

# Effects of Ramadan Fasting on Health and Athletic Performance



[www.esciencecentral.org/ebooks](http://www.esciencecentral.org/ebooks)

Edited by  
**Dr. Hamdi Chtourou**

# Effects of Ramadan Fasting on Health and Athletic Performance

**Edited by:** Dr. Hamdi Chtourou

**ISBN:** 978-1-63278-030-0

**DOI:** <http://dx.doi.org/10.4172/978-1-63278-030-0-031>

**Published Date:** June, 2015

**Printed Version:** June, 2015

Published by **OMICS Group eBooks**

731 Gull Ave, Foster City, CA 94404, USA.

## **Copyright © 2015 OMICS Group**

All book chapters are Open Access distributed under the Creative Commons Attribution 3.0 license, which allows users to download, copy and build upon published articles even for commercial purposes, as long as the author and publisher are properly credited, which ensures maximum dissemination and a wider impact of our publications. However, users who aim to disseminate and distribute copies of this book as a whole must not seek monetary compensation for such service (excluded OMICS Group representatives and agreed collaborations). After this work has been published by OMICS Group, authors have the right to republish it, in whole or part, in any publication of which they are the author, and to make other personal use of the work. Any republication, referencing or personal use of the work must explicitly identify the original source.

## **Notice:**

Statements and opinions expressed in the book are these of the individual contributors and not necessarily those of the editors or publisher. No responsibility is accepted for the accuracy of information contained in the published chapters. The publisher assumes no responsibility for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained in the book.

A free online edition of this book is available at [www.esciencecentral.org/ebooks](http://www.esciencecentral.org/ebooks)

Additional hard copies can be obtained from orders @ [www.esciencecentral.org/ebooks](http://www.esciencecentral.org/ebooks)

## **Preface**

Ramadan is the ninth month of the lunar Islamic calendar during which it is compulsory for adult healthy Muslims to fast from dawn to sunset. As Muslims observe this practice annually, it is interesting to assess how the changed lifestyle that characterizes Ramadan would influence their health, psychology and sport performance.



**Thank You,**

Dr. Hamdi Chtourou

## About Editor



Dr. Hamdi Chtourou has received his PhD in “Exercise Physiology” in the University of Carthage in Mars 2013. Currently, he is working as Assistant professor in the high institute of sports and physical education, University of Sfax, Tunisia. His research has included: Sport medicine, Sport Sciences, Chronobiology, Ramadan Fasting, Strength and conditioning, Athletic training, & Performance optimization. He is serving as an editorial member of several journals like World Journal of Medicine and Medical Science Research & Journal of Modern Physiological Research and expert Reviewers for journals like PLOS ONE, Applied Physiology, Nutrition, and Metabolism, Scandinavian Journal of Medicine and Science in Sports, Behavioral and Brain Functions, International Journal of Sports Medicine, Journal of Sports Science, Journal of Athletic Training, International Journal of Sports Physiology and Performance, & Journal of the International Society of Sports Nutrition. He has authored several research articles/books. He has numerous conference presentations that were presented at national and international conferences. Dr. Chtourou is an active member of the Tunisian association of young researchers in sciences and techniques of sports and physical activities and of the Tunisian Research Laboratory “Sport Performance Optimisation” National Centre of Medicine and Sciences in Sport (CNMSS).

## Forewords

Dr. Hamdi Chtourou is a well-recognized researcher in the area of sports science. He has published quiet extensively in the area of Ramadan fasting and is well-placed to provide the leadership in this book.

There has been a recent surge of studies in the scientific literature examining the effects of Ramadan fasting on health and exercise performance within the last few years, possibly due to the enormous publicity generated by the London Olympic Games, which was held during the Ramadan month. Ramadan fasting is a perennial event that cannot be avoided and thus there is a cogent need for scientific and evidence-based research on the effects of Ramadan fasting on health and exercise performance. It is hopeful that the information gleaned from these compiled reviews will provide the knowledge and impetus to further investigate the influence of Ramadan fasting on health and exercise performance and drive future researchers to formulate specific strategies to minimize the impact of Ramadan fasting on Muslim athlete's health and exercise performance.

**Abdul Rashid Aziz**

I know Dr. Hamdi Chtourou from a long time. He is a nice person, a good friend and a hard worker. We belong to the same research team. From the beginning of his career, Dr. Chtourou was professional, prompt and always looking for excellence. Moreover, he is an essential part of my scientific career. We made several researches together in several fields such as chronobiology and Ramadan fasting. When we work together, Dr. Chtourou's suggestions are always valuable and allow me to improve my skills. I wish that this opportunity will open to us new windows and will make our collaboration richer and more successful."

"The content of the present book is practical for people in different health conditions. Indeed, the chapters deal with the effect of Ramadan fasting on aspects related to health and some diseases, as well as the impact of fasting during Ramadan on some key factors of sport performance."

**Asma Aloui**

Ramadan is one of the five pillars of Islam. Even though patients and pregnant women, among the others, are exempted from observing this duty, they may be eager to celebrate this particular moment. However, there are no guidelines that can help physicians to properly address this issue. For this purpose, Dr. Hamdi Chtourou has edited this book, "Effects of Ramadan Fasting on Health and Athletic Performance," that undoubtedly represents an important advancement for providing evidence-based suggestions and recommendations, as well as useful insights on the impact of Ramadan on the athletic performance. Dr. Hamdi Chtourou is a recognized scientist and athlete. He holds several sports diplomas, two masters and a PhD in biological sciences. Currently, he works as Assistant Professor at High Institute of Sport and Physical Education, Sfax University, Tunisia. He is author/co-author of more than 60 peer-reviewed manuscripts and serves on different editorial boards of international journals.

**Nicola Luigi Bragazzi**

## **Acknowledgement**

I am pleased to say that the contributors to this book have provided interesting information about the effects of Ramadan fasting on health and athletic performances. I would like to express my sincere gratitude to them for their generous, voluntary contributions. I wish to express also my sincere appreciation to the reviewers contributing to the up-to-date chapters of this book.

## **Introduction**

Ramadan fasting is a religious obligation followed annually by Muslims. This practice consists of a total abstinence from some behaviors such as eating, drinking and smoking during the span between dawn and sunset. Studies dealing with the effects of Ramadan were focused on several topics. Most published studies have examined either medical aspects related to fasting during Ramadan or the pattern of features related to sport performance during Ramadan. In this book, the chapters discuss several topics related to the effect of Ramadan on sport performance, training-induced adaptations, Muslims' psychology, sleep, sports nutrition, health and some patients with chronic diseases.

<b>Contents</b>	<b>Page #</b>
<b>Chapter 1:</b> Ramadan and Oral Pathologies	1-5
<b>Chapter 2:</b> Ramadan Fasting and Immunity System	6-14
<b>Chapter 3:</b> Ramadan and Health-Related Applications for Mobiles and Smartphones: Ramadan 2.0 or The Digital Ramadan, as a New Emerging Trend	15-19
<b>Chapter 4:</b> Ramadan Fasting and Skin Disorders	20-22
<b>Chapter 5:</b> Ramadan Fasting and Cardiovascular Disease	23-29
<b>Chapter 6:</b> Ramadan Fasting and Cancer	30-34
<b>Chapter 7:</b> Ramadan Fasting and Emergencies	35-40
<b>Chapter 8:</b> Ramadan Fasting and Diabetes	41-50
<b>Chapter 9:</b> Ramadan Fasting and Infectious Diseases	51-55
<b>Chapter 10:</b> Ramadan Fasting and Chronic Kidney Disease (CKD)	56-67
<b>Chapter 11:</b> Ramadan and Psychiatric Disorders	68-73
<b>Chapter 12:</b> Involvement in Religion and Self- Regulation: Explanations of Muslims' Affects and Behaviors during Ramadan	74-85
<b>Chapter 13:</b> Ramadan Fasting and Biological Biomarkers: The New Opportunities of Systems Biology and Omics Sciences	86-90
<b>Chapter 14:</b> Ramadan Fasting and Lipid Profile	91-107
<b>Chapter 15:</b> Body Composition, Hematological and Biochemical Modifications during Ramadan Fasting	108-116
<b>Chapter 16:</b> Maintaining Fluid Balance during Day Fasting in the Month of Ramadan	117-126
<b>Chapter 17:</b> Circadian Rhythm and Sleep Disturbances during Ramadan: Implications on Sports Performance	127-139
<b>Chapter 18:</b> Ramadan Fasting and Sport Performance	140-159
<b>Chapter 19:</b> Ramadan Fasting and Diurnal Variation in Sport Performance	160-174
<b>Chapter 20:</b> Injury Rate during Ramadan	175-187
<b>Chapter 21:</b> Exercise Responses and Training during Daytime Fasting in the Month of Ramadan and its Impact on Training-Induced Adaptations	188-203
<b>Chapter 22:</b> Recommendations for Optimal Competitive Exercise Performance and Effective Training-Induced Adaptations when Ramadan Fasting	204-221



## Chapter 1

# Ramadan and Oral Pathologies

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINO GMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINO GMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though patients are exempted from observing this religious duty, they could be willing to take part into the religious ceremonies. Here, we review the extant literature focusing on the impact of Ramadan fasting on patients suffering from oral pathologies. From the collected evidences, we can claim that: 1) trans-cultural counseling of patients suffering from oral diseases is extremely important; 2) Muslim subjects could experience malodour and halitosis; the exact etiology of this phenomenon is complex, due to the accumulation of sulphur-containing compounds in the oral cavity, a decrease in salivation and changes in the oral microflora. An accurate oral hygiene when breaking the fast is recommended, for example using *miswak* which has anti-bacterial properties; 3) dental operations can be performed using special precautions, changing drugs and administering intramuscular or trans-dermal treatment instead of oral agents; appointments can be delayed or postponed, if necessary and possible; 4) patients with chronic systemic diseases, and especially metabolic disorders, such as diabetes, should take care of their oral cavity; 5) mouthwash and mouth-rinsing without water swallowing are allowed practices in Islam and ameliorate athletic performances, even though some patients or subjects could be reluctant to do it, perceiving these practices as a break of the fast.

**Keywords:** Dentistry; Halitosis; Miswak; Oral Pathologies; Oral Surgery; Ramadan Fasting

## Ramadan Fasting

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), has a great importance and meaning for all the Muslims in the world. Abstinence from eating and drinking, sexual intercourses, characterize this period. It is a month of intense and special prayers (such as the *tarawih*). Usually, patients are exempted from observing these rules, even though they may ask their doctors whether they can fast without experiencing injurious effects [1].

Darwish [2] has identified three main issues that may be encountered by a dentist during the clinical practice while addressing the needs of a Muslim client during the Ramadan fasting month: namely the halitosis and the oral hygiene practices, the compliance to treatment, and the oral surgery.

## Ramadan, Halitosis and Changes in Oral Microflora

The first issue concerns the increased presence of sulphur-containing compounds present in the oral cavity, the decreased salivation and the modified oral microflora, which can cause a marked malodour and halitosis. This may be misdiagnosed as being associated with poor oral hygiene practices or oral disease. The odor may be reduced with a proper debridement with dentifrice or *miswak* while breaking the fast.

Semiyari and collaborators [3] considering that dental caries, periodontal diseases and other oral pathologies are complex disorders arising from an interaction between diet and natural oral microflora and given that the fasting period in holy month of Ramadan represents a change in diet (that is to say, in time and amount of food intake) and in oral hygiene practices, explored Ramadan-induced modifications in oral microflora. They carried out a descriptive, case-control study, recruiting 100 high school students between 15-20 years old. They found statistically significant differences between Gram-positive cocci, Gram-positive bacilli, Gram-negative bacilli, Gram-negative spindle shaped bacteria frequency in fasting and no fasting subjects.

However, while advising the patient, dentists should be aware of the following hadith: “The smell of the mouth of a fasting person is better than the smell of musk in Allah’s Sight” (reported by Sahih Bukhari, Muslim and Abu Huraira).

## Ramadan and Compliance to Treatment

The second issue concerns the patients’ beliefs and knowledge of what is permissible and what is not during the Ramadan month. The administration of drugs may be wrongly considered *haram* (that is to say, not licit and permissible). The water spray from a hand piece, the water to rinse and prophylactic pastes may be inadvertently swallowed and so a patient may refuse such treatment while fasting. Swallowing one’s own saliva is not forbidden (*haram*), while most patients believe that it is. Furthermore, some perceive the introduction of a foreign object in the mouth, even a toothbrush, as breaking of the fast, thus not collaborating during the oral examination. This issue is extremely important for the compliance and adherence to treatment [4-8].

Medication route and delivery/ type of drug administration	Permissibility for fasting patients	Precautions/exceptions/warnings
Oral medication	Not permissible (haram, it invalidates the fast)	Emergencies resulting from acute diseases or deteriorating chronic ones; when harm may result from non taking medication Injection is non-nutritional (opinions vary) Care taken to avoid swallowing Patients may prefer to have alternative treatment, or treatment outside fasting hours - Patients may be reluctant so better to delay or re-schedule treatment
Medication by injection	Permissible	
Mouthwash/mouth rinsing	Permissible	
Varnish (sustained-release of fluoride)	Permissible	
Pulp capping medicaments	Permissible	
Local anaesthesia	Permissible	

**Table 1:** Recommendations for patients suffering from oral pathologies (slightly modified from [4] and [5]).

## Ramadan and Oral Surgery

A patient suffering from an acute oral pathology in case of emergency or with a deteriorating chronic illness could break the fast if harm would result from not taking the proper treatment. If possible, the dentist can delay or re-schedule the appointment meeting with the patient's spiritual needs, postponing it after Ramadan or late in the afternoon/evening. This can be done for example for elective surgical procedures.

In case of acute surgical operations, such as tooth extraction, since gluconeogenesis may cause syncope, the dentist should use a glucometer before and during treatment. The supine position may also prevent syncope. In particular cases, glucose can be administered orally. If dental extraction can be delayed, a preliminary pulpal extirpation can be done, suturing the dental sockets in order to eliminate the need for liquid hemostatic agents and involuntary liquid swallowing (saliva, blood), as well as using lasers for an accurate hemostasis.

In some cases, the dentist can change the treatment, administering an intramuscular or trans-dermal drug instead than an oral one, possibly with a long duration of action.

In some Arabic countries, dentists have tried to organize some "Ramadan clinics" and pre-Ramadan dental checkups. This could favor the compliance to treatment. Albarakati [9], indeed, assessed the factors for failed appointments among 200 female patients attending a dental school clinic, carrying out a cross-sectional survey. The author found that the patients who broke their appointments were married, housewives, above 40 years in age, and of low-to-middle socioeconomic status. The most common reason for failed appointments was Ramadan fasting (79.1 percent).

## Ramadan and General Pathologies with an Oral Involvement

Last but not least, a further issue regards patients with chronic conditions which could lead to an oral involvement or frank oral pathologies. Jaleel and collaborators [10], considering that severe periodontal disease often coexists with diabetes and increases its severity and associated complications, suggest a proper control and treatment of chronic oral diseases. This is essential for achieving long-term glycemic control in patients suffering from periodontal disease like gingival disease, chronic periodontitis, aggressive periodontitis, necrotizing periodontitis or periodontal abscess.

## Ramadan and Oral Health in Athletes

Che Muhamed and co-workers [11] performed a study aimed at examining the effect of mouth rinsing during endurance cycling in a hot humid environment recruiting 9 trained adolescent male cyclists. The authors found that mouth rinsing with either carbohydrate or placebo solution provided ergogenic benefits.

## Ramadan and Oral Health: Some *Ahadith* and *Fatawa*

Sahih Bukhari in the Volume 3, Hadith number 154 reported: "Narrated Abu Huraira: The Prophet said, "If somebody eats or drinks forgetfully then he should complete his fast, for what he has eaten or drunk, has been given to him by Allah." Narrated 'Amir Bin Rabi'a, "I saw the Prophet cleaning his teeth with Siwak while he was fasting so many times as I can't count." Aisha said, "The Prophet said, "It (i.e. Siwak) is purification for the mouth and it is a way of seeking Allah's pleasures." Ata' and Qatada said, "There is no harm in swallowing the resultant saliva."



Figure 1: Miswak.

Amir Ibn Rabia narrated: “I saw Hz. Muhammad (PBUH) using a *miswak* while fasting more times than I can count.” (Bukhari, Sawm: 27; Abu Dawud, Savm: 26; Tirmidhi, Sawm: 29). Ibn Umar Radiyallahu Anhum reported: “The fasting person uses miswak at the beginning and end of the day.” (Bukhari, Sawm 25).

While it is understood that the use of *miswak* belongs to Sunnah, according to Imam Abu Yusuf, it is *makrooh* (not recommended) for the fasting person, to use a *miswak* dampened with water. Imam Azam and Imam Muhammad think exactly the contrary. However, using a toothbrush with toothpaste is definitely *makrooh* when fasting. It is necessary to avoid using it even though it does not invalidate the fast.

Moreover, *miswak* has precious properties. Naseem and collaborators [12] reported that *miswak* (twigs from *Salvadora persica*) has been found to have precious inhibitory antimicrobial effects against *P. gingivalis*, *A. actinomycetemcomitans*, *H. influenzae* and less against *S. mutans* and *L. acidophilus*. This was confirmed by another study [13].

## Conclusion

From the collected evidences, we can claim that:

- 1) Trans-cultural counseling of patients suffering from oral diseases is extremely important [14,15].
- 2) Muslim subjects could experience malodour and halitosis; the exact etiology of this phenomenon is complex, due to the accumulation of sulphur-containing compounds in the oral cavity, a decrease in salivation and changes in the oral microflora. An accurate oral hygiene when breaking the fast is recommended, for example using *miswak* which has anti-bacterial properties;
- 3) Dental operations can be performed using special precautions;
- 4) Patients with chronic systemic diseases, and especially metabolic disorders, such as diabetes, should take care of their oral cavity;
- 5) Mouthwash and mouth-rinsing without water swallowing are allowed practices in Islam and ameliorate athletic performances, even though some patients and subjects could be reluctant to do it, perceiving these practices as a break of the fast.

## References

1. Alkandari JR, Maughan RJ, Roky R, Aziz AR, Karli U (2012) The implications of Ramadan fasting for human health and well-being. J Sports Sci 30: 9-19.

2. Darwish S (2005) The management of the Muslim dental patient. *Br Dent J* 199: 503.
3. Semiyari H, Farhadi S, Taheri RA, Owlia P (2010) Comparison of Salivary Micro Flora of Fasting and No Fasting Persons. *Journal of Biological Sciences* 5: 553-555.
4. Raja A, Anees K, Bedi R (2000) Transcultural oral health care: 3. Dental care and treatment during the fast of Ramadan. *Dent Update* 27: 392-394.
5. Anees K, Bedi R (2000) Transcultural oral health care: 4. Dental medication for Muslim patients. *Dent Update* 27: 449-452.
6. Aadil N, Houti IE, Moussamih S (2004) Drug intake during Ramadan. *BMJ* 329: 778-782.
7. Aslam M, Healy MA (1986) Compliance and drug therapy in fasting Moslem patients. *J Clin Hosp Pharm* 11: 321-325.
8. Aslam M, Assad A (1986) Drug regimens and fasting during Ramadan: a survey in Kuwait. *Public Health* 100: 49-53.
9. Albarakati SF (2009) Appointments failure among female patients at a dental school clinic in Saudi Arabia. *J Dent Educ* 73: 1118-1124.
10. Jaleel MA, Raza SA, Fathima FN, Jaleel BN (2011) Ramadan and diabetes: As-Saum (The fasting). *Indian J Endocrinol Metab* 15: 268-273.
11. Che Muhamed AM, Mohamed NG, Ismail N, Aziz AR, Singh R (2014) Mouth rinsing improves cycling endurance performance during Ramadan fasting in a hot humid environment. *Appl Physiol Nutr Metab* 39: 458-464.
12. Naseem S, Hashmi K, Fasih F, Sharafat S, Khanani R (2014) In vitro evaluation of antimicrobial effect of miswak against common oral pathogens. *Pak J Med Sci* 30: 398-403.
13. Sofrata AH, Claesson RL, Lingström PK, Gustafsson AK (2008) Strong antibacterial effect of miswak against oral microorganisms associated with periodontitis and caries. *J Periodontol* 79: 1474-1479.
14. Khan FA, Williams SA (1999) Cultural barriers to successful communication during orthodontic care. *Community Dent Health* 16: 256-261.
15. Peedikayil FC, Thomas A, Naushad MC, Narayanan A (2014) Management of muslim dental patient while fasting. *Eur J Gen Dent* 3: 82-84.

## Chapter 2

# Ramadan Fasting and Immunity System

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINOEMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINOEMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents the ninth month of the Muslim lunar calendar and the fourth of the five pillars of the Islam creed. Even though patients and pregnant women are exempted from observing this religious duty, they may be willing to share this particular moment of the year with their family and peers, by attending the special prayers (such as the *tarawih*), social gatherings and other ceremonies. However, there are no guidelines or standardized protocols that can help clinicians to properly address the issues and concerns of patients and pregnant women eager to fast in Ramadan and correctly advising them. Despite the extensive body of studies conducted on Ramadan fasting, no clear information is available concerning the changes of immunity system during the fasting month. We systematically searched ISI Web of Science (WoS), Scopus, MEDLINE/PubMed, Google Scholar, DOAJ, EbscoHOST, Scirus, Science Direct, the Cochrane Library and ProQuest. We used a proper string made up of a combination of key-words such as “Islam”, “Ramadan”, “Fasting” and “Immunity”. 30 original research articles were included in the current review: 14 studies focusing on immunity changes in healthy subjects, 7 in athletes, 5 in patients with metabolic disorders, 3 in individuals suffering from cardiovascular diseases and hypertension, and only 1 in pregnant women. From the collected evidences, we can conclude that: 1) Ramadan fasting does not result in severe immunological disturbances, being all the changes transient and recovering to normal values and ranges after the fasting month; 2) maternal fasting during the second trimester does not have a significant impact on maternal oxidative stress, fetal development or fetal birth weight; 3) Ramadan fasting can have beneficial effects on patients suffering from metabolic disorders (obesity and diabetes mellitus); 4) Ramadan fasting can have positive effects on patients with stable cardiac diseases and hypertension, improving cardiovascular, lipids profile and oxidative stress; 5) Ramadan can affect and impair the activity of athletes. However, the majority of the studies has

been conducted among healthy volunteers and there is a dearth of data about patients suffering metabolic and cardiovascular diseases. No data are available for patients with autoimmune disorders. Further research in the field is urgently needed.

**Keywords:** Athletes; Biological Pathway and Network; Cardiovascular Diseases; Diabetes Mellitus; Hypertension; Immunity System; Metabolic Disorders; Obesity; Oxidative Stress; Pregnancy; Ramadan Fasting

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is particularly blessed and of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*. Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 "Al-Baqarah", ayyat 183 and following verses*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. The fast is broken, taking two traditional meals, pre-dawn meal which is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable (29-30 days), mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1] or even 22 hours, in the extreme latitudes regions [1].

Patients and pregnant women are exempted from this religious duty (*Surat 2 "Al-Baqarah", ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers, by attending the special prayers (such as the *tarawih*, usually prayed in pairs of two in at least 20 *raka'at* according to Hanafis and Shafi'i schools, while some scholars believe that 8, 12 or 20 *raka'at* can be done, with a break after every 4 *rak'ah*), social gatherings and other special ceremonies [3].

The effects of Ramadan fasting on human physiology and physiopathology is not a mere academic and speculative topic or of limit interest for only the Arabic countries. It has instead clinically relevant and pragmatic implications: in a globalized society, the physicians have to face with issues like the management of diabetes mellitus and Chronic Kidney Diseases (CKDs) in Muslim patients that want to fast during Ramadan [4]. However, information is sparse and no guidelines or standardized protocols exist [4,5].

For these reasons, we carried out an extensive overview on the impact of Ramadan fasting on the immunity system.

## Materials and Method

We systematically searched ISI Web of Science (WoS), Scopus, MEDLINE/PubMed, Google Scholar, DOAJ, EbscoHOST, Scirus, Science Direct, the Cochrane Library and ProQuest. We used a proper string made up of a combination of key-words such as "Islam", "Ramadan", "Fasting" and "Immunity".

Gray literature was also manually searched. Review articles or research manuscripts not pertinent with the aim of this systematic review were excluded, while all the other research articles (including editorials, letters, case reports) were retained. No time and language filters were applied.

Topic	References
Immunity System and Healthy Subjects	Akrami Mohajeri et al., 2013 [11] Chennaoui et al., 2009 [12] Develioglu et al., 2013 [10] Faris et al., 2012a [9] Faris et al., 2012b [18] Ibrahim et al., 2008 [17] Lahdimawan et al., 2013a [13] Lahdimawan et al., 2013b [14] Lahdimawan et al., 2014 [15] Latifynia et al., 2007a [6] Latifynia et al., 2007b [7] Latifynia et al., 2008 [8] Sülü et al., 2010 [19] Zainullah et al., 2005 [16]
Immunity System and Pregnant Women	Ozturk et al., 2011 [20]
Immunity System and Metabolic Disorders	Al-Shafei, 2014a [24] El-Gendy et al., 2012 [25] Radhakishun et al., 2014 [23] Shariatpanahi et al., 2012 [22] Unalacak et al., 2011 [21]
Immunity System and Cardiac Diseases	Al-Shafei, 2014b [28] Khafaji et al., 2012 [26] Nematy et al., 2012 [27]
Immunity Systems and Athletes	Abedelmalek et al., 2011 [31] Aksungar et al., 2007 [30] Chaouachi et al., 2009 [29] Hammouda et al., 2013 [32] Hammouda et al., 2014 [33] Maughan et al., 2008 Trabelsi et al., 2012

**Table 1:** Studies divided according to their main topic.

## Immunity Changes in Healthy Individuals

Latifynia and collaborators [6] studied neutrophil respiratory burst (innate immunity) in a sample of 24 male healthy volunteers (aged 18–35 years, mean age 26.5) using chemiluminescence method. No statistically significant changes in innate immunity were observed before and after Ramadan.

The same authors [7] investigated the impact of Ramadan fasting on Circulating Immune Complexes (CICs) using the polyethylene glycol precipitation method, quantitative chemiluminescence and circulating immune techniques, before and after Ramadan. They assessed a convenience sample of 28 healthy medical students residing in dormitory of Tehran University, out of an initial list of 120 individuals. The mean age of the students was 26.2 years. The mean CIC level was  $2.04 \pm 1.86$  before Ramadan and  $2.63 \pm 2.1$  after Ramadan ( $p$ -value >0.05). The authors found that CIC level was increased in 17 cases and decreased in 11 cases, only 6 cases were out of normal range after Ramadan, and only 1 case of the 6 increased cases had high CIC level before and after Ramadan. Only 3 cases had low CIC level before Ramadan that remained abnormal after Ramadan. 3 cases decreased and set to normal group and one case remained in the abnormal group. The authors concluded that there was no significant difference between the CIC level before and after Ramadan.

The same authors [8] investigated neutrophil respiratory bust in a sample of 21 male students at Tehran University, Tehran, aged 18–35 years (mean 26.5). In 11 cases, the changes of chemiluminescence were in normal range, while 6 cases had CIC changes in normal range. In 9 cases the changes were in normal range which 2 cases had normal level of CIC, before and after Ramadan, the CIC levels in 3 cases was abnormal, however after Ramadan, the values were returned to normal, In spite, in 4 cases CL was normal, that their normal values of CIC changed to abnormal, after Ramadan. Finding that there were



no significant changes in the activity of circulating neutrophils and CIC levels before and after Ramadan, the authors concluded that Ramadan fasting has no effect on neutrophil respiratory burst.

Moreover, a correlation between CIC and neutrophil respiratory burst was found.

Faris and co-workers [9] carried out a cross-sectional study recruiting fifty (21 men and 29 women) healthy volunteers for the investigation of circulating pro-inflammatory cytokines (IL-1 $\beta$ , IL-6, TNF- $\alpha$ ), immune cells (total leukocytes, monocytes, granulocytes, and lymphocytes). The pro-inflammatory cytokines IL-1 $\beta$ , IL-6, and TNF- $\alpha$  were significantly lower ( $p$ -value <0.05). Immune cells significantly decreased during Ramadan, however within the reference ranges. These results indicate that RIF attenuates inflammatory status of the body by suppressing pro-inflammatory cytokine expression and decreasing circulating levels of leukocytes.

