood samples were collected in the afternoon (01:30 p.m.); but values were unchanged for subjects whose blood samples were collected in the morning (09:00 a.m.).

DISCUSSION

The aim of this review was to systematize the literature on hematological indices in athletes during Ramadan fasting. The studies reviewed broadly support the conclusion that the continuation of training during Ramadan fasting was associated with some dehydration; but it is less clear if there was a cumulative deficit, or whether rehydration was complete during the hours of darkness. Examination of immune function did not extend beyond differential white cell counts; but such measures showed little change with Ramadan fasting.

Ramadan observance and hematological indices of the iron and hydration status

Hct and Hb increased during Ramadan in soccer (37), rugby union (36) and rugby sevens players (40) suggesting either acute or cumulative hypohydration. Hct and Hb values recorded in the afternoon (05:00 p.m.) were significantly higher compared to those obtained in the morning (07:00 p.m.), underlining the progressive dehydration that develops over the course of a Ramadan day. An increase of Hct between the beginning and the End-R further pointed to a cumulative dehydration (36,40). In contrast, Maughan et al. (41) noted a decrease in these indices in soccer players who were tested in the afternoon during Ramadan. Additionally, Hb concentrations decreased significantly at the End-R only in the group tested in the morning (41). The fall in circulating Hb concentration suggests that some athletes over-hydrated; possibly the players concerned had been encouraged to drink a large volume of water at night, or possibly there was some expansion of the subjects' vascular space, as an adaptation to continued training (43–45).

All of these changes in hematological indices were relatively small, with values remaining within the normal laboratory reference range, suggesting that Ramadan fasting had no- pathological effect on the hydration or iron status of the athletes.

Blood platelet count

Micronutrient deficiencies in iron and certain vitamins can decrease blood platelet counts (22). However, the studies of Hosseini and Hejazi (38) and of Tayebi et al. (42) reported no- change in platelet counts during Ramadan fasting.

Table 3. Summary of included Iranian studies.

Study	Subject s	Age (years)	Sex	Activity	Level of practice	Training program	Year of the experiment al protocol	Temperatur e (°C)	Relative humidity (%)	Measuremen t period	Timing of blood sampling	Hematology indices	Effect
Tayebi et al. (42)	Control- no fasted (n=10)		Male	Weight- lifting	NM		2006			24h before and 24h after one month of fasting		RBC	Not change
												Hb	Not change
												Hct	Not change
												MCV	Not change
												MCH	Not change
												MCHC	Not change
												RDW	Not change
												BV	Not change
												RCV	Not change
	Control- fasted (n=10)											RBC	Not change
												Hb	Not change
												HCT	Decreased
												MCV	Not change
												MCH	Not change
												MCHC	Increased
												RDW	Not change
												BV	Not change
												RCV	Decreased
	Training -no fasted (n=10)					3sessions/w eek, 90 min/ session						RBC	Not change
												Hb	Not change
												HCT	Decreased
												MCV	Not change
												MCH	Not change
												MCHC	Not change
												RDW	Not change
												BV	Not change
												RCV	Not change
	Training -fasted (n=10)											RBC	Not change
												Hb	Not change
												HCT	Not change
												MCV	Not change
												MCH	Not change
												MCHC	Not change
												RDW	Not change
												BV	Not change
												RCV	Not change

White blood cells profile

Conclusions regarding immunological status are necessarily limited by the available data. However, the WBC did not change during Ramadan fasting (34,38). Further examination of natural killer cell activity and immunoglobulin concentrations is needed, since athletes are prone to upper respiratory infections. Nevertheless, the absence of modifications in subsets of WBC, as reported by Chaouachi et al. (34), argues against the presence of viral and/or bacterial diseases. Maughan et al. (41) even observed a decrease in WBC among soccer players who were tested in the afternoon; this could reflect either hyper-hydration, or a decreased release of leucocytes from bone marrow (46) and other sites of sequestration. Again, all leucocyte parameters to date have remained well within normal clinical limits. Thus, there is as yet no -evidence that the continuation of training during Ramadan fasting has affected immune defences.

However, further tests are needed in the type of situation where impairment of immune function is most commonly observed even in the absence of Ramadan fasting, such as marathon and ultra-marathon runs (11,47). Hematological indices are differentially affected as a consequence of specific sports characteristics (*e.g.,* intensity, frequency and duration of the task, the quality and duration of recovery periods between training sessions, the phase of the training program) and environmental factors (48). Much further work is needed to provide all full picture of the potential impact of Ramadan fasting.

Strengths and weaknesses

This is the first systematic review of the effect of Ramadan fasting on the hematological indices in athletes. The strengths of this study include a comprehensive coverage of the literature and a careful appraisal of study quality. However, presently reported results must be interpreted with considerable caution, due to methodological issues including the lack of control group in most studies, the poor description of subjects' characteristics and the absence of control of confounding factors (*e.g.,* the time elapsed since the last exercise session, and data on *Sahour* food and water intake).

CONCLUSIONS

Regular training during Ramadan fasting may exacerbate the dehydration resulting from decreased total water intake, with both acute and chronic increases in Hct and Hb values. However, over-compensation by coaches and athletes can, also, result in a state of hyperhydration. More detailed information is needed on potential changes in immune function, but total and differential white cell counts at least remain within normal limits. The fact that hematological indices remain within the normal reference range during Ramadan fasting suggests that intensive physical training can safely be maintained during Ramadan. However, more controlled studies are needed, and these should include better measures of immune function, as well as data on participants in long distance events.

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