Develioglu [10] and collaborators collected blood and saliva samples one week before and during the first week of Ramadan from 35 healthy male volunteers, aged 20-59 years (mean age 35.86 years). Total lymphocyte count and IgG and IgM concentrations were determined in serum, as well as salivary IgA. Serum IgG concentrations decreased significantly during Ramadan compared with before fasting, but were still within the normal range. Salivary IgA concentrations also decreased significantly, whereas serum IgM levels did not change. Lymphocyte numbers increased significantly, but there was no correlation between Ig levels and lymphocyte count.

Akrami Mohajeri [11] and collaborators studied CXCL1, CXCL10 and CXCL12 chemokines, using ELISA assay, in a sample of 58 healthy subjects, aged 20-40 years. The authors found decreased levels of pro-inflammatory CXC chemokines but unaltered levels of homeostatic ones. The scholars concluded that fasting is important in controlling of inflammation via chemokines.

Chennaoui and coauthors [13] recruited 40 healthy volunteers of normal weight, 20 females aged 20-38 years, 20 males aged 23-39 years compared with another 28 healthy age- and BMI-matched volunteers (14 males, 14 females) who did not fast. Serum IL-6, C-Reactive Protein (CRP), homocysteine was measured. IL-6, CRP and homocystein levels were significantly low during Ramadan in the fasting subjects of both genders when compared to basal values.

Lahdimawan and co-authors [14] studied the effect of Ramadan on the levels of Complement C3, inducible Nitric Oxide Synthase (iNOS), Superoxide Dismutase (SOD) levels in serum and Peripheral Blood Mononuclear Cells (PBMC) in 30 healthy male volunteers. The authors found that Ramadan has a beneficial effect on host defense against *Mycobacterium tuberculosis* and decreases the risk of tuberculosis infection in healthy subjects.

The same authors investigated the functions of macrophage activity in a sample of 27 male healthy volunteers aged 18-22 years (mean age 20.26  $\pm$  1.13 years). Macrophage IFN-gamma, TNF-alpha, iNOS increased, while SOD decreased. The authors concluded that Ramadan altered classically activated macrophage regulation and signaling and increased macrophage function, reducing macrophage oxidative stress.

A further study performed by the same authors [15] investigated the impact of Ramadan on endorphin and endocannabinoid and levels. 27 healthy volunteers male aged 18-22 years (mean age 20.26  $\pm$  1.13 years) who fasted during Ramadan participated in the study. Endorphin in the serum, PBMC and macrophage increased, as well as endocannabinoid in the serum, but endocannabinoid in the macrophage decreased. No change for endocannabinoid in the PBMCs. Ramadan has subtle effects on endocannabinoids and endorphins.

Zainullah and co-authors [16] studied the change of psychoneuroimmunological response among 13 individuals, measuring neutrophil, lymphocyte, monocyte, IgG and cortisol. On

the fifth day of the fasting, cortisol, IgG, and monocyte increased, while neutrophil count decreased. On the 16<sup>th</sup> day, cortisol, neutrophil, and monocyte count increased, while IgG level decreased. Towards the end of Ramadan, the level of these parameters returned in the previous range.

Ibrahim and co-workers [17] studied 14 healthy volunteers (9 men and 5 women aged 25-58 years), measuring Malondialdehyde (MDA), glutathione, glutathione peroxidase and catalase. Erythrocyte MDA decreased, while the reduction in lipid peroxidative damage in erythrocytes was slight.

Faris and collaborators [18] investigated the oxidative stress in 50 healthy subjects (23 men and 27 women), measuring the 15-F (2t)-Isoprostane (15FIP). 15FIP increased and correlated with the body weight and total body fat percent.

Sülü and co-workers [19] investigated malondialdehyde and glutathione levels in 45 healthy volunteers (22 females, 23 males, and mean age 28.7 years, range 21-51 years). Malondialdehyde levels increased in both genders; however the increase was statistically significant only in female subjects. Glutathione levels decreased in males, while increased in females. Ramadan could cause oxidative stress in particular subjects depending on some factors such as socio-economic conditions, nutritional habits, and gender.

In conclusion, Ramadan fasting has a modulatory effect on chemokine network, oxidative stress pathway, adaptive and innate immunity.

## **Immunity Changes in Pregnant Women**

Ozturk and collaborators [20] investigated the impact of Ramadan on the immunity system of pregnant women in a prospective controlled matched study of 42 fasting and 30 non-fasting pregnant women. Total Antioxidant Status (TAS), Total Oxidant Status (TOS) and the Oxidative Stress Index (OSI) were measured from maternal serum samples taken on a fasting day during Ramadan. No significant differences were observed between the groups studied in terms of TOS, OSI, maternal age, gestational age, parity, birth weight or weight gain during the pregnancy. The TAS level was evaluated as significantly higher (*p-value* =0.027).

In conclusion, Ramadan fasting has no impact on pregnancy.

## **Immunity Changes in Patients with Metabolic Disorders**

Unalacak and co-workers [21] recruited 10 obese males (7 suffering from a clinically diagnosed metabolic syndrome) and 10 males with a normal Body Mass Index (BMI). Serums White Blood Cells (WBC) count, IL-2, IL-8, TNF- $\alpha$  were significantly lower in both groups compared to pre-Ramadan values.

Shariatpanahi and co-authors [22] studied 65 male with metabolic syndrome, evaluating hs-CRP before and after month of Ramadan. Hs-CRP was decreased significantly, being related to waist circumference and BMI.

Radhakishun and co-workers [23] carried out a prospective cohort study in 25 obese adolescents, measuring hs-CRP levels. A statistically significant increase in hs-CRP concentration was found, recovering to baseline levels after Ramadan.

Al-Shafei [24] carried out a prospective controlled matched study recruiting 40 non diabetic subjects and 40 diabetic patients. Malondialdehyde (MDA) decreased. The scholar concluded that Ramadan fasting improves glycemic control and lipids profile and alleviates oxidative stress in diabetics.

El-Gendy and collaborators [25] studied the oxidative stress in 20 patients with diabetes mellitus. Serum Malondialdehyde (MDA) and Glutathione (GSH) were measured. MDA

decreased, while GSH increased. This study confirmed that Ramadan fasting significantly lowers oxidative stress in the body.

In conclusion, patients with controlled metabolic disorders can safely fast.

## Immunity Changes in Patients with Cardiac Diseases

Khafaji and co-authors [26] investigated immunity changes in a sample of 56 patients (80.4% were male, 67.9% were aged >50 years) of different stable cardiac illnesses were followed, collecting and measuring hs-CRP. 71.4% had no change in their symptoms during fasting while 28.6% felt better. No patient has deteriorated. 91.1% of the patients were compliant with medicine during Ramadan, 73.2% after. 89.3% were compliant with diet during Ramadan with no significant change in body weight in the follow-up period. No cardiac or noncardiac morbidity or mortality was reported. No change was observed in hs-CRP and its level correlated with total cholesterol and serum leptin. Ramadan fasting in stable cardiac patients has no effect on their clinical status, serum leptin, or hs-CRP.

Nematy and co-authors [27] carried out a prospective observational study in a group of 82 patients (38 males 44 females, aged 29-70 years, mean age  $54.0 \pm 10$  years) with at least one cardiovascular risk factor. Homocysteine, hs-CRP and complete blood count were measured. A significant improvement in 10 years coronary heart disease risk was found, as well as an increased WBC, RBC and platelet count. No other significant changes were observed. Homocysteine and hs-CRP increased during the exercise, suggesting that caloric restriction and exercise seem to ameliorate inflammatory markers of cardiovascular health.

Al-Shafei [28] studied the variation of Pulse Pressure (PP) and oxidative stress in 40 hypertensive subjects and in other 40 healthy individuals. Fasting reduced PP significantly by 17.2%, while Malondialdehyde (MDA) decreased and Glutathione (GSH) increased.

In conclusion, patients with controlled cardiovascular disorders can safely fast.

## Immunity Changes in Athletes

Chaouachi and collaborators [29] studied the impact of the fasting on immunological parameters in 15 elite male judo athletes maintaining their usual high training loads. Small but significant changes in inflammatory variables were found. Serum C-reactive protein increased from  $2.93 \pm 0.26$  mg/L to  $4.60 \pm 0.51$  mg/L, whereas homocysteine remained relatively unchanged. Immunoglobulin A increased from  $1.87 \pm 0.56$  g/L to  $2.49 \pm 0.75$  g/L and persisted high for 3 weeks. There were no changes in the leucocyte cell counts throughout the study. These results suggest that athletes who continue to train intensely during Ramadan are likely to experience a myriad of small fluctuations in immunoglobulins, antioxidants, and inflammatory responses.

Aksungar and collaborators [30] studied 8 middle-distance athletes ( $25.0 \pm 1.3$  years), performing a Maximal Aerobic Velocity (MAV) test 5 days before Ramadan and on days 7 and 21. Plasma levels of IL-6 were determined. IL-6 was increased ( $1.19 \pm 0.25$  vs.  $0.51 \pm 0.13$  pg/mL; *p-value* <0.05), but recovering to normal values after Ramadan. The authors found significant immunity changes that could affect the activity of elite athletes.

Abdelmalek and co-workers [31] studied 9 athletes performing the Wingate test. Plasma concentrations of IL-12 were measured using ELISA assay. The authors found that an acute intense exercise-induced IL-12 response is modified by daytime fasting and modifications in sleep schedule during Ramadan.

Hammouda and collaborators [32] measured the levels of hs-CRP and homocysteine during the Yo-Yo intermittent recovery test in 15 soccer players. Homocystein and hs-CRP increased during the exercise. During the end of Ramadan, the diurnal pattern of Hcy was inversed. The authors concluded that caloric restriction induced by RF seems to ameliorate

lipid and inflammatory markers of cardiovascular health during intermittent exercise performed in the evening.

The same authors [33] investigated the effects of Ramadan fasting and time-of-day on biochemical responses to an intermittent exercise, Yo-Yo test level 1, in 20 male soccer players (mean age  $17.52 \pm 0.2$  years) measuring Total Antioxidant Status (TAS). TAS was found to increase. Performance was affected by Ramadan fasting only in the evening in young soccer players.

Trabelsi and collaborators [34] investigated immune biomarkers in recreational body-builders, undergoing a hypertrophic training program for 3 times/week. They found that leucocytes, neutrophils, lymphocytes and monocytes remained unchanged.

Maughan and co-workers [35] studied immune markers in 78 Tunisian junior male soccer players aged 16-19 years who continued their usual schedule of daily training and weekly competition. They found that CRP decreased in football players, as well leucocyte count.

In conclusion, Ramadan can affect sports performances.

## Conclusions

From the collected evidences, we can conclude that:

Ramadan fasting do not result in severe immunological disturbances, being all transient changes;

- a. Maternal fasting during Ramadan during the second trimester does not have a significant effect on maternal oxidative stress, fetal development or fetal birth weight.
- b. Ramadan fasting can have beneficial effects on patients suffering from metabolic disorders;
- c. Ramadan fasting can have positive effects on patients with stable cardiac diseases, improves cardiovascular, lipids profile and oxidative stress;
- d. Ramadan can affect and impair the activity of athletes (as also summarized by Trabelsi and collaborators [36]).

However, the majority of the studies have been conducted among healthy volunteers and there is a dearth of data about patients suffering metabolic and cardiovascular diseases. No data are available for patients with autoimmune disorders. Further research in the field is urgently needed.

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: (Eds. Berbari AE, Mancina G) "Special Issues in Hypertension".
2. Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of patients with renal colic that present to an emergency department during the month of Ramadan.[Ramazan Ayinda Renal Kolikle Acil Servise Basvuran Hastaların Degerlendirilmesi]. The Journal of Academic Emergency Medicine 12: 24-26.
3. Budak A (2005) Fasting in Islam and the month of Ramadan (Islam in practice). The Light Inc Editor.
4. Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. Perit Dial Int 33: 86-91.
5. Bragazzi NL (2014) Ramadan fasting and Chronic Kidney Disease (CKD): a systematic review. Journal of research in medical science.
6. Latifynia A, Voigani M, Jafarieh H, Abofazeli T (2007) Neutrophil respiratory burst (innate immunity) during Ramadan. Journal of Biological Sciences 7: 997-1000.

7. Latifynia A, Vojgani M, Abofazeli T, Jafarieh H (2007) Circulating immune complex during Ramadan. *J Ayub Med Coll Abbottabad* 19: 15-18.
8. Latifynia A, Vojgani M, Gharagozlou MJ, Sharifian R (2008) Effect of Ramadan on neutrophil's respiratory burst (innate immunity) and circulating immune complex. *J Ayub Med Coll Abbottabad* 20: 128-131.
9. Faris MA, Kacimi S, Al-Kurd RA, Fararjeh MA, Bustanji YK, et al. (2012) Intermittent fasting during Ramadan attenuates proinflammatory cytokines and immune cells in healthy subjects. *Nutr Res* 32: 947-955.
10. Develioglu ON, Kucur M, Ipek HD, Celebi S, Can G, et al. (2013) Effects of Ramadan fasting on serum immunoglobulin G and M, and salivary immunoglobulin A concentrations. *J Int Med Res* 41: 463-472.
11. Akrami Mohajeri F, Ahmadi Z, Hassanshahi G, Akrami Mohajeri E, Ravari A, et al. (2013) Dose Ramadan Fasting Affects Inflammatory Responses: Evidences for Modulatory Roles of This Unique Nutritional Status via Chemokine Network. *Iran J Basic Med Sci* 16: 1217-1222.
12. Chennaoui M, Desgorces F, Drogou C, Boudjemaa B, Tomaszewski A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Appl Physiol Nutr Metab* 34: 587-594.
13. Lahdimawan A, Handono K, Indra MR, Prawiro SR (2014) Effect of Ramadan Fasting on the Ability of Serum, PBMC and Macrophages from Healthy Subjects to Kill M. Tuberculosis. *IOSR Journal of Pharmacy and Biological Sciences* 9: 24-29.
14. Lahdimawan A, Handono K, Indra MR, Prawiro SR (2013) Effect of Ramadan Fasting On Classically Activated, Oxidative Stress and Inflammation of Macrophage. *IOSR Journal Of Pharmacy* 3: 14-22.
15. Lahdimawan A, Handono K, Indra MR, Prawiro SR (2013) Effect of Ramadan Fasting on Endorphin and Endocannabinoid level in Serum, PBMC and Macrophage. *International Journal of Pharmaceutical Science Invention* 2: 46-54.
16. Zainullah A, Putra ST, Kabat K (2005) Psychoneuroimmunological Response Change in Ramadan Fasting Individuals A Case Study in Pesantren Hidayatullah Surabaya using Psychoneuroimmunological Approach. Abstract Disertation.
17. Ibrahim WH, Habib HM, Jarrar AH, Al Baz SA (2008) Effect of Ramadan fasting on markers of oxidative stress and serum biochemical markers of cellular damage in healthy subjects. *Ann Nutr Metab* 53: 175-181.
18. Faris MA, Hussein RN, Al-Kurd RA, Al-Fararjeh MA, Bustanji YK, et al. (2012) Impact of ramadan intermittent fasting on oxidative stress measured by urinary 15-f(2t)-isoprostane. *J Nutr Metab* 2012: 802924.
19. Ozturk E, Balat O, Ugur MG, Yazıcıoğlu C, Pence S, et al. (2011) Effect of Ramadan fasting on maternal oxidative stress during the second trimester: a preliminary study. *J Obstet Gynaecol Res* 37: 729-733.
20. Sülü B, Öztürk B, Güven A, Kiliç K (2010) The effect of long-term controlled fasting (The ramadan model) on body mass index, blood biochemistry and oxidative stress factors. *Turkiye Klinikleri Journal of Medical Sciences* 30: 855-863.
21. Unalacak M, Kara IH, Baltaci D, Erdem O, Bucaktepe PG (2011) Effects of Ramadan fasting on biochemical and hematological parameters and cytokines in healthy and obese individuals. *Metab Syndr Relat Disord* 9: 157-161.
22. Shariatpanahi MV, Shariatpanahi ZV, Shahbazi S, Moshtaqi M (2012) Effect of fasting with two meals on BMI and inflammatory markers of metabolic syndrome. *Pak J Biol Sci* 15: 255-258.
23. Radhakishun N, Blokhuis C, van Vliet M, von Rosenstiel I, Weijer O, et al. (2014) Intermittent fasting during Ramadan causes a transient increase in total, LDL, and HDL cholesterol and hs-CRP in ethnic obese adolescents. *Eur J Pediatr*.
24. Al-Shafei AI (2014) Ramadan fasting ameliorates oxidative stress and improves glycemic control and lipid profile in diabetic patients. *Eur J Nutr*.
25. El-Gendy OA, Rokaya M, El-Batae H, Tawfeek S (2012) Ramadan Fasting Improves Kidney Functions and Ameliorates Oxidative Stress in Diabetic Patients. *World Journal of Medical Sciences* 7: 38-48.
26. Khafaji HA, Bener A, Osman M, Al Merri A, Al Suwaidi J (2012) The impact of diurnal fasting during Ramadan on the lipid profile, hs-CRP, and serum leptin in stable cardiac patients. *Vasc Health Risk Manag* 8: 7-14.

27. Nematy M, Alinezhad-Namaghi M, Rashed MM, Mozhdehifard M, Sajjadi SS, et al. (2012) Effects of Ramadan fasting on cardiovascular risk factors: a prospective observational study. *Nutr J* 11: 69.
28. Al-Shafei AI (2014) Ramadan fasting ameliorates arterial pulse pressure and lipid profile, and alleviates oxidative stress in hypertensive patients. *Blood Press* 23: 160-167.
29. Chaouachi A, Coutts AJ, Wong del P, Roky R, Mbazaa A, et al. (2009) Haematological, inflammatory, and immunological responses in elite judo athletes maintaining high training loads during Ramadan. *Appl Physiol Nutr Metab* 34: 907-915.
30. Aksungar FB1, Topkaya AE, Akyildiz M (2007) Interleukin-6, C-reactive protein and biochemical parameters during prolonged intermittent fasting. *Ann Nutr Metab* 51: 88-95.
31. Abedelmalek S, Souissi N, Takayuki A, Hadouk S, Tabka Z (2011) Effect of Acute Maximal Exercise on Circulating Levels of Interleukin-12 during Ramadan Fasting. *Asian J Sports Med* 2: 154-160.
32. Hammouda O, Chtourou H, Aloui A, Chahed H, Kallel C, et al. (2013) Concomitant effects of Ramadan fasting and time-of-day on apolipoprotein AI, B, Lp-a and homocysteine responses during aerobic exercise in Tunisian soccer players. *PLoS One* 8: 79873.
33. Hammouda O, Chtourou H, Aloui A, Mejri MA, Chahed H, et al. (2014) Does Ramadan fasting affect the diurnal variations in metabolic responses and total antioxidant capacity during exercise in young soccer players? *J Sport Sciences for Health*.
34. Trabelsi K, Stannard SR, Maughan RJ, Jammoussi K, Zeghal K, et al. (2012) Effect of resistance training during Ramadan on body composition and markers of renal function, metabolism, inflammation and immunity in recreational bodybuilders. *Int J Sport Nutr Exerc Metab* 22: 267-275.
35. Maughan RJ, Leiper JB, Bartagi Z, Zrifi R, Zerguini Y, et al. (2008) Effect of Ramadan fasting on some biochemical and haematological parameters in Tunisian youth soccer players undertaking their usual training and competition schedule. *J Sports Sci* 26: 39-46.
36. Trabelsi K, Chaker A, Ghlisssi Z, Kallel C, Sahnoun Z, Zeghal KM, Hakim A (2012) Physical activity during Ramadan fasting: Effects on body composition, hematological and biochemical parameters. *IOSR Journal of Pharmacy* 2: 33-41.

## Chapter 3

# Ramadan and Health-related Applications for Mobiles and Smartphones: Ramadan 2.0 or the Digital Ramadan, as a New Emerging Trend

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINO GMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINO GMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though patients are exempted from observing this religious duty, they may be eager to take part into this religious ceremony, fully living all its implications. Here, we review the extant literature on the topic of e-health and, in particular, the new concept of Islamic e-health, introducing the important theme of the fasting in the digital era (Ramadan 2.0). Applications for mobiles and smart-phones provide a wide range of functions and services for Muslims: customers can read, listen and memorize the *Qu'ran*, and are offered the possibilities to bookmark the verses and the various *surat* (*Qu'ran* chapters). They can know exact prayer times together with the *Qibla* direction, can locate nearby mosques and also use a personalized Islamic events calendar. Applications can even mimic and reproduce the rhythmic clicking of the prayer beads as well as calculate the *zakat*. Actually, many applications specifically designed for Ramadan exist. Some help diabetic Muslims to better manage their fasting, others suggest nutritional tips or physical exercises in order to maintain the weight and have a healthy lifestyle during the fasting month. In conclusion, Islamic e-health is an emerging trend and represents an incredible opportunity that can be exploited for educating diabetic patients willing to fast during the Ramadan month, as well as treating patients suffering from other diseases or providing healthy subjects with nutritional recommendations and suggestions. However, health-care providers should be aware of this phenomenon, monitor the reliability of information provided by the applications and eventually correct misleading material, informing their patients. Further studies in the field are urgently needed, including randomized controlled trials to test whether applications are effective in assisting patients from remote during the Ramadan fasting.

**Keywords:** Digital Ramadan; Information and Communication Technologies (ICTs); Islam; Islamic e-health; Mobile and Smart-Phones Applications; Ramadan 2.0; Ramadan Fasting

# Ramadan Fasting in the Digital Era: New Challenges and Paradigms

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), has a great importance and meaning for all the Muslims in the world. Abstinence from eating, drinking and sexual intercourses characterize this period. Ramadan is indeed a period of intense prayers, social gatherings and special ceremonies. Usually, patients are exempted from observing these rules, even though they may ask their doctors whether they can fast without experiencing injurious effects [1].

Due to its importance and resonance, Ramadan is highly covered by the media [2]. In this chapter, we introduce a new concept, namely the “*Ramadan 2.0*” or the “*digital Ramadan*”, a concept similar to that of “*digital mosque*” or “*convergent mosque*” pioneered by as [3] and we review what the new media can do for Muslim customers, especially from the health perspective. As mosques are experiencing changes in design, new architectural challenges and paradigms given by a more and more expanded reality in which virtual and real/physical merge and integrate, the same is true for Ramadan. Intense moments such as prayers are shared on Facebook, YouTube and other social networks. Even though some Muslims, especially those who are strictly orthodox, consider this trend as *bida* (“innovation”), mobile applications provide Muslims with a wide range of functions, services and opportunities.

## Islamic e-health

The main objective of this book-chapter is to review the extant literature on the topic of Islamic e-health, showing how Information and Communication Technologies (ICTs) are having a deep and profound impact on Muslim spirituality and well-being and may be helpful in addressing patients’ issues and concerns and educating them.

According to Househ [4], Islamic e-health can be defined as: “the application and use of ICTs”, that is to say “the internet, electronic medical record systems, public health information systems, and mobile health technologies, to monitor and support Islamic spiritual health practices with the goal of improving Muslims’ spiritual, mental, and physical health status”.

Very common applications such as iPray, iQuran, myQuran, iSubha and Islamic Compass [5] help the Muslims to memorize the Quran, offering the possibilities to bookmark the verses and the various *surat* (*Qu’ran* chapters), know exact prayer times around the globe, giving the *Qibla* direction, locating nearby mosques and also showing an Islamic events calendar or even mimicking and reproducing the rhythmic clicking of the beads for improving focused attention during prayers, calculating the *zakat*, among the other functions and services (Figure 1).



Figure 1: some examples of Islamic e-health applications for adults (iSubha and iQuran).



Some applications have been specifically designed and implemented for children, such as My Kids Series and Kids Dua Series (Figure 2).



Figure 2: Some examples of Islamic e-health applications for children (My Kids Series and Kids Dua Series).

In the Middle East, metabolic diseases such as obesity, diabetes and cardiovascular disorders are increasing in term of epidemiological burden and societal impact [6-9]. Digital technologies which are becoming widespread can be a useful resource for managing these diseases. Some surveys have shown that the Middle East has a high penetration of mobile devices and smart-phones [10] and digital health applications have been well received in the Middle East. Digitalizing health records, they can enable healthcare providers to early identify and contain outbreaks such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), influenza and other infectious diseases [11].

Health-related digital technologies have been shown to be useful in improving immunization coverage, assisting and monitoring patients from remote.

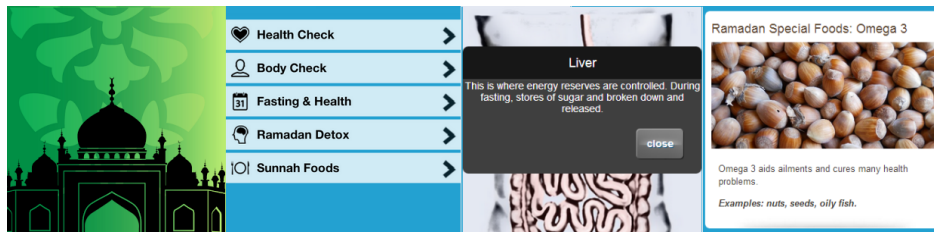
Moreover, applications such as Care of Muslim patients and Medicine of Prophet cover both traditional and modern aspects of the health-care (Figure 3).



Figure 3: Examples of applications of traditional Muslim medicine (Medicine of Prophet and Care of Muslim patients).

### Mobile Applications Specifically Designed for Ramadan

Muslims can also benefit from mobile and smart-phones applications specifically designed for Ramadan [12-16] (Figure 4).



**Figure 4:** Some examples of mobile and smart-phones applications specifically designed for Ramadan.

Applications such as Ramadan health (with suggestions and tips for maintaining a healthy lifestyle during the fasting month), Ramadan, Diabetes and me (that helps Muslim diabetics to better manage their fasting with a patient information booklet and the possibility of monitoring and tracking their blood sugar levels), mDiet (a sort of “dietician in the palm of your hand”, which provides personalized and healthy diet recipes), Ramadan Diet (which suggests meals for breaking the fast and exercises for keeping the weight as it was before the fast), WebTeb (particularly designed for pregnant women and patients suffering from chronic diseases willing to fast), AlTibbi (with educational quizzes), 3eesho (with a list of Frequently Asked Questions, FAQ), eTobb and Ramadan Recipes may be extremely useful for Muslims. Further research is needed in order to:

- a. Verify the reliability of the provided information by these applications;
- b. Health-care providers should be aware of this phenomenon, and correct eventually misleading information;
- c. The ideal situation would be when health-care workers are directly involved in the design of the applications;
- d. Randomized controlled trials should be performed to verify whether applications can play a role in better managing and assisting patients willing to fast during Ramadan.

## Conclusion

Islamic e-health is an emerging trend and represents an incredible opportunity that can be exploited for educating diabetic patients willing to fast during the Ramadan month, as well as providing healthy subjects with nutritional recommendations and suggestions. However, further studies in the field are urgently needed.

## References

1. Alkandari JR, Maughan RJ, Roky R, Aziz AR, Karli U (2012) The implications of Ramadan fasting for human health and well-being. *J Sports Sci* 1: 9-19.
2. <http://googleblog.blogspot.it/2012/07/ramadan-traditions-with-digital-twist.html>
3. AS Imadat (2006) The Digital Mosque. *Journal of Architectural Education* 60: 54–66.
4. Househ M (2013) Islamic E-health: definitions, applications and challenges. *Stud Health Technol Inform* 183: 281-285.
5. <http://www.telegraph.co.uk/technology/apple/7938633/iPray-iPhone-offers-Islamic-apps-for-Ramadan.html>
6. Zabetian A, Keli HM, Echouffo-Tcheugui JB, Narayan KM, Ali MK (2013) Diabetes in the Middle East and North Africa. *Diabetes Res Clin Pract* 101:106-122.
7. Badran M, Laher I (2012) Type II Diabetes Mellitus in Arabic-Speaking Countries. *Int J Endocrinol* 2012: 902873.
8. Badran M, Laher I (2011) Obesity in arabic-speaking countries. *J Obes* 2011: 686430.

9. Donnelly TT, Al Suwaidi JM, Alqahtani A, Assad N, Qader NA, et al. (2013) Study exploring depression and cardiovascular diseases amongst Arabic speaking patients living in the State of Qatar: Rationale and methodology. *Glob Cardiol Sci Pract* 2012: 56-66.
10. <http://www.nuviun.com/Digital-Health-Technology-to-Help-the-Middle-East-Fight-Lifestyle-Diseases>
11. Zumla A, Mwaba P, Bates M, Al-Tawfiq JA, Maeurer M, et al. (2014) The Hajj pilgrimage and surveillance for Middle East Respiratory syndrome coronavirus in pilgrims from African countries. *Trop Med Int Health* 19: 838-840.
12. <http://www.digitalqatar.qa/en/2011/07/24/mobile-apps-for-ramadan/>
13. <http://www.scoop.co.nz/stories/BU1307/S00193/islam-on-demand-iphone-app-to-launch-on-ramadan.htm>
14. <http://www.urbanhealth.com.my/health/app-to-fast-and-track-glucose-levels/>
15. <http://www.wamda.com/2013/07/5-arabic-health-platforms-that-help-users-stay-healthy-during-ramadan>
16. <http://myhalakitchen.com/need-healthy-delicious-recipes-this-ramadan-weve-got-an-app-for-that/>

## Chapter 4

# Ramadan Fasting and Skin Disorders

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINOEMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINOEMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though patients are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers. However, there are no guidelines or standardized protocols that can help physicians to properly address the issue of patients with skin disorders fasting in Ramadan and correctly advising them. Moreover, in a more interconnected and globalized society, in which more and more Muslim patients live in the Western countries, this topic is of high interest also for the general practitioner. For this purpose, we carried out an overview. Our main findings are that: 1) there is a strong need for evidence-based suggestions and guidelines. Literature on the impact of Ramadan fasting on skin diseases is scarce, and of poor quality, as well as information available from the Internet; 2) patients willing to fast should be advised about the importance of taking the proper treatment and that administration of trans-dermal/topical drugs is licit during the Ramadan fasting. Non-compliance and non-adherence can have important, clinical and economic implications for the patient management.

**Keywords:** Compliance and Adherence to Treatment; Ramadan Fasting; Skin Disorders

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*. Ramadan fasting (*as-sawm*) is considered one of the five Islamic pillars of the creed (*arkan al-Islam*), together with the faith declaration or profession (*as-shahada*), the five daily ritual prayers (*as-salah*), the pilgrimage to Mecca (*hajj*), and charity (*zakat*).

Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 "Al-Baqarah", ayyat 183*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. Pre-dawn meal is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable, since the Islamic calendar is a lunar

one and therefore the Islamic year contains 354 days (instead of 365, as in the Gregorian or solar calendar). For this reason, the Ramadan month occurs 11 days earlier every year, and may fall in any period of the year. Therefore, mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1,2] or even 22 hours, in the extreme latitudes regions [1]. Ramadan can last 29 or 30 days.

Pre-puberal and puberal children, menstruating, pregnant and breast-feeding women, sick people, debilitated older subjects; travelers are exempted from this religious duty (*Surat 2 "Al-Baqarah", ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers [3].

The effects of Ramadan fasting on kidney physiology is not a mere academic topic or of limit interest for only the Arabic countries. In a globalized society, the physicians have to face with issues like the management of CKDs in Muslim patients that want to fast during Ramadan, since more Muslims live in the Western societies [3].

However, information is sparse and no guidelines or standardized protocols exist on the impact of Ramadan fasting on patients with skin disorders. For this purpose, we have carried out an overview that could be helpful for general practitioners.

## Discussion

The belief that skin problems, such as psoriasis and acne, can disappear with the help of fasting [4], is anecdotal.

Bahammam and co-workers [5] investigated the impact of Ramadan fasting on circadian rhythm and skin temperature in a sample of 6 healthy Muslim young adults using portable armband physiological and activity sensor devices. During Ramadan, there were a delay in the acrophase of skin temperature, indicating a shift in the circadian pattern of body temperature, and a delay in the peak of energy expenditure.

Masood and collaborators [6] carried out a retrospective observational study to assess the beliefs and practices of people with diabetes about skin prick for blood glucose testing during Ramadan fasting in a sample of 806 people with diabetes (76 with type 1 and 784 with type 2) aged  $51.54 \pm 13.83$  years. About 44% of the study population was not educated. Participants with diabetes who did not performed blood glucose monitoring (33.6%) believed that skin prick would result into breaking the fast and therefore 39.8% of participants who were taking insulin never checked their blood glucose levels while fasting.

Patel and co-authors [7] carried out a prospective survey in a dermatology center in a tertiary hospital in the UK. Patients were asked if they would use topical treatment. The scholars found that more than one-third of the people interviewed would not use topical treatment while fasting, considering this a breaking of their fast. These patients wrongly believed that using steroid-based topical products, creams, emollients, and light therapy were not licit during the fast. Determinant of these wrong beliefs resulted to be only birthplace, while gender, age, educational level and socioeconomic status failed to predict patients' behaviors and practices. In particular, Muslim patients born outside the UK were significantly less likely to use topical treatment during Ramadan month.

Al-Qattan [8] performed a prospective study, assessing 10 cases of burns in epileptics in Saudi Arabia occurring in adult patients (8 females, 2 males). 4 burns happened during Ramadan fasting because of lack of compliance and adherence to anti-epileptic medication.

## Conclusions

There is a strong need for evidence-based suggestions and guidelines. Literature on the impact of Ramadan fasting on skin diseases is scarce, and of poor quality, as well as information available from the Internet.

Patients willing to fast should be advised about the importance of taking the proper treatment and that administration of trans-dermal/topical drugs is licit during the Ramadan fasting. Non-compliance and non-adherence can have important, clinical and economic implications for the patient management.

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancia G (Eds.). "Special Issues in Hypertension."
2. Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of Patients with Renal Colic that Present to an Emergency Department During the Month of Ramadan. [Ramazan Ayinda Renal Kolikle Acil Servise Basvuran Hastalarin Degerlendirilmesi] The Journal of Academic Emergency Medicine 12: 24-26.
3. Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. Perit Dial Int 33: 86-91.
4. <http://annisaamag.wordpress.com/2013/07/16/fasting-in-the-month-of-ramadhan-from-a-medical-point-of-view/>
5. Masood SN, Sheikh MA, Masood Y, Hakeem R, Shera AS (2014) Beliefs of people with diabetes about skin prick during Ramadan fasting. Diabetes Care. 37: 68-69.
6. Patel T, Magdum A, Ghura V (2012) Does fasting during Ramadan affect the use of topical dermatological treatment by Muslim patients in the UK? Clin Exp Dermatol. 37: 718-721.
7. BaHammam A, Alrajeh M, Albabtain M, Bahammam S, Sharif M (2010) Circadian pattern of sleep, energy expenditure, and body temperature of young healthy men during the intermittent fasting of Ramadan. Appetite 54: 426-429.
8. Al-Qattan MM (2000) Burns in epileptics in Saudi Arabia. Burns 26: 561-563.

## Chapter 5

# Ramadan Fasting and Cardiovascular Disease

**Amar M Salam<sup>1\*</sup>, Imtiaz Salim<sup>2</sup> and Jassim Al Suwaidi<sup>3</sup>**

<sup>1</sup>Hamad Medical Corporation, Doha, Qatar

<sup>2</sup>Department of Cardiology, Al-Khor Hospital, Hamad Medical Corporation, Doha, Qatar

<sup>3</sup>Department of Cardiology, The Heart Hospital, Hamad Medical Corporation, Doha, Qatar

**\*Corresponding author:** Amar M Salam, MBBS, FRCP (London), FESC, FACC, Assistant Professor of Clinical Medicine, Weill Cornell Medical College-Qatar, Consultant cardiologist, Hamad Medical Corporation, Doha, Qatar, Tel: (+974) 447 45408; Fax: (+974) 447 45616; E-mail: [amaramin@yahoo.com](mailto:amaramin@yahoo.com)

## Introduction

Fasting is an integral part of many religions. The pattern, duration and limitations of fasting differ among the different religion and sometime differ greatly among the subjects following the same religion. The model of Ramadan fasting is probably the most extensively researched religious fasting [1,2]. In this chapter, the impact of Ramadan fasting on cardiovascular health has been discussed. Additionally, two models of dietary restriction namely Calorie Restricted (CR) diet and Alternate Day Fasting (ADF) regimen has also been briefly explored and compared with the model of Ramadan fasting in an attempt to understand the mechanism underlying the cardiovascular effects seen in subjects undergoing fasting during the month of Ramadan.

## Dietary Restriction and Health

Decrease in daily caloric intake, typically by around 40%, also known as CR diet has been shown to prolong lifespan by as much as 50% in wide spectrum of animals [3-7]. It improves cardiovascular risk profile by decreasing heart rate, blood pressure, total cholesterol, triglyceride levels, Low Density Lipoprotein (LDL) cholesterol and by increasing the level of High Density Lipoprotein (HDL) cholesterol [8-11]. It is also associated with increase in insulin sensitivity and reduction in fasting glucose and insulin leading to an overall improvement in glucose regulation [12]. It has also been shown to prevent the occurrence and progression of wide spectrum of chronic illness like hypertension [11,12], autoimmune disease [7,13], kidney disease [14], neurodegenerative disease [15] and cancer [7]. Multiple metabolic pathways have been implicated as the cause of long life and disease prevention effect of CR diet and these pathways are being explored further to develop agents which mimic the beneficial effect of CR diet while avoiding the burden of extreme prolonged dietary restriction [16-21].

The animal model of CR diet is not feasible in humans because of ethical and practical considerations. For instance, in the rodent model of CR diet, the rodents were assigned for CR diet right after the weaning period and the intervention continued for life [3]. The limited human experience with CR diet suggests improvement in cardiovascular health by reduction in blood pressure, heart rate, total cholesterol and triglyceride levels as well as carotid intima media thickness [22-25]. The age related decline of cardiac diastolic dysfunction was also attenuated by a CR diet [26].

The ADF regimen comprise of alternate days of fasting and feasting. The subjects undergo fasting for 24 hours, during which only water intake is allowed. The period of fasting is followed by a 24 hour period of unrestricted dietary intake [27]. The sequence of fasting and feasting continues for pre specified duration. Animal studies have shown improvement in life span, reduction in cardiovascular disease, kidney disease, cancer and diabetes with ADF regimen, almost similar to that seen in animals on CR diet [27–31]. Similar reduction of heart rate and blood pressure among rodents on ADF regimen as well as rodents on 40% CR diet has been reported [32,33]. Experimental myocardial infarction induced by ligation of left coronary artery resulted in 50% smaller infarct size, lesser left ventricular remodeling, lesser infarct expansion and better left ventricular function among rodents on ADF regime as compared to normally fed controls [34]. In a later experimental study, similar cardio protective effect among experimental model of induced myocardial infarction was not seen in rodents on CR diet [8].

Human experience with ADF regimen is limited by few trials with small number of participants and short duration but overall, these studies suggest an improvement in glucose regulation and a trend towards improvement in cardiovascular risk profile [35–38]. The ADF regimen appears to offer the benefit of CR diet without the extreme and prolonged dietary restrictions characteristic of a CR diet. Contrary to CR diet, weight loss is not a consistent feature of ADF regimen [39]. The salient features of CR diet, ADF regimen and Ramadan fasting is mentioned in Table 1.

	<b>Calorie restriction</b>	<b>Alternate day fasting</b>	<b>Ramadan fasting</b>
<b>Dietary intervention</b>	Restriction of daily total caloric intake (20% to 40% reduction).	A day of fasting (drinking water allowed) followed by a day of unrestricted food, consumption	Fasting from dawn to dusk (absolute restriction of food, water and smoking) followed by unrestricted nocturnal feeding
<b>Animal experiment</b>	In yeast, rotifers, spiders, worms, flies, fish, mice, rats and primates [3–15].	In rats	None
<b>Insight from animal studies</b>	Upto 50% increase in life span among calorie restricted group. Prevents age related deterioration in left ventricular diastolic dysfunction. Improves cardiovascular disease risk factors and glucose regulatory functions in rodents and primates. Had protective effect on carcinogenesis. A consistent decrease in weight was noted [3–15].	Life span increased, cardiovascular disease risk profile improved, glucose regulatory functions improved. Size of induced myocardial infarction was 50% less, apoptotic myocytes were 75% less, infarct expansion was less, remodeling was less and deterioration in left ventricular ejection fraction was lesser. Had protective effect on carcinogenesis. Weight of the animal remained unchanged, increased or decreased [27–34].	None
<b>Human studies</b>	Limited, not sufficient to explore longevity. Available data suggest improvement in cardiovascular risk profile, glucose regulatory functions and reduce oxidative stress. Weight reduction was seen in all participants [22–26].	Limited to three short term studies (2-3 weeks) [35–37]. No change in fasting blood glucose. Insulin sensitivity increased in males. HDL increased in females while triacylglycerol decreased in males. There was no change in B.P. Weight of participants decreased in two studies while it remained unchanged in one.	No increase in incidence of acute cardiac illness was noted during Ramadan fasting. Patients with stable cardiac illness did not face any worsening of illness during Ramadan fasting. Most of the studies show that the lipid profile improved during Ramadan fasting, notably reduction in total and LDL cholesterol and increment in HDL cholesterol. Patients with diabetes mellitus fail to show improvement in lipid parameters during Ramadan fasting. The body weight/BMI of the participants remained largely unchanged or decreased while it increased in some [40–74].

**Table 1:** Models of dietary restriction.



BMI: Body Mass Index; B.P: Blood Pressure; HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein

The month of Ramadan is the ninth month of the Islamic lunar calendar and is the month of fasting. All adult Muslims, without any significant illness have to fast (absolute restriction of food, drinks, smoking and sexual activity) from dawn to dusk during the month. The Ramadan fasting model has not been replicated in animals. The huge and diverse pool of global Muslim population who undertake fasting during the month of Ramadan using the same religious principle provide an opportunity to evaluate its effect on health, although it has not been studied widely.

## Ramadan Fasting and Acute Cardiac Illness

The incidence of acute coronary syndrome, Atrial Fibrillation (AF), acute decompensated heart failure as well as stroke is similar during the month of Ramadan as compared to the other non fasting months [40–47]. Among patients who develop acute coronary syndrome during Ramadan fasting, the time of symptom onset differs and coincides with the time of breaking the fast [48]. Patients with pre existing cardiac illness are able to fast during Ramadan without any difficulty [40,49–51]. Some studies have reported decrease in incidence of acute coronary syndrome and heart failure during Ramadan fasting [40,41,44]. A case control study has reported that the incidence of acute coronary syndrome decreases by 72% among Muslims who fasted regularly during Ramadan as compared to Muslims who did not fast [52].

Overall, the incidence of Cerebrovascular Accident (CVA) is similar during the month of Ramadan as compared to the other non fasting days however a reduction in the incidence of hemorrhagic CVA is noted among hypertensive patients while an increase in incidence of ischemic CVA is noted among diabetic patients [40,45,47].

## Ramadan Fasting and Cardiovascular Disease Risk Factors

An overall improvement in cardiovascular risk profile is noted during Ramadan fasting [40,53,54]. Majority of the studies have reported increment in HDL level [55–67], no change [60,63,64,68–71] or decline in total cholesterol [55–57,59,61,62,66] and LDL levels [55–57,58,61,62] and no change in triglyceride level.

Few studies have reported decline in HDL cholesterol [68,71,73] and increment in LDL cholesterol [51,68,72]. The notable features of these studies were that either the subjects' consumption of dietary fat during Ramadan was excessive (more than twice) [72] or there were features of starvation [68] or the timing of sample collection for lipid estimation was inappropriate [51]. The improvement in lipid parameters was not seen among diabetic subjects who underwent fasting during Ramadan while on the contrary; there was a trend towards deterioration [70,73,74].

In majority of subjects, the body weight/Body Mass Index (BMI) remains unchanged or decreases during Ramadan fasting while it increases in some [40]. The mean systolic and diastolic blood pressure either remains unchanged or decreases during Ramadan fasting [40].

## Conclusion and Future Directions

Fasting during the month of Ramadan is safe for healthy individuals as well as patients with cardiovascular illness. Provided that extremes of dietary intake is avoided, preventing overcompensation for the period of fast on one hand and preventing starvation on the other, Ramadan fasting is associated with an overall improvement in cardiovascular risk profile irrespective of weight change. Patients with diabetes mellitus do not reflect this improvement [70,73,74].

The model of Ramadan fasting appears similar to the ADF regimen discussed earlier. While the ADF regimen allows intake of water during the fast and the timing of the fast and feast is artificial, based on 24 hours cycle, water intake is prohibited during the fasting hours in Ramadan and the fast and feast cycle is based on the natural phenomenon of day and night. However, both ADF regimen and Ramadan fasting have demonstrated improvement in cardiovascular risk profile which is largely independent of weight loss suggesting the possibility of a common underlying mechanism which is not yet clearly understood.

Preliminary studies have demonstrated similar outcome between subjects on CR diet and ADF regimen. Compared to CR diet, ADF regimen is seen as a practically feasible model but the 24 hours fasting period is not well tolerated by most of the subjects and modified models of ADF regimen are being evaluated which allow limited dietary intake during the fasting period [38]. The Ramadan model of fasting is generally well tolerated and the availability of huge global pool of subjects who fast during the month of Ramadan provides opportunity to explore its influence on chronic disease and life span and compare with the CR diet and ADF regimen models.

## References

1. Sabaté J (2004) Religion, diet and research. *Br J Nutr* 92: 199-201.
2. Trepanowski JF, Bloomer RJ (2010) The impact of religious fasting on human health. *Nutr J* 9: 57.
3. McCay CM, Crowell MF, Maynard LA (1989) The effect of retarded growth upon the length of life span and upon the ultimate body size 1935. *Nutrition* 5: 155-171.
4. Min KJ, Flatt T, Kulaots I, Tatar M (2007) Counting calories in *Drosophila* diet restriction. *Exp Gerontol* 42: 247-251.
5. Comfort A (1963) Effect Of Delayed And Resumed Growth On The Longevity Of A Fish (*Lebistes Reticulatus*, Peters) In Captivity. *Gerontologia* 49: 150-155.
6. Lawler DF, Larson BT, Ballam JM, Smith GK, Biery DN, et al. (2008) Diet restriction and ageing in the dog: major observations over two decades. *Br J Nutr* 99: 793-805.
7. Weindruch R, Walford RL, Fligiel S, Guthrie D (1986) The retardation of aging in mice by dietary restriction: longevity, cancer, immunity and lifetime energy intake. *J Nutr* 116: 641-654.
8. Ahmet I, Tae HJ, de Cabo R, Lakatta EG, Talan MI (2011) Effects of calorie restriction on cardioprotection and cardiovascular health. *J Mol Cell Cardiol* 51: 263-271.
9. Minamiyama Y, Bito Y, Takemura S, Takahashi Y, Kodai S, et al. (2007) Calorie restriction improves cardiovascular risk factors via reduction of mitochondrial reactive oxygen species in type II diabetic rats. *J Pharmacol Exp Ther* 320: 535-543.
10. Verdery RB, Ingram DK, Roth GS, Lane MA (1997) Caloric restriction increases HDL2 levels in rhesus monkeys (*Macaca mulatta*). *Am J Physiol* 273: 714-719.
11. Lane MA, Ingram DK, Roth GS (1999) Calorie restriction in nonhuman primates: effects on diabetes and cardiovascular disease risk. *Toxicol Sci* 52: 41-48.
12. Lane MA, Ball SS, Ingram DK, Cutler RG, Engel J, et al. (1995) Diet restriction in rhesus monkeys lowers fasting and glucose-stimulated glucoregulatory end points. *Am J Physiol* 268: 941-948.
13. Nandy K (1982) Effects of controlled dietary restriction on brain-reactive antibodies in sera of aging mice. *Mech Ageing Dev* 18: 97-102.
14. Wiggins JE, Goyal M, Sanden SK, Wharram BL, Shedden KA, et al. (2005) Podocyte hypertrophy, "adaptation," and "decompensation" associated with glomerular enlargement and glomerulosclerosis in the aging rat: prevention by calorie restriction. *J Am Soc Nephrol* 16: 2953-2966.
15. Pitsikas N, Carli M, Fidecka S, Algeri S (1990) Effect of life-long hypocaloric diet on age-related changes in motor and cognitive behavior in a rat population. *Neurobiol Aging* 11: 417-423.
16. Vaquero A, Reinberg D (2009) Calorie restriction and the exercise of chromatin. *Genes Dev* 23: 1849-1869.

17. Chen T, Shen L, Yu J, Wan H, Guo A, et al. (2011) Rapamycin and other longevity-promoting compounds enhance the generation of mouse induced pluripotent stem cells. *Aging Cell* 10: 908-911.
18. Agarwal B, Baur JA (2011) Resveratrol and life extension. *Ann N Y Acad Sci* 1215: 138-143.
19. Smoliga JM, Baur JA, Hausenblas HA (2011) Resveratrol and health--a comprehensive review of human clinical trials. *Mol Nutr Food Res* 55: 1129-1141.
20. Kyrilenko S, Baniahmad A (2010) Sirtuin family: a link to metabolic signaling and senescence. *Curr Med Chem* 17: 2921-2932.
21. Cantó C, Auwerx J (2009) Caloric restriction, SIRT1 and longevity. *Trends Endocrinol Metab* 20: 325-331.
22. Holloszy JO, Fontana L (2007) Caloric restriction in humans. *Exp Gerontol* 42: 709-712.
23. Stein PK, Soare A, Meyer TE, Cangemi R, Holloszy JO, et al. (2012) Caloric restriction may reverse age-related autonomic decline in humans. *Aging Cell* 11: 644-650.
24. Fontana L, Meyer TE, Klein S, Holloszy JO (2004) Long-term calorie restriction is highly effective in reducing the risk for atherosclerosis in humans. *Proc Natl Acad Sci U S A* 101: 6659-6663.
25. Fontana L, Villareal DT, Weiss EP, Racette SB, Steger-May K, et al (2007) Washington University School of Medicine CALERIE Group. Calorie restriction or exercise: effects on coronary heart disease risk factors. A randomized, controlled trial. *Am J Physiol Endocrinol Metab* 293:197-202.
26. Meyer TE, Kovács SJ, Ehsani AA, Klein S, Holloszy JO, et al. (2006) Long-term caloric restriction ameliorates the decline in diastolic function in humans. *J Am Coll Cardiol* 47: 398-402.
27. Mattson MP, Wan R (2005) Beneficial effects of intermittent fasting and caloric restriction on the cardiovascular and cerebrovascular systems. *J Nutr Biochem* 16: 129-137.
28. Varady KA, Bhutani S, Church EC, Klempel MC (2009) Short-term modified alternate-day fasting: a novel dietary strategy for weight loss and cardioprotection in obese adults. *Am J Clin Nutr* 90: 1138-1143.
29. Rocha NS, Barbisan LF, de Oliveira ML, de Camargo JL (2002) Effects of fasting and intermittent fasting on rat hepatocarcinogenesis induced by diethylnitrosamine. *Teratog Carcinog Mutagen* 22: 129-138.
30. Pedersen CR, Hagemann I, Bock T, Buschard K (1999) Intermittent feeding and fasting reduces diabetes incidence in BB rats. *Autoimmunity* 30: 243-250.
31. Goodrick CL, Ingram DK, Reynolds MA, Freeman JR, Cider N (1990) Effects of intermittent feeding upon body weight and lifespan in inbred mice: interaction of genotype and age. *Mech Ageing Dev* 55: 69-87.
32. Mager DE, Wan R, Brown M, Cheng A, Wareski P, et al. (2006) Caloric restriction and intermittent fasting alter spectral measures of heart rate and blood pressure variability in rats. *FASEB J* 20: 631-637.
33. Wan R, Camandola S, Mattson MP (2003) Intermittent fasting and dietary supplementation with 2-deoxy-D-glucose improve functional and metabolic cardiovascular risk factors in rats. *FASEB J* 17: 1133-1134.
34. Ahmet I, Wan R, Mattson MP, Lakatta EG, Talan M (2005) Cardioprotection by intermittent fasting in rats. *Circulation* 112: 3115-3121.
35. Heilbronn LK, Civitarese AE, Bogacka I, Smith SR, Hulver M, et al. (2005) Glucose tolerance and skeletal muscle gene expression in response to alternate day fasting. *Obes Res* 13: 574-581.
36. Heilbronn LK, Smith SR, Martin CK, Anton SD, Ravussin E (2005) Alternate-day fasting in nonobese subjects: effects on body weight, body composition, and energy metabolism. *Am J Clin Nutr* 81: 69-73.
37. Halberg N, Henriksen M, Söderhamn N, Stallknecht B, Ploug T, et al. (2005) Effect of intermittent fasting and refeeding on insulin action in healthy men. *J Appl Physiol* (1985) 99: 2128-2136.
38. Eshghinia S, Mohammadzadeh F (2013) The effects of modified alternate-day fasting diet on weight loss and CAD risk factors in overweight and obese women. *J Diabetes Metab Disord* 12: 4.
39. Varady KA, Hellerstein MK (2007) Alternate-day fasting and chronic disease prevention: a review of human and animal trials. *Am J Clin Nutr* 86: 7-13.
40. Salim I, Al Suwaidi J, Ghadban W, Alkilani H, Salam AM (2013) Impact of religious Ramadan fasting on cardiovascular disease: a systematic review of the literature. *Curr Med Res Opin* 29: 343-354.

41. Al Suwaidi J, Bener A, Hajar HA, Numan MT (2004) Does hospitalization for congestive heart failure occur more frequently in Ramadan: a population-based study (1991-2001). *Int J Cardiol* 96: 217-221.
42. Al Suwaidi J, Bener A, Suliman A, Hajar R, Salam AM, et al. (2004) A population based study of Ramadan fasting and acute coronary syndromes. *Heart* 90: 695-696.
43. Salam AM, Albinali HA, Salim I, Singh R, Asaad N, et al. (2013) Impact of religious fasting on the burden of atrial fibrillation: A population-based study. *Int J Cardiol*.
44. Temizhan A, Dönderici O, Ouz D, Demirbas B (1999) Is there any effect of Ramadan fasting on acute coronary heart disease events? *Int J Cardiol* 70: 149-153.
45. Bener A, Hamad A, Fares A, Al-Sayed HM, Al-Suwaidi J (2006) Is there any effect of Ramadan fasting on stroke incidence? *Singapore Med J* 47: 404-408.
46. Akhan G, Kutluhan S, Koyuncuoglu HR (2000) Is there any change of stroke incidence during Ramadan? *Acta Neurol Scand* 101: 259-261.
47. Çomoglu S, Temizhan A, Pesinci E, Tandogan I, Özbakir S (2003). Effects of Ramadan Fasting on Stroke. *Turk J Med Sci* 33: 237-241.
48. Al Suwaidi J, Bener A, Gehani AA, Behair S, Al Mohanadi D, et al. (2006) Does the circadian pattern for acute cardiac events presentation vary with fasting? *J Postgrad Med* 52: 30-33.
49. Chamsi-Pasha H, Ahmed WH (2004) The effect of fasting in Ramadan on patients with heart disease. *Saudi Med J* 25: 47-51.
50. Al Suwaidi J, Zubaid M, Al-Mahmeed WA, Al-Rashdan I, Amin H, et al. (2005) Impact of fasting in Ramadan in patients with cardiac disease. *Saudi Med J* 26: 1579-1583.
51. Khafaji HA, Bener A, Osman M, Al Merri A, Al Suwaidi J (2012) The impact of diurnal fasting during Ramadan on the lipid profile, hs-CRP, and serum leptin in stable cardiac patients. *Vasc Health Risk Manag* 8: 7-14.
52. Burazeri G, Goda A, Kark JD (2008) Religious observance and acute coronary syndrome in predominantly Muslim Albania: a population-based case-control study in Tirana. *Ann Epidemiol* 18: 937-945.
53. Kul S, SavaÅÿ E, OztÅ¼rk ZA, KaradaÅÿ G (2013) Does Ramadan Fasting Alter Body Weight and Blood Lipids and Fasting Blood Glucose in a Healthy Population? A Meta-analysis. *J Relig Health*.
54. Shehab A, Abdulle A, El Issa A, Al Suwaidi J, Nagelkerke N (2012) Favorable changes in lipid profile: the effects of fasting after Ramadan. *PLoS One* 7: 47615.
55. Nematy M, Alinezhad-Namaghi M, Rashed MM, Mozhdehifard M, Sajjadi SS, et al. (2012) Effects of Ramadan fasting on cardiovascular risk factors: a prospective observational study. *Nutr J* 11: 69.
56. Ibrahim O, Kamaruddin N, Wahab N, Rahman M.M (2011). Ramadan Fasting And Cardiac Biomarkers In Patients With Multiple Cardiovascular Disease Risk Factors. *The Internet Journal of Cardiovascular Research*. DOI: 10.5580/2717.
57. Nematy M, Alinezhad-Namaghi M, Rashed MM, Mozhdehifard M, Sajjadi SS, et al. (2012) Effects of Ramadan fasting on cardiovascular risk factors: a prospective observational study. *Nutr J* 11: 69.
58. Lamri-Senhadj MY, El Kebir B, Belleville J, Bouchenak M (2009) Assessment of dietary consumption and time-course of changes in serum lipids and lipoproteins before, during and after Ramadan in young Algerian adults. *Singapore Med J* 50: 288-294.
59. Mansi K, Amneh M (2007) Impact of Ramadan fasting on metabolism and on serum levels of some hormones among healthy Jordanian students. *J.Med.Sci* 7: 755-761.
60. Maislos M, Khamaysi N, Assali A, Abou-Rabiah Y, Zvili I, et al. (1993) Marked increase in plasma high-density-lipoprotein cholesterol after prolonged fasting during Ramadan. *Am J Clin Nutr* 57: 640-642.
61. Saleh SA, Elsharouni SA, Cherian B and Mourou M (2005) Effects of Ramadan fasting on Waist Circumference, Blood Pressure, Lipid Profile, and Blood Sugar on a Sample of Healthy Kuwaiti Men and Women. *Mal J Nutr* 11: 143-150.
62. Adlouni A, Ghalim N, Benslimane A, Lecerf JM, Saile R (1997) Fasting during Ramadan induces a marked increase in high-density lipoprotein cholesterol and decrease in low-density lipoprotein cholesterol. *Ann Nutr Metab* 41: 242-249.

63. Aksungar FB, Topkaya AE, Akyildiz M (2007) Interleukin-6, C-reactive protein and biochemical parameters during prolonged intermittent fasting. *Ann Nutr Metab* 51: 88-95.
64. Rahman M, Rashid M, Basher S, Sultana S, Nomani MZ (2004) Improved serum HDL cholesterol profile among Bangladeshi male students during Ramadan fasting. *East Mediterr Health J* 10: 131-137.
65. Aksungar FB, Eren A, Ure S, Teskin O, Ates G (2005) Effects of intermittent fasting on serum lipid levels, coagulation status and plasma homocysteine levels. *Ann Nutr Metab* 49: 77-82.
66. Afrasiabi A, Hassanzadeh S, Sattarivand R, Nouri M, Mahbood S (2003) Effects of low fat and low calorie diet on plasma lipid levels in the fasting month of Ramadan. *Saudi Med J* 24: 184-188.
67. Shariatpanahi ZV, Shariatpanahi MV, Shahbazi S, Hossaini A, Abadi A (2008) Effect of Ramadan fasting on some indices of insulin resistance and components of the metabolic syndrome in healthy male adults. *Br J Nutr* 100: 147-151.
68. Ziaee V, Razaei M, Ahmadinejad Z, Shaikh H, Yousefi R, et al. (2006) The changes of metabolic profile and weight during Ramadan fasting. *Singapore Med J* 47: 409-414.
69. Sadiya A, Ahmed S, Siddieg HH, Babas IJ, Carlsson M (2011) Effect of Ramadan fasting on metabolic markers, body composition, and dietary intake in Emiratis of Ajman (UAE) with metabolic syndrome. *Diabetes Metab Syndr Obes* 4: 409-416.
70. Khatib FA, Shafagoj YA (2004) Metabolic alterations as a result of Ramadan fasting in non-insulin-dependent diabetes mellitus patients in relation to food intake. *Saudi Med J* 25: 1858-1863.
71. Akturk I.F, Biyik I, Kocas C, Yalcin A.A, Erturk M, et al. (2012) PP-106 Effects of Ramadan fasting on lipid profile, brain natriuretic peptide, renal functions and electrolyte levels in patients with hypertension. *International Journal of Cardiology* 155: 134.
72. Barkia A, Mohamed K, Smaoui M, Zouari N, Hammami M, et al. (2011) Change of diet, plasma lipids, lipoproteins, and fatty acids during Ramadan: a controversial association of the considered Ramadan model with atherosclerosis risk. *J Health Popul Nutr* 29: 486-493.
73. Khaled BM, Bendahmane M, Belbraouet S (2006) Ramadan fasting induces modifications of certain serum components in obese women with type 2 diabetes. *Saudi Med J* 27: 23-26.
74. Yarahmadi Sh, Larijani B, Bastanbakhsh MH, Pajouhi M, Baradar Jalili R, et al. (2003) Metabolic and clinical effects of Ramadan fasting in patients with type II diabetes. *J Coll Physicians Surg Pak* 13: 329-332.

## Chapter 6

# Ramadan Fasting and Cancer

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINOEMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINOEMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though some subjects (among which patients) are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers. However, there are no guidelines or standardized protocols that can help physicians to properly address the issue of patients with cancer fasting in Ramadan and correctly advising them. Moreover, in a more interconnected and globalized society, in which more and more Muslim patients live in the Western countries, this topic is of high interest also for the general practitioner. For this purpose, we carried out a systematic review on the subject.

Our main findings are that:

- 1) Very few studies have been carried out, addressing this issue;
- 2) Evidence concerning quality of life and compliance to treatment is contrasting and scarce;
- 3) Generally speaking, few patients ask their physicians whether they can safely fast or not.

For these reasons, further research could be performed, given the relevance and importance of this topic.

**Keywords:** Cancer; Drug Compliance and Adherence; Quality of Life; Ramadan Fasting; Stomia

## Introduction

The Arabic word *Islam* means peace, purity and total submission to the will of Allah (the Lord of the worlds, *Rabb al-'alameen*) by conforming inwardly and outwardly to his law. The religion of Islam is based on five pillars (*arkan al-Islam*). Ramadan fasting (*as-sawm*) is considered one of the five pillars of the creed, together with the faith declaration (*as-shahada*), the ritual prayers (*as-salah*), the pilgrimage to Mecca at least once in lifetime for those who are financially and physically able (*hajj*), and charity or almsgiving (*zakat*).

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*.

Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 "Al-Baqarah", ayat 183*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. Pre-dawn meal is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable, since the Islamic calendar is a lunar one and therefore the Islamic year contains 354 days (instead of 365, as in the Gregorian or solar calendar). For this reason, the Ramadan month occurs 11 days earlier every year, and may fall in any period of the year. Therefore, mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1,2] or even 22 hours, in the extreme latitudes [1].

Pre-puberal and puberal children, menstruating, pregnant and breast-feeding women, sick people, debilitated older subjects; travelers are exempted from this religious duty (*Surat 2 "Al-Baqarah", ayat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers [3].

The effects of Ramadan fasting on patients suffering from cancer is not a mere academic topic or of limit interest for only the Arabic countries. In a globalized society, the physicians have to face with issues like the management of cancer in Muslim patients that to want to fast during Ramadan, since more Muslims live in the Western societies [4]. However, information is sparse and no guidelines or standardized protocols exist [3].

For this purpose, we have carried out a systematic review that could be helpful for general practitioners. We have mined different databases: namely, ISI/Web of Science (WoS), MEDLINE/PubMed, Scopus, Scirus, Directory of Open Access Journals (DOAJ), Google Scholar.

## Ramadan and Cancer: Quality of Life and Adherence to Religious Worship

Kuzu and collaborators [4] investigated quality of life and compliance to religious duties (such as praying and fasting) in 178 patients living with a permanent colostomy. 75 underwent abdominoperineal resection (APR, or Miles' operation), 51 sphincter-saving resection, and 52 anterior resection including sigmoid colectomy. Quality of life was measured with the Medical Outcomes Study Short Form 36 Health Survey (SF-36) and a questionnaire with items about work, sexual life and compliance to religious worship. They found that a significantly number of patients in the abdominoperineal resection group stopped praying daily (either alone or in a mosque) and fasting during Ramadan. They concluded that colorectal cancer, besides affecting quality of life, has a profound impact on religious worship. The authors recommended a preoperative counseling, involving local religious authorities.

Celasin and coworkers [5] carried out a prospective study recruiting 93 Muslim patients after surgery for colorectal carcinoma: 50 underwent APR, 22 sphincter-saving resection and 1 anterior resection including sigmoid colectomy. Quality of life was assessed pre- and postoperatively at 15-18 months with the SF-36 questionnaire and a modified version of the American Society of Colorectal Surgeons (ASCRS) Fecal Incontinence questionnaire. Life standards, including religious practice, were measured using the Ankara University Life Standard Questionnaire (AULSQ). Authors found that religious worship (praying alone, praying in mosques, fasting during Ramadan and purifying alms) was not significantly different among the groups. Probably this was the effect of a proper religious counseling and its importance, advocated by Kuzu and collaborators in the previous article [4], is here confirmed.

Zeeneldin and co-authors [6] conducted a cross-sectional study during Ramadan, August-September 2009, investigating 102 patients suffering from breast cancer (31%), acute leukemia (24%), colorectal cancer (7%), non-Hodgkin lymphoma (5%), bladder cancer (4%), lung cancer (4%), and laryngeal cancer (4%). Treatments included chemotherapy, radiotherapy, hormonal therapy, and nonspecific therapy in 42%, 31%, 10%, and 17%, respectively. Co-morbidities were present in 22% of the patients. Authors found that 40% of patients did not fast during Ramadan, 36% and 24% were partial and complete fasters. Being female patients, having a good and stable performance status, suffering from a non-metastatic solid tumor, and receiving non-intravenous chemotherapy as outpatients were found to be predictor of compliance to fasting. However, only 46% of patients sought the treating oncologist advice on whether they could fast.

Altuntas and coworkers [7] carried out a prospective study investigating 56 patients with a cancer-related fecal stoma over two periods of Ramadan to analyze the effect of fasting on nutritional and metabolic status and quality of life. 14 patients were fasting. They had their stoma for a longer period of time than patients in the non fasting group, and the proportion of patients with a permanent stoma was higher in the fasting group than in the non fasting group. Ramadan fasting had almost no influence on quality of life.

Tas and collaborators [8] performed a survey of 701 adult Turkish Muslim cancer patients during the month of Ramadan in 2012. Before diagnosis of cancer, 93.1% of the patients used to fast completely or partially. After diagnosis of cancer, this rate fell down to 15%. 83.9% of patients who fasted before diagnosis, gave up observing the religious duty. Patients who decided to go on fasting after the diagnosis of cancer thought that observing Ramadan would have lead to Patients who were females, those with good performance status, those without any comorbid disease (in particular, diabetes mellitus), who had non-metastatic disease, those with history of surgery, young, those treated with radiotherapy and those being treated with single agents, oral chemotherapeutic agents or not receiving drugs being in the follow-up period were more likely to be fasting than others. The fasting ones suffered from lymphoma, urogenital cancer (in particular, testicular tumor) and breast cancer; conversely, the rate of fasting status among patients with lung and gastrointestinal cancer was quite low. Gynecologic, head and neck, sarcoma and skin cancers did not correlate with fasting status. Only 20.8% of all patients asked their physician whether it was alright for them to fast and physicians generally had a negative attitude towards fasting (83.2%). 13.3% of physicians allowed patients to choose whether to fast or not. Physicians were concerned about the possibility of fasting in patients at risk of tumor lysis syndrome, taking nephrotoxic drugs or other drugs that could lead to vomiting, diarrhea or renal failure. The authors concluded that majority of cancer patients are not fasting during the month of Ramadan, and a small part of patients consult this situation to their physician.

## **Ramadan and Cancer: Adherence to Drug Treatment**

Drug compliance during Ramadan generally tends to fall, as noticed by some scholars [9-11]. Other authors, such as Zeeneldin and coauthors [12], however, have found that Ramadan fasting does not impair patient's adherence to treatment. During Ramadan 2010, 139 patients suffering from breast cancer were asked about compliance to fasting and religious duties as well as to treatment with Oral Hormonal Therapy (OHT) in Ramadan and in the preceding month. Tamoxifen and aromatase inhibitors were used in 64% and 36%, respectively. Adherence rates to OHT during Ramadan and before were 94.2% and 95.7%, respectively (not statistically significant). Non-adherence prior to Ramadan and shorter duration of OHT were predictors of non-adherence during Ramadan, whilst fasting status, age, performance status, presence of metastases and type of OHT were not good predictors of adherence.



## Results and Discussion

Despite our extensive search, we managed to find only 6 studies addressing the issue of patients suffering from cancer fasting during Ramadan: in particular, 5 focusing on the impact of fasting on quality of life and compliance to worship, 1 focusing on adherence to drug treatment. Despite the importance and relevance of this topic and given the burden imposed by the cancer, very few scholars have investigated the impact of Ramadan fasting on the health of patients with tumor.

The effect of Ramadan on quality of life appears to be controversial: whilst three studies confirm this relationship, two other researches fail to find any impact. Also the effect of fasting on compliance to worship seems to be quite contrasting.

As far as the compliance to drug treatment is concerned, there is only 1 study available and therefore it is not possible to collect any evidence.

## Conclusion

There is a strong need for evidence-based suggestions and guidelines [3]. Very few studies are available, with contrasting findings.

This could be done within a multidisciplinary team, made up of an oncologist, a nutritionist, a psychiatrist or a psychologist. Patients should be carefully checked and assessed, considering both the clinical symptoms and the laboratory exams. Also psychological aspects, such as motivation, and patient preferences and adherence/compliance to treatment should be investigated and taken into account.

Patients suffering from metastatic, disseminated, aggressive tumor, lysis syndrome, taking nephrotoxic drugs which could cause diarrhea, vomiting or renal failure, or with a history of non-compliance with therapy and dietary modifications should not fast during the month of Ramadan.

In conclusion, if stable, patient's eagerness to fast should be taken into account and even encouraged, since spirituality plays a key role in cancer. The patient feels indeed himself/herself more active being involved in the religious activities, and less depressed and isolated [3].

A particular aspect that should be addressed is the management of terminal patients during Ramadan. From the literature, it is known that some Muslim patients with terminal illnesses may express a strong spiritual and religious wish [13,14]. This calls for cooperation between the family and the interdisciplinary palliative care team. On the contrary, some scholars like Tas and collaborators [8] have shown that there is poor cooperation between physician and patient. Facing patients' needs is likely to have a great positive impact on the patient's sense of well being.

However, once again, also this topic has been poorly explored. Further research in the field is needed.

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancia G (eds.). Special Issues in Hypertension. Springer-Verlag, Milan, Italy. Pg:331-336.
2. Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of Patients with Renal Colic that Present to an Emergency Department During the Month of Ramadan. The Journal of Academic Emergency Medicine 12: 24-26.
3. Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. Perit Dial Int 33: 86-91.
4. Kuzu MA, Topçu O, Uçar K, Ulukent S, Unal E, et al. (2002) Effect of sphincter-sacrificing surgery for rectal carcinoma on quality of life in Muslim patients. Dis Colon Rectum 45: 1359-1366.

5. Celasin H, Karakoyun R, Yılmaz S, Elhan AH, Erkek B, et al. (2011) Quality of life measures in Islamic rectal carcinoma patients receiving counselling. *Colorectal Dis* 13: 170-175.
6. Zeeneldin AA, Taha FM (2012) Fasting among Muslim cancer patients during the holy month of Ramadan. *Ann Saudi Med* 32: 243-249.
7. Altuntas YE, Gezen FC, Sahoniz T, Kement M, Aydin H, et al. (2013) Ramadan fasting in patients with a stoma: a prospective study of quality of life and nutritional status. *Ostomy Wound Manage* 59: 26-32.
8. Tas F, Karabulut S, Ciftci R, Yildiz I, Keskin S, et al. (2014) The behavior of Turkish cancer patients in fasting during the holy month of Ramadan. *Jpn J Clin Oncol* 44: 705-710.
9. Celik I, Barista I, Firat D (1996) Cancer therapy during Ramadan. *J Natl Cancer Inst* 88: 838.
10. Patel T, Magdum A, Ghura V (2012) Does fasting during Ramadan affect the use of topical dermatological treatment by Muslim patients in the UK? *Clin Exp Dermatol* 37: 718-721.
11. Yakasai AM, Muhammad H, Babashani M, Jumare J, Abdulmumini M, et al. (2011) Once-daily antiretroviral therapy among treatment-experienced Muslim patients fasting for the month of Ramadan. *Trop Doct* 41: 233-235.
12. Zeeneldin AA, Gaber AA, Taha FM (2012) Does fasting during Ramadan trigger non-adherence to oral hormonal therapy in breast cancer patients? *J Egypt Natl Canc Inst* 24: 133-137.
13. Tazi I (2008) Ramadan and cancer. *J Clin Oncol* 26: 5485.
14. Whyte A (2010) Ready for Ramadan. *Nurs Stand* 24: 18-19.

## Chapter 7

# Ramadan Fasting and Emergencies

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINO GMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINO GMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though some subjects (among which patients) are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers. However, there are no guidelines or standardized protocols that can help physicians to properly address the issue of patients with emergencies and fasting in Ramadan and correctly advising them. Moreover, in a more interconnected and globalized society, in which more and more Muslim patients live in the Western countries, this topic is of high interest also for the physicians. For this purpose, we carried out a systematic review on the subject.

Our main findings are that:

- 1) Few studies have been carried out, addressing this issue;
- 2) These studies have contrasting results.

For these reasons, further research could be performed, given the relevance and importance of this topic. However, physicians should stay alert and organize particular “Ramadan walk-in clinics” meeting the needs of their patients during this month.

**Keywords:** Emergencies; Ramadan Fasting

## Introduction

The Arabic word *Islam* means wholeness, safeness, peace, purity and total submission to the will of Allah (the Lord of the worlds, *Rabb al-'alameen*) by conforming inwardly and outwardly to his law. Islam is a monotheistic and Abrahamic religion, whose creed is contained in the *Qur'an* and in the teachings and normative examples (called the *Sunnah* and composed of *hadith*) of Muhammad (570 CE – 8 June 632 CE), the last prophet of God. Islam is the complete and universal version of a primeval faith that was revealed before and widespread, even though partially corrupted and altered or misunderstood, by the prophets Adam, Noah, Abraham, Moses and Jesus. With more than one billion and half of followers (a quarter of earth's population), Islam is the second-largest religion and probably the fastest-growing religion in the world.

The religion of Islam is based on five pillars (*arkan al-Islam*). Ramadan fasting (*as-sawm*) is considered one of the five pillars of the creed, together with the faith declaration (*as-shahada*), the ritual prayers (*as-salah*), the pilgrimage to Mecca at least once in lifetime for those who are financially and physically able (*hajj*), and charity or almsgiving (*zakat*).

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*.

Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 "Al-Baqarah", ayyat 183*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. Fasting is observed from dawn to sunset. Pre-dawn meal is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable, because daylight hours vary considerably between summer and winter months and the Islamic calendar is a lunar one. Therefore, the Islamic year contains 354 days (instead of 365, as in the Gregorian or solar calendar). For this reason, the Ramadan month occurs 10-11 days earlier every year, and may fall in any period of the year. Therefore, mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1,2] or even 22 hours, in the extreme latitudes [1].

Pre-puberal and puberal children, menstruating, pregnant and breast-feeding women, sick people, debilitated older subjects; travelers are exempted from this religious duty (*Surat 2 "Al-Baqarah", ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers [3].

The effects of Ramadan fasting on patients suffering from diseases and accessing the Emergency Department (ED) is not a mere academic topic or of limit interest for only the Arabic countries. In a globalized society, the physicians have to face with issues like the management of cancer in Muslim patients that to want to fast during Ramadan, since more Muslims live in the Western societies [4]. However, information is sparse and no guidelines or standardized protocols exist [3].

For this purpose, we have carried out a systematic review that could be helpful for the physicians. We have mined different databases: namely, ISI/Web of Science (WoS), MEDLINE/PubMed, Scopus, Scirus, Directory of Open Access Journals (DOAJ) and Google Scholar. Further highly specialized journals (termed as "targeted journals") were manually inspected for inclusion of any potential pertinent article. These targeted journals were: Journal of religion and health, and Journal of fasting and health. As far as the search string is concerned, we exploited a proper combination of words such as "Ramadan", "fasting" and "emergencies", selecting when appropriate as option Medical Subject Headings (MeSH) terms (<http://www.nlm.nih.gov/mesh/>) and using Boolean operators. No time limit or language restrictions were applied. Original research articles, including also editorials, letters to the editor, commentaries containing sufficient quantitative information, were retained in our search, whilst any kind of review articles (narrative reviews, systematic reviews) and case report series were excluded. Articles not directly pertinent or not fitting with the scope of the current review were also excluded (Table 1).

Search strategy item	Description
1. Accessed databases	ISI/Web of Science (WoS), MEDLINE/PubMed, Scopus, Google Scholar, Scirus, Directory of Open Access Journals (DOAJ)
2. Search string	A proper combination of words such as "Ramadan", "fasting" and "emergencies", using MESH terms and Boolean operators
3. Included articles	Original research articles, also commentaries, editorials and letters to the editor when containing sufficient quantitative information

4.	Excluded articles	Review of any kind (narrative, systematic, overview); case report, articles not pertinent to the scope of the present review
5.	Targeted journals	Journal of fasting and health, Journal of religion and health

**Table 1:** Search strategy items (accessed databases, search string, included and excluded articles, targeted journals).

## Ramadan and Emergencies

Halasa [4] did not find any change in ED attendance before and during Ramadan, if not a slight change in timing of the clinical presentations but not in their frequency. Al Suwaidi and colleagues [5] reported a similar change in timing of the presentations for acute cardiac events. A similar result was obtained by Pekdemir and co-workers [6], in a study which recruited 2,079 patients. The authors found that, during Ramadan, the clinical features of patients admitted to the ED and the number of ED admissions for specific pathologies did not change significantly. The authors concluded that Ramadan has no effect on ED use.

On the contrary, Langford and collaborators [7] observed an increase of ED attendance during Ramadan. Other scholars noticed some differences in the pattern of ED use during the month of the fasting: an increase in the road traffic accidents as found by Bener et al., Shanks et al., Tahir and collaborators [8-10], in diabetic complications as found by Ahmad and colleagues, Topacoglu et al., [11,12], in neurological complications as described by Topacoglu et al., [12], in nephro-urological disorders at least for the first weeks of the month as reported by Abdolreza and co-workers [13] or in gastro-intestinal pathologies as described by Göçmen et al., Herrag and co-authors, Ozkan and collaborators and by Parrilla Ruiz et al., [14-17].

However, some scholars, such as Khanmash and al-Shouha [18], found a decrease in road traffic accidents during Ramadan. Al Sifri et al., Benbarka et al., Fatim et al., Katibi et al., Pinelli and Jaber [19-23] did not observe any change in frequency of diabetic emergencies. Al-Hadramy [24] did not observe any correlation between colic episodes and Ramadan. Bener and coworkers [25] could not replicate the finding of an increase of the frequency of gastrointestinal complications during Ramadan. Temizhan and collaborators [26] observed a decrease in frequency of acute cardiac events.

## Results and Discussion

Performing an extensive search (Table 1), we managed to find 26 pertinent studies addressing the issue of patients accessing the ED during Ramadan. However, after careful examination of the quality of the evidences, we had to exclude 3 of them [27-29], because of anecdotal reporting (Table 2).

Pertinent excluded articles	Reasons
Bakker et al., 2013 [27]	Anecdotal report of superior mesenteric artery syndrome
Ghose et al., 2009 [28]	Anecdotal report of poisoning
Ghose et al., 2009 [29]	Anecdotal report of poisoning

**Table 2:** List of pertinent but excluded articles, with reason.

In particular (Table 3), the 23 included studies focused on diabetic emergencies (7 articles), on gastro-intestinal complications (5 articles), on road traffic accidents (4 articles), on acute cardiac events (2 articles), on urological complications (2 articles), on neurological complications (1 article) and on hypertensive emergency (1 article).

Kind of emergency	References
Acute cardiac events	Al Suwaidi et al., 2006 [5] Temizhan et al., 1999 [26]

Diabetes complications	Ahmad et al., 2012 [11] Al Sifri et al., 2011 [19] Benbarka et al., 2010 [20] Fatim et al., 2011 [21] Katibi et al., 2001 [22] Pinelli and Jaber, 2011 [23] Topacoglu et al., 2005 [12]
Gastro-intestinal complications (ulcer perforation and hemorrhage, acute mesenteric ischaemia)	Bener et al., 2006 [25] Göçmen et al., 2004 [14] Herrag et al., 2010 [15] Ozkan et al., 2009 [16] Parrilla Ruiz et al., 2003 [17]
Hypertensive emergency	Topacoglu et al., 2005 [12]
Nephro-urological complications (kidney stones and colic episodes)	Abdolreza et al., 2011 [13] Al-Hadramy 1997 [24]
Neurological complications (headache)	Topacoglu et al., 2005 [12]
Road traffic accidents	Bener et al., 1992 [8] Khanmash and al-Shouha, 2006 [18] Shanks et al., 1994 [9] Tahir et al., 2014 [10]

**Table 3:** Kind of emergency for each article included in the current review.

Table 4 lists all the included articles, with a summary of the main findings.

References	Observed effect
Abdolreza et al., 2011 [13]	Increase in colic episodes
Ahmad et al., 2012 [11]	Increase in diabetic emergencies
Al-Hadramy, 1997 [24]	No changes (for colic episodes)
Al Sifri et al., 2011 [19]	No changes (for diabetic complications)
Al Suwaidi et al., 2006 [5]	Changes in timing of clinical presentations of acute cardiac events
Benbarka et al., 2010 [20]	No changes (for diabetic complications)
Bener et al., 1992 [8]	Increase in road traffic accidents
Bener et al., 2006 [25]	No changes (for gastro-intestinal complications)
Fatim et al., 2011 [21]	No changes (for diabetic complications)
Göçmen et al., 2004 [14]	Increase in gastro-intestinal complications
Halasa, 2014 [4]	Changes in timing of clinical presentations, not in frequency
Herrag et al., 2010 [15]	Increase in gastro-intestinal complications
Katibi et al., 2001 [22]	No changes (for diabetic complications)
Khanmash and al-Shouha, 2006 [18]	Decrease in road traffic accidents
Langford et al., 1994 [7]	Increase in ED attendance
Ozkan et al., 2009 [16]	Increase in gastro-intestinal complications
Parrilla Ruiz et al., 2003 [17]	Increase in gastro-intestinal complications
Pekdemir et al., 2010 [6]	No changes
Pinelli and Jaber, 2011 [23]	No changes (for diabetic complications)
Shanks et al., 1994 [9]	Increase in road traffic accidents
Tahir et al., 2014 [10]	Increase in road traffic accidents
Temizhan et al., 1999 [26]	Decrease in acute cardiac events
Topacoglu et al., 2005 [12]	Increase in hypertensive, neurological and diabetic emergencies

**Table 4:** Summary of the observed effect for each article included in the current review.

In conclusion (Table 5), 11 articles reported an increase in the frequency of ED access, whilst 2 articles found a decrease in ED use, 10 articles described no changes in ED attendance.

Kind of observed effect	References
Increase	Abdolreza et al., 2011 [13] Ahmad et al., 2012 [11] Bener et al., 1992 [8] Göçmen et al., 2004 [14] Herrag et al., 2010 [15] Langford et al., 1994 [7] Ozkan et al., 2009 [16] Parrilla Ruiz et al., 2003 [17] Shanks et al., 1994 [9] Tahir et al., 2014 [10] Topacoglu et al., 2005 [12]
Decrease	Khanmash and al-Shouha, 2006 [18] Temizhan et al., 1999 [26]
No changes	Al-Hadramy, 1997 [24] Al Sifri et al., 2011 [19] Al Suwaidi et al., 2006 [5] Benbarka et al., 2010 [20] Bener et al., 2006 [25] Fatim et al., 2011 [21] Halasa, 2014 [4] Katibi et al., 2001 [22] Pekdemir et al., 2010 [6] Pinelli and Jaber, 2011 [23]

**Table 5:** Kind of observed effect (increase; decrease; no changes in emergency department use) for each article included in the current review.

## Conclusion

There is a strong need for evidence-based suggestions and guidelines [3]. Few studies are available, with contrasting findings. Research is needed to shed light on this highly clinically relevant topic. Physicians should stay alert during the month of the fasting and organize particular “Ramadan walk-in clinics”, addressing the specific needs of the patients during this month. Adequate counseling and collaboration with local religious authorities are very important.

## References

- Berberi AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancia G (eds.). *Special Issues in Hypertension*. Springer-Verlag, Milan, Italy. Pg:331-336.
- Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of Patients with Renal Colic that Present to an Emergency Department During the Month of Ramadan. *The Journal of Academic Emergency Medicine* 12: 24-26.
- Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. *Perit Dial Int* 33: 86-91.
- Halasa W (2014) Effect of Ramadan fasting on emergency walk-in-clinics in Jordan. *Br J Gen Pract* 64: 388.
- Al Suwaidi J, Bener A, Gehani AA, Behair S, Al Mohanadi D, et al. (2006) Does the circadian pattern for acute cardiac events presentation vary with fasting? *J Postgrad Med* 52: 30-33.
- Pekdemir M, Ersel M, Yılmaz S, Uygun M (2010) No significant alteration in admissions to emergency departments during Ramadan. *J Emerg Med* 38: 253-256.
- Langford EJ, Ishaque MA, Fothergill J, Touquet R (1994) The effect of the fast of Ramadan on accident and emergency attendances. *J R Soc Med* 87: 517-518.
- Bener A, Absood GH, Achan NV, Sankaran-Kutty M (1992) Road traffic injuries in Al-Ain City, United Arab Emirates. *J R Soc Health* 112: 273-276.
- Shanks NJ, Ansari M, al-Kalai D (1994) Road traffic accidents in Saudi Arabia. *Public Health* 108: 27-34.
- Tahir MN, Macassa G, Akbar AH, Naseer R, Zia A, et al. (2014) Road traffic crashes in Ramadan: an observational study. *East Mediterr Health J* 19: 147-151.

11. Ahmad J, Pathan MF, Jaleel MA, Fathima FN, Raza SA, et al. (2012) Diabetic emergencies including hypoglycemia during Ramadan. *Indian J Endocrinol Metab* 16: 512-515.
12. Topacoglu H, Karcioğlu O, Yuruktumen A, Kiran S, Cimrin AH, et al. (2005) Impact of Ramadan on demographics and frequencies of disease-related visits in the emergency department. *Int J Clin Pract* 59: 900-905.
13. Abdolreza N, Omalbanin A, Mahdieh TS, Mohammad Ali MR, Reza MS, et al. (2011) Comparison of the number of patients admitted with renal colic during various stages of peri-Ramadan month. *Saudi J Kidney Dis Transpl* 22: 1199-1202.
14. GÃşmen E, KoÃş M, Tez M, YoldaÃ O, Bilgin A, et al. (2004) Effect of Ramadan on surgical emergencies. *Ann Emerg Med* 44: 283-285.
15. Herrag M, Lahmiti S, Yazidi AA (2010) Ramadan: a different side of the emergencies? *Afr Health Sci* 10: 215-216.
16. Ozkan S, Durukan P, Akdur O, Vardar A, Torun E, et al. (2009) Does Ramadan fasting increase acute upper gastrointestinal haemorrhage? *J Int Med Res* 37: 1988-1993.
17. Parrilla Ruiz F, Cárdenas Cruz DP, Vargas Ortega DA, Cárdenas Cruz A (2003) The Ramadan fast and an emergency unit. *Aten Primaria* 32: 61-63.
18. Khammash MR, Al-Shouha TF (2006) Do road traffic accidents increase during the fasting month of Ramadan. *Neurosciences (Riyadh)* 11: 21-23.
19. Al Sifri S, Basiounny A, Echtay A, Al Omari M, Harman-Boehm I, et al. (2011) The incidence of hypoglycaemia in Muslim patients with type 2 diabetes treated with sitagliptin or a sulphonylurea during Ramadan: a randomised trial. *Int J Clin Pract* 65: 1132-1140.
20. Benbarka MM, Khalil AB, Beshyah SA, Marjei S, Awad SA (2010) Insulin pump therapy in Moslem patients with type 1 diabetes during Ramadan fasting: an observational report. *Diabetes Technol Ther* 12: 287-290.
21. Fatim J, Karoli R, Chandra A, Naqvi N (2011) Attitudinal determinants of fasting in type 2 diabetes mellitus patients during Ramadan. *J Assoc Physicians India* 59: 630-634.
22. Katibi IA, Akande AA, Bojuwoye BJ, Okesina AB (2001) Blood sugar control among fasting Muslims with type 2 diabetes mellitus in Ilorin. *Niger J Med* 10: 132-134.
23. Pinelli NR, Jaber LA (2011) Practices of Arab American patients with type 2 diabetes mellitus during Ramadan. *J Pharm Pract* 24: 211-215.
24. al-Hadramy MS (1997) Seasonal variations of urinary stone colic in Arabia. *J Pak Med Assoc* 47: 281-284.
25. Bener A, Derbala MF, Al-Kaabi S, Taryam LO, Al-Ameri MM, et al. (2006) Frequency of peptic ulcer disease during and after Ramadan in a United Arab Emirates hospital. *East Mediterr Health J* 12: 105-111.
26. Temizhan A, Dönderici O, Ouz D, Demirbas B (1999) Is there any effect of Ramadan fasting on acute coronary heart disease events? *Int J Cardiol* 70: 149-153.
27. Bakker ME, Van Delft R, Vaessens NA, Rosias PR (2014) Superior mesenteric artery syndrome in a 15-year-old boy during Ramadan. *Eur J Pediatr* 173: 1619-1621.
28. Ghose A, Sayeed AA, Hossain A, Rahman R, Faiz A, et al. (2009) Mass barium carbonate poisoning with fatal outcome, lessons learned: a case series. *Cases J* 2: 9069.
29. Ghose A, Sayeed AA, Hossain A, Rahman R, Faiz A, et al. (2009) Mass barium carbonate poisoning with fatal outcome, lessons learned: a case series. *Cases J* 2: 9327.



## Chapter 8

# Ramadan Fasting and Diabetes

**Meghit Boumediene Khaled\***

Faculty of Biotechnology and Biomolecular Sciences, Department of Biochemistry, University Putra Malaysia, UPM Serdang, Selangor, Malaysia

**\*Corresponding author:** Meghit Boumediene Khaled, Faculty of Biotechnology and Biomolecular Sciences, Department of Biochemistry, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia, Tel: + 60 123 957 916; E-mail: [khaled\\_m@upm.edu.my](mailto:khaled_m@upm.edu.my)

## Abstract

Ramadan fasting, the ninth month of Islamic *Hijri* Calendar is a religious duty of Islam, annually followed by millions of Muslims worldwide to fulfil their worship and to abstain from food and water from dawn to sunset. Fasting during Ramadan is commonly seen as beneficial for health. Among disabled individuals with acute or chronic diseases, certain diabetes patients can be exempted from this obligation. On one hand, many people with this long-term-illness still prefer or insist to observe fasting, without medical guidance, exposing themselves to certain health risks as a direct consequence of fasting, or of a change in food and frequency of medication intake. Education provided by a well-trained health care team appears to have a major effect on diabetes management during Ramadan to reduce major complications.

The present chapter emphasizes on the effect of Ramadan fasting on diabetes patients and the risks associated, focusing on the pre-Ramadan assessment for those who want to fast safely. Furthermore, it provides the latest updated recommendations and advices in terms of diet, medication and prevention.

**Keywords:** Diabetes; Fasting; Ramadan

**Abbreviations and Acronyms:** ADA: American Diabetes Association; EPIDIAR: Epidemiology of Diabetes and Ramadan; GLP-1: Glucagon-Like Peptide-1; HbA1C: Glycated Haemoglobin A1C; HCP: Healthcare Providers; OHA: Oral Hypoglycemic Agents; TEI: Total Energy Intake; T2D: Type 2 Diabetes

## Introduction

Ramadan, one of the five main pillars of Islam, is the ninth month in the Islamic calendar. Its duration varies according to geographical location and season; it precedes by 10–11 days every year, and generally lasts 28–30 days. Fasting during Ramadan involves refraining from any food, drink, smoking, sexual activities and oral medications from dawn to sunset. Blood taking, insulin injections, using inhalers for asthma and vaccinations do not invalidate the fast. Ramadan fasting is a duty for all healthy adult Muslims. However, children under the age of puberty, the old and frail, individuals who are sick, mainly those with chronic illnesses in whom fasting may be detrimental to health, traveling, pregnant, breast-feeding, menstruating, or debilitated are exempt from fasting “God intends every

facility for you, he does not want to put you into difficulties” (Quran 2:185).

Most Muslims who are fasting Ramadan eat two main meals; the first before sunrise (known as *Sahor*) and the second after sunset (known as *Iftar*). The main objective of fasting Ramadan is to inculcate in Muslims the spirit of sacrifice, to teach moral and self-discipline and sympathy for the poor [1,2].

## Ramadan Fasting and Diabetes

Studies concerning the effect of Ramadan fasting are controversial and not yet well established in diabetic subjects particularly with regards to who could observe fasting without any health risk [3].

Among disabled individuals with acute or chronic diseases, certain diabetics can be exempted from fasting. Many people with diabetes still prefer to fast, without medical guidance, exposing themselves to certain health risks as a direct consequence of fasting or because of a change in food and frequency of medication intake. Although the benefit of experimental supplemented fasting has been well demonstrated, in diabetics, the consequential effects of fasting during Ramadan remain often controversial [4-7].

Recent collaboration between the International Islamic Fiqh Academy and The Islamic Organization for Medical Sciences produced a comprehensive guidance based on extensive review of the evidence of possible risk to diabetic patients if they observe fasting [8,9]. The new guidance categorized people with diabetes into 4 groups according to their risk (Table 1).

<b>Category 1: Very high-risk group</b>	<ul style="list-style-type: none"> <li>• Severe hypoglycemia within the last 3 months prior to Ramadan</li> <li>• Patients with a history of recurrent hypoglycemia</li> <li>• Patients with lack of hypoglycemia awareness</li> <li>• Patients with sustained poor glycemic control</li> <li>• Ketoacidosis within the last 3 months prior to Ramadan</li> <li>• Type 1 diabetes</li> <li>• Acute illness</li> <li>• Hyperosmolar hyperglycemic coma within the previous 3 months</li> <li>• Patients who perform intense physical labor</li> <li>• Pregnancy</li> <li>• Patients on chronic dialysis</li> </ul>
<b>Category 2: High-risk group</b>	<ul style="list-style-type: none"> <li>• Patients with moderate hyperglycemia blood glucose levels of 10.0–16.5 mmol/L (180–300 mg/dL) or high HbA1C (&gt;10%)</li> <li>• Patients with renal insufficiency</li> <li>• Patients with advanced macro vascular complications</li> <li>• People living alone who are treated with insulin or sulphonyl ureas</li> <li>• Patients living alone with comorbid conditions that present additional risk factors</li> <li>• Old age with ill health</li> <li>• Drugs that may affect cognitive state</li> </ul>
<b>Category 3: Moderate risk</b>	<ul style="list-style-type: none"> <li>• Well-controlled patients treated with short-acting insulin</li> </ul>
<b>Category 4: Low risk</b>	<ul style="list-style-type: none"> <li>• Well-controlled patients treated with diet alone, metformin, or a thiazolidinedione, who are otherwise healthy</li> </ul>

**Table 1:** Expert recommendations for risk stratification related to Ramadan fasting in patients with diabetes (Organization of the Islamic Conference) [8,9].

HbA1c: Glycatedhaemoglobin A<sub>1c</sub>

## Pathophysiology of Fasting

### In healthy people

Ramadan fasting constitutes a period of food and water abstinence which may vary from 12 to 18 hours from dawn to sunset, depending on region and season. The body adapts to these metabolic changes and develops regulation mechanisms to maintain a normal level of

serum glucose and ensure the supply of energy through tissue involving counter-regulatory hormones glucagon and catecholamines [10].

In healthy individuals eating stimulates the secretion of insulin. This in turn results in glycogenesis and storage of glucose as glycogen in liver and muscle. However, during fasting a reduction of insulin secretion is observed while counter-regulatory hormones glucagon and catecholamines are increased. This leads to glycogenolysis and gluconeogenesis. The low level of insulin in circulation induces an elevation of fatty acid release and oxidation that generates ketones which are used as a source of energy (Figure 1A).

Concerning body weight, results on the effects of Ramadan fasting on weight changes have been controversial. A recent systematic review, on the effect of fasting during Ramadan, have shown that the weight lost during Ramadan is relatively small and body weight variations during Ramadan fasting are mostly reversed after Ramadan, gradually returning to pre-Ramadan status [11]. These variations in body weight are mainly due to lifestyle modification during Ramadan month. Nevertheless, restrictions in meal frequencies or energy intake alone cannot explain these variations. Other factors could have a significant effect on body weight such dehydration, changes in diet, physical activity and even sleeping hours [11].

### In diabetic people

An excessive glycogenolysis, gluconeogenesis and ketogenesis has been seen among patients with type 1 diabetes and severe insulin deficiency, which may lead to hyperglycemia and ketoacidosis that may be life-threatening [1] (Figure 1B).

Results about the effect of Ramadan fasting on body weight among individuals with diabetes remain controversial. Some authors reported a decrease in body weight [3,12-19], while others noticed an increase [20-22] or non-change [23-26]. The EPIDIAR study revealed weight was unchanged in the majority of patients with type 1 (62.5%) and type 2 diabetes (54.1%) [27].

Concerning the effect of fasting during Ramadan on glycemic control, several studies reported no change in Glycated Hemoglobin (HbA1c) or fructosamine levels [24,28]. However, the main issue for people with diabetes, who want to fast and for the healthcare professionals, is the variation in glycaemia (hypo and hyperglycemia). Ramadan fasting has no significant effects on well controlled patients under oral medication or diet [29].

Modifying eating habits during Ramadan fasting and then significantly increasing one's intake after breaking the fast, could unbalance the metabolism of patients with diabetes and influence their nutritional intake and their anthropometric parameters.

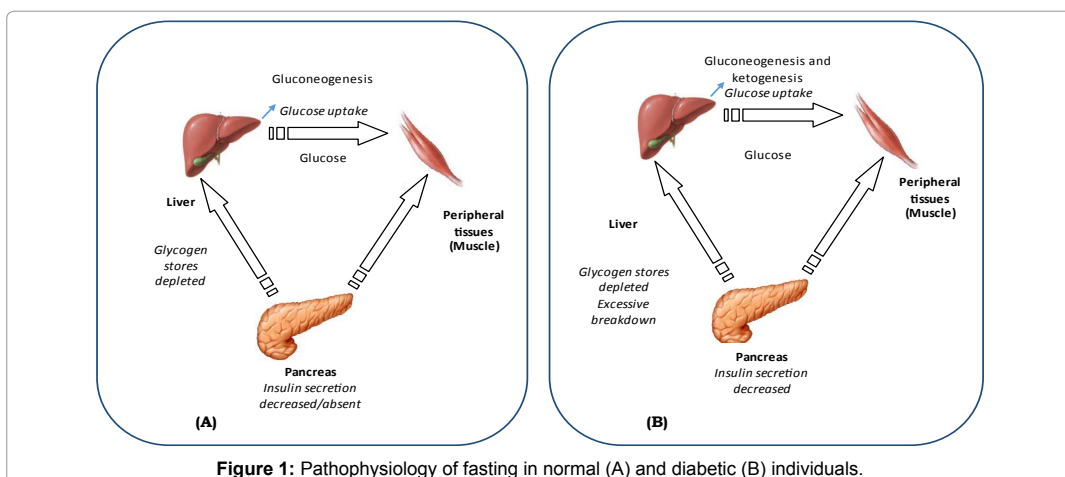


Figure 1: Pathophysiology of fasting in normal (A) and diabetic (B) individuals.

## Risks Associated with Fasting Ramadan and Diabetes

The exact medical effect of fasting during Ramadan on diabetic individuals is not well studied. However, both the religious and medical advice clearly demonstrates clearly demonstrates that some people with diabetes are exempt from and should avoid fasting due to the risks to their metabolic condition [10].

The ADA (American Diabetes Association) published a consensus statement on the management of diabetes during the month of Ramadan in 2005 aiming the reduction of risks related to fasting during this period [1]. The metabolic effects of fasting for people with diabetes are multiple. They range from the risk of increased frequency of hypoglycemia, postprandial hyperglycemia with or without diabetic ketoacidosis, dehydration and thrombosis.

### Hypoglycemia

The Epidemiology of Diabetes and Ramadan (EPIDIAR) study of 12,243 Muslim patients showed that: 1,070 (8.7%) patients with type 1 diabetes and 11,173 (91.3%) patients with type 2 diabetes, reported that fasting during Ramadan increased the risk of severe hypoglycemia by 7.5-fold (from 0.4 to 3 events per 100 people per month). During Ramadan, 2% of patients with type 2 diabetes had experienced at least one episode of severe hypoglycemia requiring hospitalization and 42.8% of patients with type 1 diabetes and 78.7% with type 2 diabetes fasted for at least 15 days [27].

A prospective cohort study concluded that fasting during Ramadan increased the rate of symptomatic hypoglycemia for patients with type 2 diabetes about 1.6 fold [30].

### Hyperglycemia

Varying effects of fasting have been reported in people with diabetes: deteriorating, improving, and showing no change. The EPIDIAR study showed a five-fold increase in the incidence of severe hyperglycemia (requiring hospitalization) during Ramadan in people with type 2 diabetes. The excessive reductions in blood glucose-lowering medications may be one of the main causes [27].

### Diabetic ketoacidosis

Diabetic patients who fast Ramadan are at elevated risk for developing diabetic ketoacidosis, particularly if they have high blood glucose levels before the period of fasting begins. The risk for diabetic ketoacidosis may be majored further increased due to excessive reduction of insulin – based on the assumption that food intake is reduced during the month of Ramadan of Ramadan [31].

### Dehydration and thrombosis

A reduction intake of fluids can induce dehydration particularly in hot and humid climates, and among people who perform hard physical labor. Furthermore, hyperglycemia can result in the loss of body fluid through excessive urination, and contribute to depletion of electrolytes in the body. People with pre-existing nerve damage may develop symptoms of low blood pressure. This can lead to loss of consciousness, falls, and injuries, such as bone fractures. People with diabetes have lower levels of endogenous anticoagulants and are at risk for blood clotting – which might result in heart attack or stroke. Increased blood viscosity as a result of dehydration may exacerbate the risk of thrombosis [32,33].

It should be mentioned that effects of fasting may be affected by genetic and environmental factors, such as nutrition habits and the length of fasting day. Therefore, difference in the effects of Ramadan fasting may occur between seasons and countries [34].

For that purpose, a Pre-Ramadan diabetes assessment is highly recommended so that patients can be made aware of individual risks and recommended strategies to minimize these risks – or even advised to refrain from full observance due to their current health status [10].

## Assessment before Ramadan

Expert opinion recommends that, if a patient wishes to fast during Ramadan, the primary physicians and/or diabetes care specialists should make an assessment several months before Ramadan [35]. Specific attention should be paid to people’s overall well-being and to the control of their blood glucose levels, blood pressure, and lipids. Appropriate blood tests should be ordered and evaluated. People with diabetes should receive specific medical advice concerning the potential risks involved in fasting (Table 2).

<p><b>Medical assessment</b></p> <ul style="list-style-type: none"> <li>• Tailored to individual needs.</li> <li>• Review of overall glycaemic control, BP &amp; lipids, renal function, weight and BMI.</li> <li>• Review of diabetes medications, i.e. therapy options, timing and dosage adjustment.</li> </ul> <p><b>Ramadan focused structured education</b></p> <p>To educate patients, family and carers on the effects of fasting on diabetes, including:</p> <ul style="list-style-type: none"> <li>• Meal planning and dietary advice with dietician.</li> <li>• Appropriate exercise.</li> <li>• Blood glucose monitoring.</li> <li>• Recognition and management of acute complications e.g. hypo-, hyperglycaemia, dehydration, and when to break fast.</li> </ul>
--

**Table 2:** The pre-Ramadan assessment (2-4 months before Ramadan) [28].

It should be noticed that Muslim religious leaders play an important role too, regarding religious fasting, for patients with diabetes, by providing them education and support, especially for those who insist to fast regardless the risks involved, and also for patients who do not wish to fast but do so in order not to alienate themselves from the rest of the Muslim community [9,28].

## Recommendations for Safer Ramadan Fasting

Several months prior to Ramadan, leaflets, booklets, posters, classes and group sessions containing information and advice should be provided in diabetes healthcare centers [36]. The physician and/or diabetes healthcare team should be seen at least one month prior to the start of the fast [1,36]. Treatment should be individualized to take into account overall health status, metabolic control, dietary practices, customs and lifestyle.

A novel program called READ (Ramadan Education and Awareness in Diabetes) has been designed in UK and endorsed by the National Institute for Health and Clinical Excellence. This Ramadan-focused education program was aimed, on one hand, to provide a structured education among people with type 2 diabetes who wanted to fast Ramadan and, on the other hand, to determine its effectiveness on weight and hypoglycemic episodes during the fasting period [37]. Table 3 outlines the objectives of the program [37].

<p><b>Meal planning and dietary advice</b></p> <ul style="list-style-type: none"> <li>• The diet during Ramadan should not differ from a healthy balanced diet.</li> <li>• Slow energy-release food (such as wheat, semolina, beans, rice) is favoured.</li> <li>• Reduce food high in saturated fat (such as ghee, samosas and pakoras).</li> </ul> <p><b>Exercise</b></p> <ul style="list-style-type: none"> <li>• Light and moderate exercise is recommended for T2D patients.</li> <li>• Rigorous exercise during evening times may cause hypoglycaemia.</li> <li>• <i>Tarawaih</i> prayers (a series of prayers after the sunset meal) should be considered as part of the daily exercise regimen.</li> </ul> <p><b>Medical assessment</b></p> <ul style="list-style-type: none"> <li>• Encourage patients to seek medical advice from their general practitioners before Ramadan with regarding to any necessary medication change or dose adjustment.</li> </ul>	<p><b>Blood glucose monitoring</b></p> <ul style="list-style-type: none"> <li>• Blood glucose testing does not constitute breaking fast.</li> <li>• Patients who fast should know how to test their blood glucose.</li> <li>• We encourage patients to test their blood glucose when symptomatic or unwell.</li> </ul> <p><b>Recognizing and managing complications</b></p> <ul style="list-style-type: none"> <li>• Major symptoms of hypoglycaemia, dehydration and hyperglycaemia should be well known by T2D patients and how to manage them.</li> <li>• Furthermore, for patients’ safety, fast should be broken when hypoglycaemia occurs.</li> </ul>
---	---

**Table 3:** Aims of the Ramadan education and awareness in diabetes [28,38].

## Diet during Ramadan

During the month of Ramadan the majority of people have a meal after sunset, referred to as *Iftar* (breaking of the fast), and a smaller meal before dawn referred to as *Sahor* (pre-dawn). Few studies have assessed the food intake among type 2 diabetics and we find conflicting results with those reported by Azizi and Siahkolah by Azizi and Siahkolah [8]. A decrease in daily calorie intake has been seen as one of the advantages in Ramadan fasting [8,12,19,23,24,26,29,39]. Some authors [12] observed a decrease in energy intake (103 Kcal/d), though not statistically significant, which is correlated with meal frequency [23]. However, in another study [21], the Total Daily Energy Intake (TEI) remained unchanged.

Diet during non-fasting hours should not differ from the usual recommended healthy and balanced diet for people with diabetes [1,40]. Meals should not be skipped and the “*Sahor*” meal should be taken as late as possible and not at midnight [1,41]. Ideally, three meals a day spaced four to six hours apart would still be consumed. Culturally important foods do not have to be forbidden, but very sweet desserts and high-fat and fried foods should be limited to small portions [40]. Gorging and overconsumption should be avoided. Concerning dehydration during Ramadan, it represents the greatest health risk for a full-day fast. To reduce the risk, two liters of water or sugar- and caffeine-free liquid should be consumed.

As a general rule, people should maintain a healthy and balanced diet during Ramadan month. The common practice of ingesting large amounts of foods that are high in fat and carbohydrates, especially at the sunset meal, should be avoided. It is recommended that non-caloric fluid intake be increased during the non-fasting hours. The pre-dawn meal should be taken as late as possible before the start of the daily fast.

### Medical assessment

**People with type 1 diabetes:** In general, people with type 1 diabetes are at very high risk of developing severe complications, and should be strongly advised to not fast during Ramadan [10].

Typically, people with type 1 diabetes who insist on fasting will need two daily injections of NPH (Neutral Protamine Hagedorn) intermediate-acting insulin, administered before the pre-dawn and sunset meals, in combination with short-acting insulin to cover food intake during the associated meals. However, there is an increased risk of hypoglycemia around midday due to peaking of the early morning insulin dose [31].

Using long-acting ultralente insulin is an option – twice-daily injections at 12-hour intervals to mimic basal insulin, plus rapid- or short-acting insulin before the two meals. Ultralente cannot really be considered basal insulin, since it has a broad peak of action – 8 to 14 hours. Therefore, protracted hypoglycemia can occur, especially since the duration of action of ultralente varies widely – between 18 and 30 hours [1].

### People with type 2 diabetes

**Oral medications:** Since there are no large randomized controlled trials to assess the safety and efficacy of the various (OHA) Oral Hypoglycemic Agents for people with diabetes during Ramadan, it is recommended to avoid drugs increasing the risk of developing hypoglycemia [10]. However, another issue can arise, many health care providers advise to reduce OHA during Ramadan in order to avoid hypoglycemia [27] leading to the elevation of the postprandial hyperglycemia. In addition, the timing of medication needs to be modified according to the type of drug, and the dose adjustment will vary according to individual glycemic control [10].

In general, OHA that act by increasing insulin sensitivity are associated with a lower risk of hypoglycemia. People who take metformin may fast safely because the risk of developing

hypoglycemia is reduced. However, the timing of the doses should be modified: two thirds of the total daily dose to be taken immediately before “*Iftar*”, with the other third taken before undertaking the fast i.e., at “*Sahor*”. People on insulin sensitizers (rosiglitazone and pioglitazone) have a low risk of hypoglycemia. Usually no change in dose is required [31]. Concerning sulfonylureas, they should be used with caution during fasting, because of the inherent risk of hypoglycemia. Newer members of the sulfonylureas: gliclazide MR [42], glimepiride [43] have been shown to be effective, resulting in a lower risk of hypoglycemia.

**Incretin-based therapies (exenatide and gliptins):** DPP-4 inhibitors prevent the rapid degradation of endogenous Glucagon-Like Peptide-1 (GLP-1) and glucose-dependent insulinotropic peptide and increases plasma levels of their intact, active form. Vildagliptin, an anti OHA, which acts by an enhancement of pancreatic islet function, with improved  $\beta$ - and  $\alpha$ -cell sensitivity to glucose [44], is associated with minimal risk of hypoglycemia in combination with metformin, sulphonyl urea or a thiazolidinedione [45,46]. In a recent study, vildagliptin add-on to metformin reduced HbA1c without causing hypoglycemia [47].

Glucagon-Like Peptide-1 (GLP-1) is a naturally occurring peptide hormone, released from the gut after eating. The GLP-1 analogues have shown their effectiveness as unique agents providing glycemic decrease with a significant low risk of hypoglycemia during Ramadan. However, further evidence regarding their use is needed [48].

**Insulin:** Insulin can be safely used in type 2 diabetic individuals. Twice daily premixed insulins such as lispro mix 25/75 (25% insulin lispro and 75% neutral protamine lispro) and human insulin 30/70 have been used safely during Ramadan. People with T2D under insulin face similar problems to those associated with type 1 diabetes, so the incidence of hypoglycemia episodes is lower among them [31]. Long-acting insulin, such as glargine, should be given at “*Iftar*” to avoid hypoglycemia during daytime fasting [49]. It is recommended that the usual morning dose can be used with the sunset meal and half the usual evening dose can be used with the pre-dawnmeal. In a Turkish study, the authors reported that meal-time repaglinide three times a day plus single-dose insulin glargine was safe (no hypoglycemia episodes, no change in glycemic control or weight gain) for individuals who insisted on fasting with low risk [50].

**Pregnancy and fasting in people with diabetes:** Pregnant women belong to the category with very high risk, basically they should not fast. The Quran exempts pregnant and breast feeding women from fasting in the absence of diabetes. Evidently, diabetic pregnant women are at a higher risk if they undertake fasting during the whole month. Hence, guidelines for the management of diabetes in Ramadan strongly advise against fasting [24].

**Breaking the fast:** When fasting may have a negative impact on health an exemption from fasting is offered by Islam, as said in the sacred book Quran:“(Fasting) for a fixed number of days; but if any of you is ill, or on a journey, the prescribed number (Should be made up) from days later. For those who can do it (With hardship), is a ransom, the feeding of one that is indigent” (Al-Qur’an, 2:184). All patients should break the fast if blood glucose is  $<3.3$  mmol/L or exceeds 16.7 mmol/L [1]. They should be advised to break the fast if blood glucose is  $<3.9$  mmol/L in the morning if the patient is taking sulfonylurea or insulin [1].

## Conclusion

Ramadan fasting remains a real challenge for Muslim diabetic patients and their health care providers since religion and culture have a great impact on the management of diabetes during this month. Since the decision is ultimately up to the patient, more education and care is required, and more medical training for physicians, need to be given. The Pre-Ramadan period is crucial to offer work group and awareness campaigns on diabetes education, with sessions focused on Ramadan fasting and adjustment of treatment [37,51].

Finally, more research is welcome on Ramadan fasting and diabetes as there is a lack of strong evidence-based practice.



## References

1. Al-Arouj M, Bouguerra R, Buse J, Hafez S, Hassanein M, et al. (2005) Recommendations for management of diabetes during Ramadan. *Diabetes Care* 28: 2305-2311.
2. Qureshi B (2002) Diabetes in Ramadan. *J R Soc Med* 95: 489-490.
3. Khaled BM, Bendahmane M, Belbraouet S (2006) Ramadan fasting induces modifications of certain serum components in obese women with type 2 diabetes. *Saudi Med J* 27: 23-26.
4. Afifi ZE (1997) Daily practices, study performance and health during the Ramadan fast. *J R Soc Health* 117: 231-235.
5. Finch GM, Day JE, Razak, Welch DA, Rogers PJ (1998) Appetite changes under free-living conditions during Ramadan fasting. *Appetite* 31: 159-170.
6. Farad-Bensenouci S, Maillot F, Lamise F (2002) Les risques du Ramadan chez les sujets sains et les patients diabétiques. *CahNutrDiet* 37: 96-104.
7. Bouguerra R, Jabrane J, Maâtki C, Ben Salem L, Hamzaoui J, et al. (2006) [Ramadan fasting in type 2 diabetes mellitus]. *Ann Endocrinol (Paris)* 67: 54-59.
8. Azizi F, Siahkoleh B (2003) Ramadan fasting and diabetes mellitus. *Archives of Iranian Medicine* 6: 237-242.
9. Beshyah SA (2009) Fasting during the month of Ramadan for people with diabetes: Medicine and Fiqh United at last. *Ibnosina J Med Biomed Sci* 1: 58-60.
10. Hassanein MM (2010) Diabetes and Ramadan-How to achieve a safer fast for Muslims with diabetes. *Br J Diabetes Vasc Dis* 10: 246-250.
11. Sadeghirad B, Motaghipisheh S, Kolahtooz F, Zahedi MJ, Haghdoost AA (2012) Islamic fasting and weight loss: a systematic review and meta-analysis. *Public Health Nutr.*
12. Mafauzy M, Mohammed WB, Anum MY, Zulkifli A, Ruhani AH (1990) A study of the fasting diabetic patients during the month of Ramadan. *Med J Malaysia* 45: 14-17.
13. Athar S, Habib M (1994) Management of stable type 2 diabetes NIDDM during Ramadan fasting. First International Congress on Health and Ramadan. Casablanca Morocco, FRSMR (Hassan II Foundation for Scientific and Medical Research on Ramadan) 19-22.
14. Navaei L, Mehrabi Y, Azizi F (2001) Changes in body weight, blood pressure, consumption pattern and biochemical parameters in diabetic patients during fasting in Ramadan. *Irn J Endocrinol Metab* 3: 125-132.
15. Khatib FA, Shafagoj YA (2004) Metabolic alterations as a result of Ramadan fasting in non-insulin-dependent diabetes mellitus patients in relation to food intake. *Saudi Med J* 25: 1858-1863.
16. Ziaee V, Razaee M, Ahmadinejad Z, Shaikh H, Yousefi R, et al. (2006) The changes of metabolic profile and weight during Ramadan fasting. *Singapore Med J* 47: 409-414.
17. Al-Hourani HM, Atoum MF (2007) Body composition, nutrient intake and physical activity patterns in young women during Ramadan. *Singapore Med J* 48: 906-910.
18. Salehi M, Neghab M (2007) Effects of fasting and a medium calorie balanced diet during the holy month Ramadan on weight, BMI and some blood parameters of overweight males. *Pak J Biol Sci* 10: 968-971.
19. Khaled BM, Belbraouet S (2009) Effect of Ramadan fasting on anthropometric parameters and food consumption in 276 type 2 diabetic obese women. *Int J Diabetes Dev Ctries* 29: 62-68.
20. Rashed H (1992) The fast of Ramadan: No problem for the well: the sick should avoid fasting. *BMJ* 304: 521-522.
21. Klocker N, Belkhadir J, El Ghomari H, Mikou A, Naciri M, et al. (1997) Effects of extreme chrono- biological diet alternations during Ramadan on metabolism in NIDDM with oral treatment. Second International Congress on Health and Ramadan. Istanbul, Istanbul, Turkey, Morocco: FRSMR (Hassan II Foundation for Scientific and Medical Research on Ramadan) 78-79.
22. Yarahmadi Sh, Larjani B, Bastanhigh MH, Pajouhi M, Baradar Jalili R, et al. (2003) Metabolic and clinical effects of Ramadan fasting in patients with type II diabetes. *J Coll Physicians Surg Pak* 13: 329-332.



23. Bouguerra R, Belkadhi A, Jabrane J, Hamzaoui J, Maâtki C, et al. (2003) Metabolic effects of the month of Ramadan fasting on type 2 diabetes. *East Mediterr Health J* 9: 1099-1108.
24. Sari R, Balci MK, Akbas SH, Avci B (2004) The effects of diet, sulfonylurea, and Repaglinide therapy on clinical and metabolic parameters in type 2 diabetic patients during Ramadan. *Endocr Res* 30: 169-177.
25. Uysal AR, Erdoğyan MF, Sahin G, Kamel N, Erdoğyan G (1998) Clinical and metabolic effects of fasting in 41 type 2 diabetic patients during Ramadan. *Diabetes Care* 21: 2033-2034.
26. Belkhadir J, el Ghomari H, Klöcker N, Mikou A, Nasciri M, et al. (1993) Muslims with non-insulin dependent diabetes fasting during Ramadan: treatment with glibenclamide. *BMJ* 307: 292-295.
27. Salti I, Bernard E, Detoumay B, Bianchi-biscay M (2004) Epidiar study. A population-based study of diabetes and its characteristics during the fasting month of Ramadan 1422/2001 (Epidiar) study group. *Diabetes Care* 27: 2306-2311.
28. Hui E, Devendra D (2010) Diabetes and fasting during Ramadan. *Diabetes Metab Res Rev* 26: 606-610.
29. Chandalia HB, Bhargava A, Kataria V (1987) Dietary pattern during Ramadan fasting and effect on the metabolic control of diabetes. *Practical Diabet* 4: 287-290.
30. Loke SC, Rahim KF, Kanesvaran R, Wong TW (2010) A prospective cohort study on the effect of various risk factors on hypoglycaemia in diabetics who fast during Ramadan. *Med J Malaysia* 65: 3-6.
31. Ibrahim MA (2007) Managing diabetes during Ramadan. *Diabetes Voice* 52(2): 19-22.
32. Alghadyan AA (1993) Retinal vein occlusion in Saudi Arabia: possible role of dehydration. *Ann Ophthalmol* 25: 394-398.
33. Temizhan A, Dönderici O, Ouz D, Demirbas B (1999) Is there any effect of Ramadan fasting on acute coronary heart disease events? *Int J Cardiol* 70: 149-153.
34. Azizi F (2013) Islamic Fasting and Diabetes. *J Fasting Health* 1: 15.
35. Al-Arouj M, Assaad-Khalil S, Buse J, Fahdil I, Fahmy M, et al. (2010) Recommendations for management of diabetes during Ramadan: update 2010. *Diabetes Care* 33: 1895-1902.
36. Beshyah S, Benbarka M, Sherif I (2007) Practical Management of Diabetes during Ramadan Fast. *Libyan J Med* 2: 185-189.
37. Bravis V, Hui E, Salih S, Mehar S, Hassanein M, et al. (2010) Ramadan Education and Awareness in Diabetes (READ) programme for Muslims with Type 2 diabetes who fast during Ramadan. *Diabet Med* 27: 327-331.
38. Hui E, Bravis V, Hassanein M, Hanif W, Malik R, et al. (2010) Management of people with diabetes wanting to fast during Ramadan. *BMJ* 340: c3053.
39. Laajam MA (1990) Ramadan fasting and non-insulin-dependent diabetes: effect on metabolic control. *East Afr Med J* 67: 732-736.
40. Benaji B, Mounib N, Roky R, Aadil N, Houti IE, et al. (2006) Diabetes and Ramadan: review of the literature. *Diabetes Res Clin Pract* 73: 117-125.
41. Akbani MF, Saleem M, Gadit WU, Ahmed M, Basit A, et al. (2005) Fasting and feasting safely during Ramadan in the patient with diabetes. *Pract Diabetes Int* 22: 100-104.
42. Zargar AH, Siraj M, Jawa AA, Hasan M, Mahtab H (2010) Maintenance of glycaemic control with the evening administration of a long acting sulphonylurea in male type 2 diabetic patients undertaking the Ramadan fast. *Int J Clin Pract* 64: 1090-1094.
43. Glimpeiride in Ramadan (GLIRA) Study Group (2005) The efficacy and safety of glimepiride in the management of type 2 diabetes in Muslim patients during Ramadan. *Diabetes Care* 28: 421-422.
44. Ahrén B, Foley JE (2008) The islet enhancer vildagliptin: mechanisms of improved glucose metabolism. *Int J Clin Pract* 8-14.
45. Garber AJ, Sharma MD (2008) Update: vildagliptin for the treatment of Type 2 diabetes. *Expert Opin Investig Drugs* 17: 105-113.
46. Ferrannini E, Fonseca V, Zinman B et al. (2009) Fifty-two-week efficacy and safety of vildagliptin vs. glimepiride in patients with type 2 diabetes mellitus inadequately controlled on metformin monotherapy. *Diabetes Obes Metab* 11: 157-166.

47. Hassanein M, Hanif W, Malik W, Kamal A, Geransar P, et al. (2011) Comparison of the dipeptidyl peptidase-4 inhibitor vildagliptin and the sulphonyl urea gliclazide in combination with metformin, in Muslim patients with type 2 diabetes mellitus fasting during Ramadan: results of the VECTOR study. *Curr Med Res Opin* 27: 1367-1374.
48. Pathan MF, Sahay RK, Zargar AH, Raza SA, Khan AK, et al. (2012) South Asian Consensus Guideline: Use of GLP-1 analogue therapy in diabetes during Ramadan. *Indian J Endocrinol Metab* 16: 525-527.
49. Cesur M, Corapcioglu D, Gursoy A, Gonen S, Ozduman M, et al. (2007) A comparison of glycemic effects of glimepiride, repaglinide, and insulin glargine in type 2 diabetes mellitus during Ramadan fasting. *Diabetes Res Clin Pract* 75: 141-147.
50. Bakiner O, Ertorer ME, Bozkirli E, Tutuncu NB, Demirag NG (2009) Repaglinide plus single-dose insulin glargine: a safe regimen for low-risk type 2 diabetic patients who insist on fasting in Ramadan. *Acta Diabetol* 46: 63-65.
51. Gaborit B, Dutour O, Ronsin O, Atlan C, Darmon P, et al. (2011) Ramadan fasting with diabetes: an interview study of inpatients' and general practitioners' attitudes in the South of France. *Diabetes Metab* 37: 395-402.

## Chapter 9

# Ramadan Fasting and Infectious Diseases

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINOEMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINOEMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

According to the *Sunnah*, Ramadan fasting represents the fourth of the five pillars of the Islam creed. Even though patients are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers, by attending the special prayers, social gatherings and other ceremonies. However, there are no guidelines or standardized protocols that can help physicians to properly address the issues and concerns of patients with infectious diseases fasting in Ramadan and correctly advising them. Moreover, in a more interconnected and globalized society, in which more and more Muslim patients live in the Western countries, this topic is of high interest also for the general practitioner. For this purpose, we carried out a systematic review. No time and language restrictions were applied. Our main findings are that: 1) patients suffering from type 1 and 2 diabetes mellitus at risk of developing infectious complications should not fast; 2) Ramadan fasting has little or scarce impact on diarrheal patients; 3) Human Immunodeficiency Virus (HIV) represents a challenge and *ad hoc* combinations and regimens should be counseled and recommended to patients, as well as they should be advised not to take too heavy fatty meals when breaking the fast since this could interfere with the treatment; 4) Ramadan fasting has no effect on the effectiveness of anti-helminthic therapy; 5) patients with healed, non-active ulcer and with eradicated *Helicobacter pylori* can safely fast and take proton-pump inhibitors, whilst patients with active ulcer disease should not fast, since they have a higher probability of developing complications such as perforation.

**Keywords:** Diabetes Mellitus; Diarrhea; Human Immunodeficiency Virus; Hookworm and Tropical Infections; Infectious Diseases; Ramadan Fasting; Ulcer Disease

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is particularly blessed and of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*. Ramadan fasting (*as-sawm*) is considered one of the five Islamic pillars of the creed (*arkan al-Islam*), being the fourth according to the *Sunnah*, together with the faith declaration or profession (*as-shahada*), the ritual five daily prayers

(*as-salah*), the pilgrimage to Mecca (*hajj*), and charity (*zakat*). According to the *Shiaa*, Ramadan is the second practice of faith.

Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 “Al-Baqarah”, ayyat 183 and following verses*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. The fast is broken, taking two traditional meals, pre-dawn meal which is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable, since the Islamic calendar is a lunar one and therefore the Islamic year contains 354 days (instead of 365, as in the Gregorian or solar calendar). It can last 29 or 30 days. For this reason, the Ramadan month occurs 11 days earlier every year, and may fall in any period of the year. It makes a complete cycle in a span of 33-36 years. Therefore, mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1] or even 22 hours, in the extreme latitudes regions [1].

Pre-puberal and puberal children, menstruating, pregnant and breast-feeding women, sick people, debilitated older subjects and travelers (i.e., for a distance > 84 km) are exempted from this religious duty (*Surat 2 “Al-Baqarah”, ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers, by attending the prayers, social gatherings and other special ceremonies.

The effects of Ramadan fasting on patients with infectious diseases or at a risk of developing an infectious complication is not a mere academic topic or of limit interest for only the Arabic countries. In a globalized society, the physicians have to face with issues like the management of infectious diseases in Muslim patients that to want to fast during Ramadan, since more Muslims live in the Western societies [1]. However, information is sparse and no guidelines or standardized protocols exist. For this purpose, we have carried out a systematic review that could be helpful for general practitioners.

## Material and Methods

We systematically searched ISI Web of Science (WoS), Scopus, MEDLINE/PubMed, Google Scholar, DOAJ, EbscoHOST, Scirus, and ProQuest. We used a proper string made up of a combination of key-words such as “Islam”, “Ramadan”, “Fasting” and “Infection”.

Review articles or research manuscripts not pertinent with the aim of this systematic review were excluded. No time and language filters were applied.

## Results

We identified 10 studies (Table 1, divided according to their main topic), and we coded them. 3 studies focused on Human Immunodeficiency Virus (HIV), while other 3 research articles described the complications of ulcer disease during Ramadan. 2 studies assessed the infectious complications of patients suffering from type 1 and 2 diabetes mellitus. 1 study described the impact of Ramadan fasting on diarrheal patients and another 1 investigated the effect of fasting on the anti-helminthic therapy.

Investigated topic	References
Diabetes	Elmehdawi et al., 2009 [2] Kobeissy et al., 2008 [3] Surahio et al., 2009 [4]
Diarrhea	Leung et al., 2014 [6]
HIV	Güven, 2004 [7] Habib et al., 2009 [8] Yakasai et al., 2011 [9]
Hokworm and tropical infections	Sacko et al., 1999 [10]

Ulcer disease	Bdioui et al., 2012a [11] Bdioui et al., 2012b [12] Gökakin et al., 2012 [13]
---------------	---

**Table 1:** Studies divided according to their main topic.

## Discussion and Conclusions

There is a strong need for evidence-based suggestions and guidelines, since the literature on infectious diseases is scarce.

Kobeissy and coworkers [2] reviewed clinical recommendations for subjects suffering from type 1 diabetes mellitus and advised against fasting for those at risk of infections. This suggestion is valid also for type 2 diabetes, whose infectious complications were studied by Elmehdawi and coworkers [3]. The authors carried out a descriptive retrospective database-based analysis for the period 2007-2008. They found that infection was the commonest precipitating factor for Diabetic Ketoacidosis (DKA) during Ramadan (46.6%) followed by lack of adherence and compliance to treatment, even though there was no increase in the incidence and mortality rate for DKA. Surahio and collaborators [4] investigated another complication, namely the necrotizing fasciitis. They implemented a prospective observational study recruiting 35 patients. They found that the major co-morbid factors were old age, diabetes mellitus, hypertension and renal failure.

Other aspects of diabetes management have been already covered in other book-chapters [5].

The impact of religious fasting on diarrheal disease has been rarely studied. WeLeung and collaborators [6] conducted a retrospective database-based study and used data from the surveillance system of the International Centre for Diarrheal Disease Research, Bangladesh, Dhaka Hospital, from 1996 to 2012, to compare the pathogenesis and clinical presentation of patients suffering from diarrhea during Ramadan to that of control periods (that is to say, 30 days immediately before Ramadan). They found that the prevalence of enteric pathogens was comparable, even though *Shigella spp.* was less detected during Ramadan. The authors speculated that this may be due to differences in food preparation (closer to scheduled mealtime and with higher temperature) and hygiene (increased frequency of hand and foot washing, because of the intense period of prayers). Also symptoms during Ramadan among adult Muslim patients were largely similar to those admitted during control periods, even though patients during Ramadan were characterized by a more severe sense of thirst and a longer hospital stay. There were no differences in the prevalence of severe dehydration, duration of diarrhea, intravenous fluid use, and severe complications such as hypotensive shock or death rate. Slight differences were noticed in patients suffering from cholera. The authors concluded that Ramadan has a scarce impact on the clinical presentation of diarrheal patients.

Sub-Saharan countries such as Ethiopia, Kenya, Nigeria, Somalia, South-Africa, Tanzania and Uganda are plagued by a heavy burden of HIV Infection. According to Güven [7], HIV patients may suffer from decreased bone density both because of less calcium uptake during Ramadan fasting and impaired drug functioning. Indeed some antiretroviral drugs, such as Lopinavir, Indinavir, Nelfinavir, and Ritonavir require food consumption, others like Didanosine, Zidovudine and unboosted Indinavir and Amprenavir are instead affected by heavy fatty meals uptake (such as the traditional Ramadan meals) and others having a short half-life like Zalcitabine, Delavirdine, Indinavir, Nelfinavir and soft-gel Saquinavir are affected by dosing schedule, regular frequency of assumption, concentration. An irregular intake of HIV therapies may impair the clinical outcome, leading to a worsening of the symptoms and favoring the insurgence of drug resistance and to virological failure, as well as altering pharmacodynamics, pharmacokinetics, tolerability and effectiveness profiles. Moreover, they may be exposed to anxiety disorder. On the other hand, fasting could be beneficial, mitigating the adverse effects of HIV treatment, such as hypercholesterolemia

and hypertriglyceridemia. Habib and collaborators [8] studied treatment adherence and compliance as well as other customary practices like self-reported health-related quality of life among 243 patients on Anti-Retroviral Therapy (ART) (142 willing to fast, 101 not fasting) in Kano, in northern Nigeria, in the period of 23 September–22 October 2006. Adherence on ART during Ramadan was 96% among fasting subjects and 98% among non-fasting individuals, and ever since commencement of ART, 80% and 88%, respectively. Observing a similar adherence and side-effects rates between the two groups and not noticing any impact on body weight and CD4 cell count, they concluded that fasting during Ramadan for HIV patients was safe. Yakasai and collaborators [9] replicated and confirmed these findings recruiting a sample of 17 heavily treatment-experienced stable patients (10 men) in Nigeria. They compared once-daily versus twice-daily dosed Ritonavir boosted Lopinavir with fixed-dose Tenofovir-Emtricitabine once-daily. They did not find any changes in treatment adherence and compliance, diarrhoea, CD4 cell count, viral load, haematocrit level, kidney and liver function, and lipid concentration. Effectiveness, safety and tolerability were not affected by Ramadan fasting, in particular by changes in nutritional pattern, food behavior and circadian rhythm. However, two patients (one being fully virologically suppressed) had post-Ramadan viral rebound with a significant decrease in CD4 cell count. In conclusion, summarizing the studies, clinicians can be provided with some useful suggestions [8,9]:

- a. Nelfinavir should be taken with meals twice at higher doses instead of thrice daily;
- b. Protease Inhibitors (PIs) like Lopinavir or Ritonavir twice daily or Atazanavir once daily should be advised;
- c. If possible PIs can be boosted by Ritonavir;
- d. once-daily dose regimens (combinations such as Tenofovir/Lamivudine, Emtricitabine/Efavirenz or Tenofovir/Lamivudine/Efavirenz) should be recommended;
- e. Didanosine usage should be not recommended;
- f. Pharmacogenetic tests could be used in order to select those HIV patients that can safely fast, not having genetic variants related to drug resistance;
- g. Patients with prior known ART clinical failure should not fast;
- h. HIV patients should be counseled and advised about the meals for breaking the fast, for example, they should avoid heavy fatty meals.

Further research and studies are needed for optimizing ART regimens, considering the therapeutic window and schedule of each ARV and their combination.

Sacko and collaborators [10] performed a randomized, single-blind, placebo-controlled trial in order to test whether the Ramadan fasting would compromise the efficacy of some anti-helminthic drugs. They tested pyrantel, mebendazole and albendazole, which are used for the treatment of hookworm infections (*Necator americanus*). The study was carried out in January 1998, in Sikasso, southern Mali, and West Africa. 285 subjects were recruited (about 68% of local population), and in 151 of them hookworm infection was diagnosed. Albendazole proved to be the most effective drug with an efficacy in the range 92.1-99.7%. Fasting did not interfere with the efficacy of the drug.

*Helicobacter pylori* causes ulcer disease, whose reactivation and perforation risk is increased during Ramadan [11-13], because of increased gastric acidity. Bdioui and collaborators [11,12] conducted a retrospective comparative study of 224 cases and found a twofold increase in the frequency of the upper gastrointestinal hemorrhage. In conclusion:

- a. The patient with ulcer can safely fast while using a Proton Pump Inhibitor (PPI) if the ulcer is not active and *Helicobacter pylori* has been properly eradicated;
- b. The patient with an active ulcer should not fast.

Urinary tract infections have been already covered in another book-chapter [14].

The management of patients suffering from infectious diseases or at risk of developing an infectious complication is complex and requires a multidisciplinary team. Patients should be carefully checked and assessed, considering both the clinical symptoms and the laboratory exams. Also psychological aspects, such as motivation, and patient preferences and adherence/compliance to treatment should be investigated and taken into account. Care through faith and religious based practices should be explored [14].

Patients should be monitored during Ramadan and should be instructed to recognize some alarm symptoms. Patient empowerment plays a major role in the clinical management.

In conclusion, if stable, patient's eagerness to fast should be taken into account and even encouraged, since spirituality plays a key role. The patient feels indeed himself/herself more active being involved in the religious activities, and less depressed and isolated [14]. Some studies have shown that religiosity can increase treatment adherence and compliance among HIV patients [8,9].

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancina G (Eds.). "Special Issues in Hypertension".
2. Elmehdawi R, Ehmdida M, Elmagrehi H (2009) Incidence of Diabetic Ketoacidosis during Ramadan Fasting in Benghazi-Libya. *Oman Med J* 24: 99-102.
3. Kobeissy A, Zantout MS, Azar ST (2008) Suggested insulin regimens for patients with type 1 diabetes mellitus who wish to fast during the month of Ramadan. *Clin Ther* 30: 1408-1415.
4. Surahio AR, Khan AA, Farooq MU, Fatima I, Azhar MZ (2009) Prevalence of necrotizing fasciitis during Ramadan and Hajj 1427-H. *J Ayub Med Coll Abbottabad* 21: 125-129.
5. Khaled BM (2014) Ramadan Fasting and Diabetes. In: (Ed. Chtourou H) "Effects of Ramadan Fasting on Health and Athletic Performance". OMICS Group eBooks.
6. Leung DT, Das SK, Malek MA, Qadri F, Faruque AS, et al. (2014) Impact of Ramadan on clinical and microbiologic parameters of patients seen at a diarrheal hospital in urban Dhaka, Bangladesh, 1996-2012. *Am J Trop Med Hyg* 90: 294-298.
7. Güven GS (2004) Can HIV-infected patients fast during the month of Ramadan? *J Acquir Immune Defic Syndr* 35: 537-538.
8. Habib AG, Shepherd JC, Eng MK, Babashani M, Jumare J, et al. (2009) Adherence to anti retroviral therapy (ART) during Muslim Ramadan fasting. *AIDS Behav* 13: 42-45.
9. Yakasai AM, Muhammad H, Babashani M, Jumare J, Abdulmumini M, et al. (2011) Once-daily antiretroviral therapy among treatment-experienced Muslim patients fasting for the month of Ramadan. *Trop Doct* 41: 233-235.
10. Sacko M, De Clercq D, Behnke JM, Gilbert FS, Dorny P, et al. (1999) Comparison of the efficacy of mebendazole, albendazole and pyrantel in treatment of human hookworm infections in the southern region of Mali, West Africa. *Trans R Soc Trop Med Hyg* 93: 195-203.
11. Bdioui F, Melki W, Ben Mansour W, Loghmani H, Hellara O, et al. (2012) [Duodenal ulcer disease and Ramadan]. *Presse Med* 41: 807-812.
12. Bdioui F, Melki W, Dhibi K, Hamdi A, Saffar H (2012) Ramadan fasting and duodenal ulcer perforation before and after the era of *Helicobacter pylori*. A retrospective comparative study of 224 cases. *Presse Med* 41: 878-879.
13. GÃ¼nkakÄ±n AK, Kurt A, Atabey M, Koyuncu A, TopÅŖu O, et al. (2012) The impact of Ramadan on peptic ulcer perforation. *Ulus Travma Acil Cerrahi Derg* 18: 339-343.
14. Bragazzi NL (2014) Ramadan Fasting and Chronic Kidney Disease (CKD). In: Chtourou H (Ed.). "Effects of Ramadan Fasting on Health and Athletic Performance". OMICS Group eBooks.

## Chapter 10

# Ramadan Fasting and Chronic Kidney Disease (CKD)

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINO GMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINO GMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam creed. Even though patients are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers. However, there are no guidelines or standardized protocols that can help physicians to properly address the issue of patients with Chronic Kidney Disease (CKD) fasting in Ramadan and correctly advising them. Moreover, in a more interconnected and globalized society, in which more and more Muslim patients live in the Western countries, this topic is of high interest also for the general practitioner. For this purpose, we carried out a systematic review, including also articles written in Arabic, Turkish and Persian languages. Our main findings are that: 1) recipients of kidney allograft can safely fast during Ramadan; 2) evidences for safety in patients with nephrolithiasis and CKD are instead mixed and controversial. On the other hand, 3) most studies have been carried out during Ramadan falling in cold seasons, and there is scarce information about Ramadan fasting in hot seasons. For these reasons, the findings may be not generalizable and therefore cautions should be taken and applied when advising patients; the physicians should carefully monitor their patients during the fasting period with an adequate follow-up, in order to avoid any injurious effect.

**Keywords:** Chronic Kidney Disease (CKD); Hemodialysis; Kidney Transplantation; Peritoneal Dialysis; Ramadan Fasting; Renal Colic

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is of great value and significance among Muslims, representing the month of the descent of the *Qu'ran*. Ramadan fasting (*as-sawm*) is considered one of the five Islamic pillars of the creed (*arkan al-Islam*), together with the faith declaration (*as-shahada*), the ritual prayers (*as-salah*), the pilgrimage to Mecca (*hajj*), and charity (*zakat*).



Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 “Al-Baqarah”, ayyat 183*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. Pre-dawn meal is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable, since the Islamic calendar is a lunar one and therefore the Islamic year contains 354 days (instead of 365, as in the Gregorian or solar calendar). For this reason, the Ramadan month occurs 11 days earlier every year, and may fall in any period of the year. Therefore, mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1,2] or even 22 hours, in the extreme latitudes regions [1].

Pre-puberal and puberal children, menstruating, pregnant and breast-feeding women, sick people, debilitated older subjects, and travelers are exempted from this religious duty (*Surat 2 “Al-Baqarah”, ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers [3].

The effects of Ramadan fasting on kidney physiology and physiopathology are not a mere academic topic or a subject of interest limited only to the Arabic countries. In a globalized society, the physicians have to face with issues like the management of CKDs in Muslim patients that want to fast during Ramadan, since more Muslims live in the Western societies [4]. However, information is sparse and no guidelines or standardized protocols exist [3]. For this purpose, we have carried out a systematic review that could be helpful for general practitioners.

## Material and Methods

We systematically searched ISI Web of Science (WoS), Scopus, MEDLINE/PubMed, Google Scholar, Directory of Open Access Journals (DOAJ), EbscoHOST, Scirus, and ProQuest. We used a proper string made up of a combination of key-words such as “Islam”, “Ramadan”, “Fasting” and “Kidney”.

Gray literature was also manually searched and inspected. Review articles or research manuscripts not pertinent with the aim of this systematic review were excluded, while all the other research articles (including editorials, letters, case reports) were retained. No time and language filters were applied.

## Results and Discussion

We identified 26 studies (Table 1, divided according to their main topic), and we coded them, summarizing in Tables 2 and 3 the demographic characteristics, the clinical suggestions and interventions as well as the main findings, the investigated parameters and the used statistical techniques [2-26]. 15 studies investigated the effects and the impact of Ramadan fasting on recipients of kidney allograft, while 7 focused on patients suffering from renal colic and only 4 on CKD patients. Most studies were prospective and observational, with the exception of that by Basiri and collaborators, which is a retrospective, database-based study [12]. Most studies did not find any differences between fasters and not fasters, or between before and after Ramadan fasting (Table 4). The study by Bernieh and collaborators found improvements during the fasting and after [13]. Only 3 studies presented mixed evidences of an increased risk for fasting patients during Ramadan, and 3 showed clear negative evidences. However, most of studies (11/26) were conducted in cold seasons, while only 3 in hot seasons, for the other 12 no information was available (Table 5). For this reason, the findings may be not generalizable to hot seasons and therefore cautions should be taken and applied when fasting in those periods.

Kidney Pathology	Reference
Kidney transplant	Qurashi et al., 2012 [22] Mousavi et al., 2011 [20] Salem et al., 2010 [25] Boobes et al., 2009 [15] Einollahi et al., 2009 [16] Ghalib et al., 2008 [4] Einollahi et al., 2005 [17] Argani et al., 2003 [11] Said et al., 2003 [24] Abdalla et al., 1998 (First study) [5] Abdalla et al., 1998 (Second study) [5] Ouziala et al., 1998 [21] Al-Khader et al., 1996 [9] Bernieh et al., 1994 [14] Rashed et al., 1989 [23]
Renal colic	Günaydın et al., 2012 [2] Miladipour et al., 2012 [19] Abdolreza et al., 2011 [6] Bernieh et al., 2010 [13] Zghal et al., 2005 [26] Basiri et al., 2004 [12] Al-Hadramy, 1997 [7]
CKD	Al Wakeel et al., 2013 [3] El Wakil et al., 2007 [18] Al Muhanna, 1998 [10] Al-Khader et al., 1991 [8]

**Table 1:** Studies divided according to their main topic.

Reference	Investigated Parameters	Statistical Analysis
Al Wakeel et al., 2013 [3]	Weight, blood pressure, average daily urine output (as estimate of residual renal function), weekly creatinine clearance.	Not described in the test (method section).
Günaydın et al., 2012 [2]	Heart rate, systolic blood pressure, blood glucose, urine volume and density/specific gravity, urea, creatinine, leukocyte count in urine, erythrocyte count in urine, ketonuria.	Student's t-test, Pearson correlation analysis.
Miladipour et al., 2012 [19]	Total excretion of calcium, oxalate, uric acid, citrate, phosphate, magnesium, sodium and potassium in 24-hour urine, urine volume, urine concentration of calcium, oxalate, uric acid, citrate, phosphate, magnesium, sodium, and potassium, uric acid super saturation, calcium phosphate and calcium oxalate super saturation.	Student's t-test.
Qurashi et al., 2012 [22]	MDRD GFR, e-GFR, serum creatinine.	Student's t-test, chi square test, Wilcoxon signed-rank test.
Abdolreza et al., 2011 [6]	Number of visits and admissions to ED, mean room temperature, humidity.	ANOVA.
Mousavi et al., 2011 [20]	Systolic and diastolic blood pressure, serum urea, creatinine, BUN.	Not described in the test (method section).
Bernieh et al., 2010 [13]	Weight, systolic and diastolic blood pressure, hemoglobin, e-GFR, blood sugar, Hb A1c, serum creatinine, proteinuria, urinary sodium, potassium, carbonate, urea, lipid profile (HDL, LDL, total cholesterol, triglycerides), osmolality, protein/creatinine ratio.	ANOVA.
Salem et al., 2010 [25]	Body weight, blood pressure, urine volume, serum urea, creatinine, cyclosporine A, and creatinine clearance, urinary total count of leukocytes and erythrocytes, proteinuria.	Not described in the test (method section).

Boobes et al., 2009 [15]	Weight, systolic and diastolic blood pressure, creatinine, urea, uric acid, albumin, lipid profile (HDL, LDL, total cholesterol, triglycerides), ciclosporine A, tacrolimus, hemoglobin, MDRD GFR, sodium, potassium and carbonate.	Unpaired 2 tail Student's t-test.
Einollahi et al., 2009 [16]	Body weight and BMI, GFR, hemoglobin, creatinine clearance, serum BUN, creatinine, uric acid, blood glucose, electrolytes, lipid profile.	Paired Student's t-test, Pearson chi square test, Fisher exact test, Wilcoxon signed-rank test, Mann-Withney test.
Ghalib et al., 2008 [4]	Body weight, MAP, plasma creatinine, proteinuria.	Paired Student's t-test, chi square test, Wilcoxon signed-rank test, multiple linear regression.
El-Wakil et al., 2007 [18]	GFR, mean blood pressure, NAG, blood glucose, BUN, serum sodium, potassium, albumin, glucose, lipid profile (cholesterol, triglycerides), proteinuria.	Paired Student's t-test, Mann-Withney test, Wilcoxon signed-rank test, Spearman's rank correlation analysis.
Einollahi et al., 2005 [17]	Body weight, standing and lying blood pressure, serum levels BUN, creatinine, uric acid, lipids, and hemoglobin.	Not described in the test (method section).
Zghal et al., 2005 [26]	Crystalluria and other urinalysis parameters.	NA.
Basiri et al., 2004 [12]	Number of visits and admissions to ED.	Unpaired Student's t-test.
Argani et al., 2003 [11]	Body weight, blood pressure, BUN, lipid profile (LDL, VLDL, HDL cholesterol), C3, C4, IgA, IgG, IgM, B-cell count, T-cell count, proteinuria.	ANOVA, Friedman test.
Said et al., 2003 [24]	Serum urea, creatinine, systolic and diastolic blood pressure, blood sugar.	Pearson chi-square, Fisher exact test, Wilcoxon signed-rank test.
Abdalla et al., 1998 [5]	Serum potassium, sodium, urea, creatinine, ciclosporine A, urinary osmolality, FENa.	Paired Student's t-test.
Ouziala et al., 1998 [21]	Body weight, standing and lying blood pressure, serum sodium, potassium, chloride, calcium, phosphorus, uric acid, urea, creatinine, bicarbonate, total protein, lipid profile (triglycerides, cholesterol), bilirubin, aspartate amino transferase, alanine amino transferase, alkaline phosphatase, hemoglobin, white blood cells, proteinuria, FENa and hematuria, urine volume.	Student's t-test.
Al-Hadramy, 1997 [7]	Number of visits and admissions to ED for renal colic episodes.	Pearson product moment, correlation analysis, Student's t-test.
Al-Khader et al., 1996 [9]	Body weight, blood pressure, urinary osmolality, FENa.	NA.
Bernieh et al., 1994 [14]	Body weight, standing and lying blood pressure, total leukocyte count, hemoglobin, serum potassium, sodium, urea, creatinine, total protein, glucose, albumin, ciclosporine A, lipid profile (cholesterol, triglycerides), FENa, urine volume, proteinuria.	Student's t-test.
Al-Khader et al., 1991 [8]	Body weight, blood pressure, urinalysis.	NA.
Rashed et al., 1989 [23]	NA.	NA.

**Table 2:** Studies summarized according to the investigated parameters and the used statistical techniques.

**Abbreviations:** ANOVA: Analysis of Variance; BMI: Body Mass Index; BUN: Blood Urea Nitrogen; ED: Emergency Department; e-GFR: estimated Glomerular Filtration Rate; FENa: Fractional Excretion of sodium; GFR: Glomerular Filtration Rate; Hb: Hemoglobin; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; MAP: Mean Arterial Pressure; MDRD: Modification of Diet in Renal Disease; NA: Not Available; NAG: N-Acetyl-B-D-Glucosaminidase; VLDL: Very Low-Density Lipoprotein

Reference	Demographic Characteristics	Main Findings
Al Wakeel et al., 2013 [3]	<p>Study Design: prospective cohort observational/interventional study.</p> <p>Sample: 18 patients (10 F, 8 M) out of an initial cohort of 31 under PD; 8 on CAPD, 10 on CCPD.</p> <p>Age: mean age 41.8 ± 15.7 years, in the range of 17-66 years.</p> <p>Mean Fasting Duration: 14 hours.</p> <p>Patients Monitoring: 3-4 weeks before Ramadan, during Ramadan, 4 weeks after Ramadan.</p> <p>Inclusion Criteria: good and stable general health, autonomy and compliance to treatment.</p> <p>Exclusion Criteria: co-morbidities, lack of autonomy and compliance to treatment.</p> <p>Place: Saudi Arabia.</p> <p>Time: Ramadan 2009 (August-September).</p>	<p>Complication rates: 5/18 (27.8%).</p> <p>No statistically significant changes in the biomarkers and parameters.</p>
Günaydın et al., 2012 [2]	<p>Study Design: matched case-control prospective observational study.</p> <p>Sample: 61 subjects (45 M, 16 F), 35 fasting (25 M, 10 F), 26 non-fasting (20 M, 6 F) as control group.</p> <p>Age: mean age 41.13 years.</p> <p>Mean Fasting Duration: 18 hours.</p> <p>Patients Monitoring: during Ramadan.</p> <p>Inclusion Criteria: faster, aged more than 18 years, with episodes of renal colic, accessing the ED.</p> <p>Place: Turkey.</p> <p>Time: Ramadan 2011 (August).</p>	<p>No significant changes apart from heart rate (<i>p-value</i>=0.007). Some significant correlations between urea and creatinine (<i>r</i>=0.38, <i>p-value</i>=0.003), between urine erythrocyte and leukocyte number (<i>r</i>=0.29, <i>p-value</i>=0.026), and between fasting days and blood pressure (<i>r</i>=0.48, <i>p-value</i>=0.015) were observed. A correlation between urine density and dehydration was NOT observed.</p>
Miladipour et al., 2012 [19]	<p>Study Design: prospective matched case-control observational study.</p> <p>Sample: 57 men, 37 with kidney calculi, matched with a randomly selected group of 20 subjects with no history of kidney calculi.</p> <p>Age: mean age 41.66 ± 6.80 years, in the range of 30-55 years.</p> <p>Mean Fasting Duration: 15 hours.</p> <p>Patients Monitoring: one day before Ramadan, during Ramadan, one day after Ramadan.</p> <p>Inclusion Criteria: subjects with a history of kidney calculi.</p> <p>Exclusion Criteria: co-morbidities.</p> <p>Place: Iran.</p> <p>Time: NA.</p>	<p>Total excretions of calcium, phosphate, and magnesium in 24-hour urine, as well as urine volume during fasting were significantly lower. Urine concentration of calcium during fasting was significantly lower (<i>p-value</i> &lt;0.001), while urine concentrations of uric acid, citrate, phosphate, sodium, and potassium were significantly higher. Uric acid super saturation was increased, while calcium phosphate super saturation was decreased significantly during fasting.</p>
Qurashi et al., 2012 [22]	<p>Study Design: prospective matched case-control observational study.</p> <p>Sample: 43 fasters <i>versus</i> 37 non fasters.</p> <p>Age: mean age 43.7 ± 15.6 years for the fasting group. <i>versus</i> mean age 41.8 ± 15.4 for the non-fasting group.</p> <p>Mean Fasting Duration: 12-14 hours.</p> <p>Patients Monitoring: NA.</p> <p>Inclusion Criteria: recipients of kidney allograft. Mean length of time after transplant in the 2 groups was 64.4 ± 30.4 (for the fasters) and 27.7 ± 36.7 months (for the non-fasters). Mean follow up 7.6 ± 1.3 months.</p> <p>Exclusion Criteria: NA.</p> <p>Place: Saudi Arabia.</p> <p>Time: Ramadan 2011 (August).</p>	<p>No statistically significant differences.</p>
Abdolreza et al., 2011 [6]	<p>Study Design: prospective observational cohort study.</p> <p>Sample: 610 patients with renal colic (441 M, 169 F).</p> <p>Age: in the range 15-85 years (mean age 37.6 years).</p> <p>Patients Monitoring: 2 weeks before Ramadan, during Ramadan, 2 weeks after Ramadan.</p> <p>Inclusion Criteria: patients with episodes of renal colic.</p> <p>Exclusion Criteria: none.</p> <p>Time: Ramadan 2008 (September).</p> <p>Place: Iran.</p>	<p>The number of admissions due to renal colic was high during the first two weeks of Ramadan.</p>

Mousavi et al., 2011[20]	<p>Study Design: clinical case reports.  Sample: 5 patients (2 M, 3 F); 2 suffering from glomerulonephritis, 1 from diabetes mellitus.  Age: mean age 32.6 ± 6.7 years, in the range 25-40 years.  Mean Fasting Duration: NA.  Patients Monitoring: NA.  Inclusion Criteria: NA.  Exclusion Criteria: NA.  Time: NA.  Place: Iran.</p>	No statistically significant changes.
Bernieh et al., 2010 [13]	<p>Study Design: prospective observational cohort study.  Sample: 31 CKD patients (19 M, 12 F) from an initial cohort of 45 subjects, 14 in stage III, 12 in stage IV, 5 in stage V; 19 suffering from diabetes, 22 from hypertension.  Age: mean age 54.0 ± 14.2 years, in the range of 23-81 years.  Mean Fasting Duration: NA.  Patients Monitoring: 1 month before Ramadan, during Ramadan, 1 month after Ramadan.  Inclusion Criteria: patients with CKD, age more than 18 years.  Exclusion Criteria: patients with kidney transplant, history of acute tubular necrosis and renal colic, severe co-morbidities, pregnancy, needing to assume medications more than twice a day.  Time: Ramadan 2005 (October-November).  Place: United Arab Emirates.</p>	Weight reduction and lower systolic and diastolic blood pressure. e-GFR showed a significant improvement during the fasting month and the month after. The blood sugar was high during fasting with an increment in the Hb A1c level. Better lipid profile and reduction of the proteinuria and FENa were observed.
Salem et al., 2010 [25]	<p>Study Design: prospective cohort observational study.  Sample: 25 patients recipient of kidney allograft (from an initial cohort of 100 subjects), 15 M and 10 F; mean post-transplantation duration of 8.5 years, with a range of 1.5-26 years; 5 patients suffering from hypertension; the final list of patients includes 20 patients (5 did not complete the follow-up).  Age: mean age 41.7 ± 9.8 years (range 28-57 years) for the M subjects, mean age of 44.9 ± 12.3 years (range 32-62 years) for the F patients.  Mean Fasting Duration: NA.  Patients Monitoring: 2weeks before Ramadan, during Ramadan, 2 weeks after Ramadan.  Inclusion Criteria: good renal function.  Exclusion Criteria: NA.  Time: Ramadan 2008 (September).  Place: Libya.</p>	No statistically significant changes.
Boobes et al., 2009 [15]	<p>Study Design: prospective cohort observational study.  Sample: 22 patients (10 M, 12 F).  Age: mean age 47 ± 11.6 years (age in the range 25-69 years).  Mean Fasting Duration: 12 hours and half.  Patients Monitoring: 1 month before Ramadan, during Ramadan, 1 month after Ramadan.  Inclusion Criteria: recipients of kidney allografts.  Exclusion Criteria: NA.  Time: Ramadan 2004 (October-November).  Place: United Arab Emirates.</p>	No statistically significant changes apart from albumin ( <i>p-value</i> =0.02), triglycerides ( <i>p-value</i> =0.0011) and ciclosporine A level ( <i>p-value</i> =0.03). No complications or adverse effects.
Einollahi et al., 2009 [16]	<p>Study Design: prospective matched case-control observational study.  Sample: 41 fasting patients matched with 41 non-fasting subjects.  Age: mean age 42 ± 12 years for the fasting group versus mean age 43 ± 12 years for the non-fasting group.  Mean Fasting Duration: NA.  Patients Monitoring: during Ramadan.  Inclusion Criteria: transplantation at least 1 year prior to the study and stable renal function for at least 6 months prior to the study.  Exclusion Criteria: NA.  Time: Ramadan 2007 (September-October).  Place: Iran.</p>	No statistically significant changes.

Ghalib et al., 2008 [4]	<p>Study Design: prospective matched case-control observational study.</p> <p>Sample: 35 fasting patients matched with 33 non-fasting subjects.</p> <p>Age: mean age <math>39.5 \pm 13.2</math> years for the fasting group <i>versus</i> mean age <math>41.5 \pm 14.0</math> years for the non-fasting group.</p> <p>Mean Fasting Duration: 12-14 hours.</p> <p>Patients Monitoring: during Ramadan and throughout the 3 years of this study.</p> <p>Inclusion Criteria: good and stable renal functions.</p> <p>Exclusion Criteria: impaired e-GFR/GFR, severe co-morbidities.</p> <p>Time: Ramadan 2004 (October-November), Ramadan 2005 (October-November), Ramadan 2006 (September-October).</p> <p>Place: Saudi Arabia.</p>	No statistically significant changes.
El-Wakil et al., 2007 [18]	<p>Study Design: prospective observational cohort study.</p> <p>Sample: 15 pre-dialysis CKD patients (9 F, 6 M); 6 healthy volunteers as control group. Patients were suffering from diabetes mellitus (21.4% of the cases), hypertension (21.4%), chronic pyelonephritis (21.4%), chronic glomerulonephritis (14.2%), polycystic kidney disease (14.2%) and obstructive uropathy (7.14%).</p> <p>Age: mean age <math>53.0 \pm 15.6</math> years, in the range of 23-82 years.</p> <p>Mean Fasting Duration: NA.</p> <p>Patients Monitoring: NA.</p> <p>Inclusion Criteria: good and stable renal functions, creatinine clearances below 60 ml/min.</p> <p>Exclusion Criteria: age less than 20 years, severe co-morbidities.</p> <p>Time: Ramadan 2001 (November).</p> <p>Place: Egypt.</p>	There was a significantly positive correlation between the NAG values and the change in the blood glucose level ( $p$ -value=0.001).
Einollahi et al., 2005 [17]	<p>Study Design: prospective matched case-control observational study.</p> <p>Sample: 19 fasting patients (11 M, 8 F) matched with a group of 20 subjects who had not fasted in the last 3 years.</p> <p>Age: <math>33.5 \pm 10.5</math> years for the fasting group <i>versus</i> mean age <math>38.3 \pm 10.2</math> years for the non-fasting group.</p> <p>Mean Fasting Duration: 13-14 hours.</p> <p>Inclusion Criteria: transplantation at least 1 year prior to the study and serum creatinine values below 1.5 mg/dL.</p> <p>Exclusion Criteria: co-morbidities and need for medications more than twice a day; and polyuria (urine volume <math>&gt;2.5</math> L/d).</p> <p>Time: NA.</p> <p>Place: Iran.</p>	No statistically significant changes.
Zghal et al., 2005 [26]	<p>Study Design: matched case-control observational study.</p> <p>Sample: 90 patients divided in 3 groups of healthy fasting individuals, healthy non fasting individuals, and non-fasting patients with calcium lithiasis.</p> <p>Age: NA.</p> <p>Mean Fasting Duration: NA.</p> <p>Patients Monitoring: during Ramadan.</p> <p>Inclusion Criteria: episodes of renal colic.</p> <p>Exclusion Criteria: NA.</p> <p>Time: NA.</p> <p>Place: Tunisia.</p>	Crystalluria was higher in patients with lithiasis compared with healthy non-fasting individuals (58% <i>versus</i> 11.4%). An increase in serum and urinary urea concentration was observed.
Basiri et al., 2004 [12]	<p>Study Design: retrospective observational study, database-based.</p> <p>Sample: 574 subjects (398 M, 176 F); 43 subjects fasting in Ramadan period.</p> <p>Age: mean age <math>36.4 \pm 14.0</math> years.</p> <p>Mean Fasting Duration: 12 hours.</p> <p>Patients Monitoring: not applicable.</p> <p>Inclusion Criteria: subjects accessing the ED, with a history of renal colic.</p> <p>Exclusion Criteria: NA.</p> <p>Time: Ramadan 2000 (November-December), Ramadan 2001 (November-December).</p> <p>Place: Iran.</p>	There was no statistically significant difference between frequency of admissions for renal stone colic episodes in Ramadan and mean admission during the year for the 2 years of the study.

Argani et al., 2003 [11]	<p>Study Design: prospective observational cohort study.  Sample: 24 patients out of an initial cohort of 30 subjects (15 M, 15 F).  Age: mean age 39 ± 4 years.  Mean Fasting Duration: 12 hours.  Patients Monitoring: 1month before Ramadan, during Ramadan, 1 month after Ramadan.  Inclusion Criteria: recipients of kidney allograft, 30 months after the transplantation, with serum creatinine less than 1.8 mg/dL under triple immunosuppression and not taking drugs more than twice a day.  Exclusion Criteria: severe co-morbidities, diabetes mellitus.  Time: NA.  Place: Iran.</p>	No statistically significant differences between the 2 groups apart from the level of blood VLDL and HDL cholesterol, C3, C4 and IgM.
Said et al., 2003 [24]	<p>Study Design: prospective matched case-control study.  Sample: 145 kidney transplant recipients divided in two matched groups of fasting (71) and non-fasting (74) subjects.  Age: in the range of 18-64 years.  Mean Fasting Duration: 12 hours.  Patients Monitoring: 1 year before Ramadan, during Ramadan, 1 year after Ramadan.  Inclusion Criteria: good and stable general health, serum creatinine level less than 200 µmol/L for at least 6 months before Ramadan.  Exclusion Criteria: active peptic ulcer disease or renal stone disease.  Time: Ramadan 2000 (November).  PLACE: Kuwait.</p>	No statistically significant differences apart from the level of blood sugar (especially in patients suffering from diabetes type 1).
Abdalla et al., 1998 (First study) [5]	<p>Study Design: prospective observational cohort study.  Sample: 23 transplant recipients (18 M, 5 F), 17 with a normal function and 6 with an impaired but stable function with plasma creatinine levels not exceeding 300 mmol/l.  Age: mean age 35.5 years (age in the range 20-60 years).  Patients Monitoring: 1 week before Ramadan, during Ramadan, 1 week after Ramadan.  Inclusion Criteria: recipients of kidney allograft. Mean post-transplant period was 2.0 (range 0.6-6.3) years.  Exclusion Criteria: severe co-morbidities.  Time: NA.  Place: Saudi Arabia.</p>	No statistically significant changes apart from a small but statistically significant ( <i>p-value</i> =0.017) increase in serum potassium.
Abdalla et al., 1998 (Second study) [5]	<p>Study Design: prospective observational cohort study.  Sample: 34 patients with a mean post-transplant period of 6.2 (range 1.6–15.3) years, 8 of them had impaired function with a mean serum creatinine level of 193.6 (range 142–263) mmol/l.  Patients Monitoring: 1 week before Ramadan, during Ramadan, 1week after Ramadan.  Inclusion Criteria: good and functional allograft.  Exclusion Criteria: severe co-morbidities.  Time: NA.  Place: Saudi Arabia.</p>	No statistically significant differences.
Al Muhanna, 1998 [10]	<p>Study Design: prospective observational cohort study.  Sample: 36 patients (18 M and 18 F), with moderate to severe renal failure.  Age: mean age of 39 ± 5 years.  Monitoring Patients: during Ramadan, 2 weeks after Ramadan.</p>	There was a statistically significant elevation of serum creatinine, BUN, uric acid during the month of Ramadan and two weeks after Ramadan. There was a statistically significant deterioration of creatinine clearance and other biochemical parameters. Complications rate: 25% (liquid and fluid accumulation, lower limb edema, weight gain, poor control of blood pressure).

Ouziala et al., 1998 [21]	<p>Study Design: prospective observational cohort study</p> <p>Sample: 14 patients (9 M, 5 F).</p> <p>Age: mean age 26.4 years (age in the range 18-32 years); transplantation 1-7 months before the beginning of the study.</p> <p>Mean Fasting Duration: 11 hours and half.</p> <p>Inclusion Criteria: stable renal functions, less than 12 months from the transplantation, not high immunosuppressive regimen.</p> <p>Exclusion Criteria: severe co-morbidities.</p> <p>Time: Ramadan 1997 (December-January).</p> <p>Place: Algeria.</p>	<p>There was no significant change in serum values apart from a significant elevation of total plasma proteins, urea, uric acid, hemoglobin, triglycerides, cholesterol, urinary sodium and potassium concentration (<i>p-value</i> &lt;0.05). 5 patients (35.7%) showed changes in body weight.</p>
Al-Hadramy, 1997 [7]	<p>Study Design: prospective observational cohort study.</p> <p>Sample: 447 M subjects with history of renal colic.</p> <p>Inclusion Criteria: subjects accessing the ED (80,951 ED recorded visits).</p> <p>Time: Ramadan 1992 (March-April), Ramadan 1993. (February-March), Ramadan 1994 (February-March).</p> <p>Place: Saudi Arabia.</p>	<p>There was no statistically significant difference between frequency of ED visits and admissions in Ramadan and in Haj festival (<i>Tholhejah</i>) and mean admission during the 3 years of the study. A significant correlation was found between urinary stone colic and both temperature and atmospheric pressure (<i>p-value</i> &lt;0.0001), but not with relative humidity.</p>
Al-Khader et al., 1996 [9]	<p>Study Design: prospective cohort observational study.</p> <p>Sample: 58 patients recipients of kidney allograft. No other information available.</p> <p>Age: NA.</p> <p>Patients Monitoring: NA.</p> <p>Inclusion Criteria: NA.</p> <p>Exclusion Criteria: NA.</p> <p>Time: NA.</p> <p>Place: Saudi Arabia.</p>	<p>No statistically significant differences.</p>
Bernieh et al., 1994 [14]	<p>Study Design: prospective observational cohort study.</p> <p>Sample: 11 patients (7 M, 4 F) out of an initial cohort of 45 subjects; the patients were transplanted between 12 to 62 months before and the mean age of the grafts was 30+15.6 months.</p> <p>Age: in the range 17-50 years.</p> <p>Inclusion Criteria: stable renal functions. Hypertension does not constitute an exclusion criterion.</p> <p>Exclusion Criteria: severe co-morbidities.</p> <p>Time: Ramadan 1993 (February-March).</p> <p>Place: Saudi Arabia.</p>	<p>There were no statistically significant changes apart from potassium (<i>p-value</i>=0.044) and blood pressure (<i>p-value</i>=0.013).</p>
Al-Khader et al., 1991 [8]	<p>Study Design: prospective observational cohort study.</p> <p>Sample: 40 patients on hemodialysis, fasting on non-dialysis days.</p> <p>Inclusion Criteria: being on hemodialysis for at least 6 months.</p> <p>Time: NA.</p> <p>Place: NA.</p>	<p>An increase in serum potassium and inter-dialytic weight gain were observed. No complications such as pulmonary edema or hyperkalemia were recorded.</p>
Rashed et al., 1989 [23]	<p>Study Design: prospective matched case-control study.</p> <p>Sample: 43 recipients of kidney transplant.</p> <p>Age: NA.</p> <p>Inclusion Criteria: stable renal functions.</p> <p>Time: NA.</p> <p>Place: NA.</p>	<p>No statistically significant differences.</p>

**Table 3:** Studies summarized according to the demographic characteristics of the sample and their clinical suggestions, interventions and main findings.

**Abbreviations:** BUN: Blood Urea Nitrogen; CAPD: Continuous Ambulatory Peritoneal Dialysis; CCPD: Continuous Cycling Peritoneal Dialysis; ED: Emergency Department; e-GFR estimated Glomerular Filtration Rate; F: Female; FENa: Fractional Excretion of sodium; GFR: Glomerular Filtration Rate; Hb: Hemoglobin; HDL: High-Density Lipoprotein; M: Male; NA: Not Available; NAG: N-Acetyl-B-D- Glucosaminidase; PD: Peritoneal Dialysis; VLDL: Very Low-Density Lipoprotein



Outcomes	Reference
Neutral (no difference between fasters and non fasters)	Al Wakeel et al., 2013 [3] Günaydın et al., 2012 [2] Qurashi et al., 2012 [22] Mousavi et al., 2011 [20] Salem et al., 2010 [25] Boobes et al., 2009 [15] Einollahi et al., 2009 [16] Ghalib et al., 2008 [4] Einollahi et al., 2005 [17] Basiri et al., 2004 [12] Argani et al., 2003 [11] Said et al., 2003 [24] Abdalla et al., 1998 (First study) [5] Abdalla et al., 1998 (Second study) [5] Ouziala et al., 1998 [21] Al-Hadramy, 1997 [7] Al-Khader et al., 1996 [9] Bernieh et al., 1994 [14] Rashed et al., 1989 [23]
Positive (fasters have benefit)	Bernieh et al., 2010 [13]
Negative (fasters may experience injurious effects)	Abdolreza et al., 2011 [6] El-Wakil et al., 2007 [18] Al Muhanna, 1998 [10]
Mixed	Miladipour et al., 2012 [19] Zghal et al., 2005 [26] Al-Khader et al., 1991 [8]

**Table 4:** Some studies did not find any differences between fasters and not fasters, or between before and after Ramadan fasting, while other studies reported statistically significant differences or mixed evidences.

Ramadan Season in which the Study has been Conducted	References
Hot seasons	Al-Wakeel et al., 2013 [3] Günaydın et al., 2012 [2] Qurashi et al., 2012 [22]
Cold seasons	Abdolreza et al., 2011 [6] Bernieh et al., 2010 [13] Boobes et al., 2009 [15] Einollahi et al., 2009 [16] Ghalib et al., 2008 [4] El-Wakil et al., 2007 [18] Basiri et al., 2004 [12] Said et al., 2003 [24] Ouziala et al., 1998 [21] Al-Hadramy, 1997 [7] Bernieh et al., 1994 [14]
No available information	Miladipour et al., 2012 [19] Mousavi et al., 2011 [20] Salem et al., 2010 [25] Einollahi et al., 2005 [17] Zghal et al., 2005 [26] Argani et al., 2003 [11] Abdalla et al., 1998 (First study) [5] Abdalla et al., 1998 (Second study) [5] Al Muhanna, 1998 [10] Al-Khader et al., 1996 [9] Al-Khader et al., 1991 [8] Rashed et al., 1989 [23]

**Table 5:** Studies divided according to the Ramadan season in which they have been carried out.

## Conclusions

There is a strong need for evidence-based suggestions and guidelines [3]. An alarming letter was published, calling for caution in fasting patients during Ramadan and advising of a “R<sup>2</sup> syndrome” (religion and renal failure) [27].

Even though the content of this letter is a bit exaggerated, patients with kidney diseases should be properly advised and counseled before the beginning of Ramadan, as well as during and after the fasting period, about the proper dietary and pharmacological regimen and other behaviors to follow.

This could be done within a multidisciplinary team, made up of a nephrologist, a nutritionist, a psychiatrist or a psychologist. Patients should be carefully checked and assessed, considering both the clinical symptoms and the laboratory exams. Also psychological aspects, such as motivation, and patient preferences and adherence/compliance to treatment should be investigated and taken into account.

Patients suffering from uncontrolled diabetes or other dysmetabolic disorders, hypertension, angina, postural hypotension, significant co-morbidities leading to marked limitation and amendment of daily activities, or a history of non-compliance with therapy and dietary modifications should not fast during the month of Ramadan.

Patients should take regularly their treatment twice a day (with *suhoor* and *iftar* respectively); if they should need drugs more than 2/die, they should consider switching to the former regimen (consulting their physician). If not possible, they should not fast.

If needed, patients can choose between the two clinically available regimens of Peritoneal Dialysis (PD): modified continuous ambulatory PD (3 exchanges during the night and icodextrin infusion), modified continuous cycling PD (exchanges over 6-7 hours and icodextrin infusion) or CCPD. CAPD is generally preferred by younger patients, whilst CCPD by older subjects [3]. They should break the fasting if the plasma creatinine increases by the 30% above the baseline values and/or if you observe clinical symptoms due to changes in serum potassium and sodium [5].

Patients should be monitored during Ramadan and should be instructed to recognize some alarm symptoms such as swelling, shortness of breath, dizziness, anorexia or hyporexia, or a sense of lethargy [3]. Body weight, blood pressure, biochemical parameters such as fluid and electrolytes should be regularly checked throughout the Ramadan. Patients should attend regular follow-up every one-two weeks.

When breaking the fasting, they should avoid high-potassium diet (such as dates, apricots, fried food, nuts, cheese, soft juices and drinks, coffee), and should drink up to 1-2.5 l of water in order to re-hydrate themselves but avoid exceeding in liquid amount [3]. If they have a tendency to hyperkalemia, they should take some calcium resonium powder (30 g/day with lactulose once a day). Anecdotal episodes of hyperkalemia/hypokalemia have been reported in the literature [28].

In conclusion, if stable, patient's eagerness to fast should be taken into account and even encouraged, since spirituality plays a key role in CKDs. The patient feels indeed himself/herself more active being involved in the religious activities, and less depressed and isolated [3].

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancia G (Eds.). Special Issues in Hypertension, Springer-Verlag, Milan, Italy.
2. Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of Patients with Renal Colic that Present to an Emergency Department During the Month of Ramadan. Ramazan Ayında Renal Kolikle Acil Servise Basvuran Hastaların Degerlendirilmesi. The Journal of Academic Emergency Medicine 12: 24-26.
3. Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. Perit Dial Int 33: 86-91.
4. Ghalib M, Qureshi J, Tamim H, Ghamdi G, Flaiw A, et al. (2008) Does repeated Ramadan fasting adversely affect kidney function in renal transplant patients? Transplantation 85: 141-144.
5. Abdalla AH, Shaheen FA, Rassoul Z, Owda AK, Popovich WF, et al. (1998) Effect of Ramadan fasting on Moslem kidney transplant recipients. Am J Nephrol 18: 101-104.

6. Abdolreza N, Omalbanin A, Mahdieh TS, Mohammad Ali MR, Reza MS, et al. (2011) Comparison of the number of patients admitted with renal colic during various stages of peri-Ramadan month. *Saudi J Kidney Dis Transpl* 22: 1199-1202.
7. Al-Hadramy MS (1997) Seasonal variations of urinary stone colic in Arabia. *J Pak Med Assoc* 47: 281-284.
8. Al-Khader AA, Al-Hasani MK, Dhar JM, Al-Sulaiman M (1991) Effects of diet during Ramadan on patients on chronic hemodialysis. *Saudi Med J* 12: 30-31.
9. Al-Khader AA, Al-Sulaiman MH, Mousa DH, Al-Hawas F (1996) Some of the Lessons Learnt from Renal Transplant Recipients Cared-for at the Riyadh Armed Forces Hospital. *Saudi J Kidney Dis Transpl* 7: 139-144.
10. Al Muhanna FA (1998) Ramadan fasting and renal failure. *Saudi Medical Journal* 319-321.
11. Argani H, Mozaffari S, Rahnema B, Rahbani M, Rejaie M, et al. (2003) Evaluation of biochemical and immunologic changes in renal transplant recipients during Ramadan fasting. *Transplant Proc* 35: 2725-2726.
12. Basiri A, Moghaddam SM, Khoddam R, Nejad ST, Hakimi A (2004) Monthly variations of urinary stone colic in Iran and its relationship to the fasting month of Ramadan. *J Pak Med Assoc* 54: 6-8.
13. Bernieh B, Al Hakim MR, Boobes Y, Abu Zidan FM (2010) Fasting Ramadan in chronic kidney disease patients: clinical and biochemical effects. *Saudi J Kidney Dis Transpl* 21: 898-902.
14. Bernieh BO, Mohamed AO, Wafa AM (1994) Ramadan fasting and renal transplant recipients: Clinical and biochemical effects. *Saudi J Kidney Dis Transpl* 5: 470-473.
15. Boobes Y, Bernieh B, Al Hakim MR (2009) Fasting Ramadan in kidney transplant patients is safe. *Saudi J Kidney Dis Transpl* 20: 198-200.
16. Einollahi B, Lessan-Pezeshki M, Pourfarziani V, Aghdam B, Rouzbeh J, et al. (2009) Ramadan fasting in kidney transplant recipients with normal renal function and with mild-to-moderate renal dysfunction. *Int Urol Nephrol* 41: 417-422.
17. Einollahi B, Lessan-Pezeshki M, Simforoosh N, Nafar M, Pour-Reza-Gholi F, et al. (2005) Impact of Ramadan fasting on renal allograft function. *Transplant Proc* 37: 3004-3005.
18. El-Wakil HS, Desoky I, Lotfy N, Adam AG (2007) Fasting the month of Ramadan by Muslims: could it be injurious to their kidneys? *Saudi J Kidney Dis Transpl* 18: 349-354.
19. Miladipour AH, Shakhssalim N, Parvin M, Azadvari M (2012) Effect of Ramadan fasting on urinary risk factors for calculus formation. *Iran J Kidney Dis* 6: 33-38.
20. Mousavi BSS, Golzari K, Hayati F, Motemednia F, Mousavi BM (2011) Is Ramadan Fasting Safe for Kidney Transplant Patients with Normal Renal Function? 5 Case Reports. *Shiraz E-Medical Journal* 12: 203-205.
21. Ouziala M, Ouziala S, Bellaoui A, Drif M (1998) Fasting During the First Year of Transplantation: Is it Safe? *Saudi J Kidney Dis Transpl* 9: 440-443.
22. Qurashi S, Tamimi A, Jaradat M, Al Sayyari A (2012) Effect of fasting for Ramadan on kidney graft function during the hottest month of the year (August) in Riyadh, Saudi Arabia. *Exp Clin Transplant* 10: 551-553.
23. Rashed AH, Siddiqui SA, Abu Romeh SH, Hayden CT, Garcia-Buñuel L, et al. (1989) Clinical problems during fast of Ramadan. *Lancet* 333: 1396.
24. Said T, Nampoory MR, Haleem MA, Nair MP, Johny KV, et al. (2003) Ramadan fast in kidney transplant recipients: a prospective comparative study. *Transplant Proc* 35: 2614-2616.
25. Salem EE, Akhili IM, Akikli AB (2010) The Effect of Ramadan Fasting on the Kidney Function of Renal Transplant Recipients. *Arab Journal of Nephrology and Transplantation* 3: 29-32.
26. Zghal A, Fellah H, Zerelli L, Daudon M, Belkeha C, et al. (2005) [Variation of biochemical parameters of the first morning urine during month of Ramadan]. *Tunis Med* 83: 591-594.
27. Gupta A, Lal C, Khaira A, Agarwal SK, Tiwari SC (2010) R2 syndrome: religion and renal failure. *J Assoc Physicians India* 58: 201.
28. Achar KN, Abduo TJ, Menon NK (1989) Severe hypokalemic rhabdomyolysis due to ingestion of liquorice during Ramadan. *Aust N Z J Med* 19: 365-367.

## Chapter 11

# Ramadan and Psychiatric Disorders

**Nicola Luigi Bragazzi<sup>1,2\*</sup>, and Mohsen Rezaeian<sup>3</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINOGLI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

<sup>3</sup>Department of Social Medicine, Occupational Environmental Research Center, Rafsanjan Medical School, Rafsanjan University of Medical Sciences, Rafsanjan, Iran

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINOGLI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents one of the five pillars of the Islam Sunni creed and the second Practice of Faith for the Shiites. Even though patients are exempted from observing this religious duty (*Surat al-Baqarah*, verses 184-185), they may be willing to fast and ask their clinicians for advice. Here, in this book chapter we review the extant literature on the relationship between the Ramadan fasting and psychiatric disorders. To our knowledge, this is the first systematic review which covers this topic. Since results are not conclusive, we call for further scholarly and high-quality researches in the field.

**Keywords:** Bipolar and Related Disorders; Eating Disorders; Koro-Like Syndrome; Psychiatric Disorders; Ramadan Fasting; Sexuality; Substance-Related and Addictive Disorders

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), has a great importance and meaning for all the Muslims in the world.

Ramadan fasting (*sawm*, literally “abstinence”) represents the fourth of the five pillars of the Islam Sunni creed (*arkan al-Islam* or *arkan al-din*), being the declaration or faith or *Shahada* the first and being the others the prayer or *Salat*, *Zakat* or Charity, and *Hajj* or Pilgrimage. It is the second Practice of Faith for the Shiites (being the *Salat* the first, the others being *Hajj*, *Zakat*, *Khums* or taxes, literally “one-fifth”, *Jihad* or struggle, effort, *Amr-bil-ma’ruf* or Commanding what is good, *Nahi-anil-munkar* or Forbidding what is evil, *Tawalla* or Expressing love towards God and His friends, and *Tabarra* or Expressing dissociation from evil).

Abstinence from eating and drinking, sexual intercourses, from sunrise to sunset, as well as intense prayers characterize this period. Usually, patients are exempted from

observing these rules, even though they may ask their doctors whether they can fast without experiencing injurious effects [1,2].

Since there are no guidelines and protocols on the relationship between Ramadan fasting and psychiatric disorders, the main objective of this book chapter is to review the extant literature, in order to draw the main conclusions that can help the physicians in addressing their patients' concerns and to call for further research in the field.

## Bipolar and Related Disorders

Bipolar Disorder, (BD) also termed as bipolar affective disorder, manic-depressive disorder, or simply manic depression, and Bipolar-Related Disorders (BRDs) are severe mental illnesses characterized by alternating episodes of elevated mood known as mania, and episodes of depression. About 2-3% of people have BD worldwide [3,4], even though a systematic review of the epidemiology of BRDs in Arabic countries is still missing. The pathogenesis of BD is not clearly understood, but both neuro-anatomic, genetic [5,6] and environmental [7] risk factors are believed to play a role. Treatments usually include mood stabilizing drugs, above all lithium, and psychotherapy [8].

There are few, sparse studies focusing on BRDs, limited to clinically stable BD, and with contrasting findings [9].

Kadri and collaborators [10] investigated a cohort of 20 Muslim patients (out of 40 eligible subjects), who elected to fast during Ramadan in January 1997, suffering from BD clinically diagnosed according to ICD-10 criteria, and on lithium therapy for at least three months. They administered *ad hoc* psychometric scales and analyzed the blood lithium concentration. They found that 45% of them (n = 9 patients) relapsed during Ramadan, 70% during the second week, the remaining subjects at the end of the fasting, and 71.4% of those relapses were characterized by manic episodes. Side-effects and toxicity of lithium increased and were observed in 48% of the sample. However, this finding was not conclusive since the relapse rate did not correlate with the blood lithium concentration. The authors speculated that the course of the illness of bipolar patients can be influenced by Ramadan-induced social disrupting, even though the scholars did not use a specific psychometric scale to investigate the impact, if any, of this parameter on the mood state.

Eddahby and coworkers [11] investigated 170 patients with stabilized BRDs, clinically diagnosed according to the DSM-IV criteria. They evaluated 111 fasters and 59 matched non-fasters, during the Ramadan month in 2011 and 2012. Patients were assessed for depression, mania, anxiety, stress and religiosity. Sleep and eating patterns, use of stimulants and other drugs, as well as plasma lithium levels were assessed, one week before the month of Ramadan, on the second and fourth week of Ramadan, and two weeks after the end of the Ramadan month. The difference of relapse rate between fasters and non-fasters was statistically significant; in particular the risk of relapse among bipolar patients was increased by 2.77 fold in comparison to non-fasters.

Farooq [12] investigated 62 patients meeting the ICD-10 criteria of BPRDs receiving lithium treatment for prophylaxis. Serum lithium level, electrolytes, depression and mania were assessed as well as the potential side-effects of lithium. The authors found that blood lithium concentration did not vary in a statistically significant way, as well as the side-effect and toxicity rates. The mood of the patients seemed to improve during the fasting and no relapse was noticed. The authors concluded that the patients who have stable mental state and lithium levels before Ramadan can be maintained on lithium during Ramadan.

Nazar and co-workers [13] investigated a sample of 57 subjects (out of an initial cohort of 62 patients) in order to assess the safety of lithium therapy during the Ramadan month. They carried out this study from September to November 2006. Apart from weight gain, no statistically significant difference was found in the adverse side effects of Lithium in pre-Ramadan as compared to mid-Ramadan period.

Ahmed and collaborators [14] used an animal model in order to investigate the impact of fasting on blood lithium concentration. The authors did not find any statistically significant differences and concluded that lithium can be safely used by fasting BD patients.

## Substance-Related and Addictive-Disorders

Al-Adawi and Powell [15] investigated the effect of Ramadan fasting on Muslim smokers who were asked to give up smoking for the entire month or at least during daylight hours. They found that abstaining smokers experienced a certain degree of cognitive impairment as well as an impaired dopaminergic function, which ameliorated after tobacco consumption, thus suggesting a boosting effect of the nicotine. Withdrawal symptoms were less severe for those who managed to abstain from smoking for the entire period.

This finding should be taken into account when exploiting Ramadan as a “teachable moment” and an opportunity to promote tobacco quitting for faith-based interventions [16-21].

Al-Sinawi and co-workers [22] have described a very unusual case of *koro*-like symptoms in a 48-year-old man, married with six children, from Muscat (Oman). This clinical presentation was probably induced by alcohol withdrawal during the Ramadan fasting. *Koro* (literally “head of the turtle” in Malay, known also as “shrinking penis syndrome” or *suk yeong* in Cantonese or “genital retraction syndrome” or “genital theft syndrome”) is a culture-bound disorder in which a subject wrongly believes that his/her genitals are retracting and/or changing and that will disappear, despite the lack of any genital anomalies. It was initially described in Southern Sulawesi people of Indonesia, in Southern Chinese immigrants in Hong Kong and South East Asia, above all in males, rarely in females. Some patients refer genital paraesthesia, whilst others fear intra-abdominal organ change and/or shrinkage, sex change, becoming eunuch, urinary and genital obstruction, sterility and infertility, abrupt madness or death, *djinn* or *hassad* (spirit) possession and a feeling of being victim of sorcery (*sihr* in Arabic language). Symptoms are acute anxiety attacks which rarely persist for years in a chronic condition, indicating a putative co-morbidity with dysmorphophobic disorders. The patient of the case report had vegetative symptoms like sweating and tachycardia, severe hand tremors, anxiety, and fluctuating episodes of agitation, irritation, dysphoria and impaired sensations. A long story of alcohol abuse may be the cause of erectile dysfunction, whose anxiety was the content of the patient’s delusion. The authors refer that according to their clinical experience patients with alcohol-related disorders often present with severe withdrawal symptoms every Ramadan.

Using a nested logit model which is a sophisticated logistic regression method, Celen [23] performed a study to assess predictors of alcohol consumption in Turkey. Despite being a Muslim country, alcohol is not illegal in Turkey, even though there are some restrictions and control policies. The author of the article utilized a balanced panel data set covering 50 monthly observations regarding the brewery products from March 1998 to April 2002, using as variables the observance of fasting during the month of Ramadan, the temperature, the prices of the products and the disposable income as well as other demand factors. The Ramadan was associated with lower alcohol usage, whilst the disposable income predicted an increase in alcohol consumption. The temperature, instead, was not a statistically significant predictor.

## Feeding and Eating-disorders

Despite the general knowledge that spirituality may have a role in Eating Disorders (EDs), there are few studies on this topic; especially there is a dearth in the field of psychiatric epidemiology [24]. Weight loss during Ramadan tends to be modest and weight gradually returns to pre-Ramadan status according to a meta-analysis [25,26], even though has a certain effect in males, according to another meta-analysis [27].

Akgül and collaborators [28], considering that culture-based contributors play a major role in EDs, reviewed the previous clinical cases and reported that in the years 2012-2013 8 out of 23 subjects were diagnosed of EDs during or shortly after Ramadan. In particular, they have studied in-depth 6 of the 23 adolescent patients (age in the range 14-17 years, 5 females, 1 male). The authors concluded that a drastic change in one's diet, food intake and nutritional patterns such as that which occurs during Ramadan plays an important role in triggering EDs in adolescents with a predisposition or may exacerbate an eating pathology.

Bhadrinath [29] reported that during Ramadan two of the three patients' symptoms worsened during the fasting, one patient began vomiting after the big meals.

Erol and coworkers [30], considering that Ramadan fasting can be considered as a kind of dietary restriction and given that eating restriction is a risk factor for later development of EDs, investigated a sample of 79 healthy volunteers from a 10<sup>th</sup> grade high school (63 female and 16 males). No statistically significant differences were found between the scores of EAT (Eating Attitude Test) and BITE (Bulimic Investigatory Test, Edinburgh).

Savas and collaborators [31] conducted a study to evaluate whether Ramadan fasting influences the eating behaviors of 34 obese women, using EAT and BITE questionnaires. No statistically significant differences were found and the authors concluded that the Ramadan fasting restrictions do not seem to have an impact on the eating behaviors of obese women.

## Suicides and Parasuicides

Evidence on suicides (completed or attempted), self-injury behaviors and para-suicides in the Muslim countries is poor, since few studies, in most cases descriptive, have been performed [32].

Demirci and collaborators [33] carried out a retrospective and systematic study of 4,881 death examinations and autopsies from 2000 to 2009. In that period, a total of 491 deaths (10.1%) occurred in Ramadan, and suicide was the cause in 27 (5.5%). During Ramadan, suicides tend to decrease, as well as parasuicides, as found by a study carried out by Daradkeh [34], in Jordan, from 1986 to 1991, consulting the Police Registers. Significantly fewer parasuicides but not suicides were reported during Ramadan than the month preceding it and the month that follows Ramadan. The Holy Month has a protective effect, which however does not persist into the following months.

## Sexuality

Sexuality is a particularly challenging topic in Islam, living between repression and modern openness [35]. Kadri and collaborators [36] carried out a study aiming at exploring sexual behaviors in terms of frequency and perceived quality, and prevalence of dysfunction during Ramadan compared to other periods of the year. The sample included 100 people. The frequency of sexual intercourses decreased during Ramadan, as well as their reported quality. Erectile dysfunction was noted during Ramadan, while sexual aversion and dyspareunia were less noted.

## Conclusion

So far no standardized protocols and guidelines exist that can assist clinicians in properly advising their psychiatric patients whether to fast or not during the Ramadan month. To our knowledge, this is the first systematic review conducted on this topic. From the collected evidences, we can conclude that:

- a. There is no consensus whether BD patients can safely fast during the Ramadan month; however, a tailored advice should be given to a patient, especially when he/



she is clinically stable and with steady blood lithium level. Since the side-effects and toxicity of lithium may increase because of dehydration, fasting during the hottest months of the year should not be recommended, at least for the sake of precaution;

- b. Withdrawal symptoms due to quitting smoking are not heavy and Ramadan could be exploited as a “teachable moment” for faith-based interventions;
- c. Literature on the treatment of subjects suffering from substance-use is sparse, however the case-report of the Koro-like syndrome seems to be anecdotal, even though the authors report that according to their clinical experience lot of patients with heavy drinking come to psychiatric ward with this presentation during Ramadan;
- d. There is no consensus whether patients suffering from EDs can safely fast during the Ramadan month; according to some authors, fasting could trigger or worsen symptoms, whilst for other scholars Ramadan seems not to exert any influence;
- e. Suicides and parasuicides tend to decrease during the Holy month;
- f. Ramadan fasting seems to exert a certain impact on sexuality and mental health.

Due to its importance, there is an urgent need of scholarly, high quality studies and researches that address the topics of our systematic review.

## References

1. Alkandari JR, Maughan RJ, Roky R, Aziz AR, Karli U (2012) The implications of Ramadan fasting for human health and well-being. *J Sports Sci* 30: 9-19.
2. Azizi F (2010) Islamic fasting and health. *Ann Nutr Metab* 56: 273-282.
3. Kessler RC, Chiu WT, Demler O, Merikangas KR, Walters EE (2005) Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry* 62: 617-627.
4. Latalova K, Prasko J, Grambal A, Havlikova P, Jelenova D, et al. (2013) Bipolar disorder and anxiety disorders. *Neuro Endocrinol Lett* 34: 738-744.
5. Radaelli D, Sferazza Papa G, Vai B, Poletti S, Smeraldi E, et al. (2014) Fronto-limbic disconnection in bipolar disorder. *Eur Psychiatry*.
6. Kerner B (2014) Genetics of bipolar disorder. *Appl Clin Genet* 7: 33-42.
7. Karatsoreos IN (2014) Links between Circadian Rhythms and Psychiatric Disease. *Front Behav Neurosci* 8: 162.
8. Reinares M, Sánchez-Moreno J, Fountoulakis KN (2014) Psychosocial interventions in bipolar disorder: what, for whom, and when. *J Affect Disord* 156: 46-55.
9. Eddahby S, Kadri N, Moussaoui D (2013) [Ramadan and bipolar disorder: Example of circadian rhythm disturbance and its impact on patients with bipolar disorders]. *Encephale* 39: 306-312.
10. Kadri N, Mouchtaq N, Hakkou F, Moussaoui D (2000) Relapses in bipolar patients: changes in social rhythm? *Int J Neuropsychopharmacol* 3: 45-49.
11. Eddahby S, Kadri N, Moussaoui D (2014) Fasting during Ramadan is associated with a higher recurrence rate in patients with bipolar disorder. *World Psychiatry* 13: 97.
12. Farooq S, Nazar Z, Akhtar J, Irfan M, Subhan F, et al. (2010) Effect of fasting during Ramadan on serum lithium level and mental state in bipolar affective disorder. *Int Clin Psychopharmacol* 25: 323-327.
13. Nazar Z, Akhtar J, Farooq S, Irfan M, Shaheen R (2011) Adverse side effects of lithium and fasting (Ramadan). *Journal Of Postgraduate Medical Institute (Peshawar – Pakistan)* 23: 7-13.
14. Ahmed Z, Subhan F, Shah MT, Farooq S (2014) Effect of fasting on serum lithium levels: an experimental study in animal models. *Pak J Pharm Sci* 27: 33-37.
15. Al-Adawi S, Powell J (1997) The influence of smoking on reward responsiveness and cognitive functions: a natural experiment. *Addiction* 92: 1773-1782.



16. White M, Bush J, Kai J, Bhopal R, Rankin J (2006) Quitting smoking and experience of smoking cessation interventions among UK Bangladeshi and Pakistani adults: the views of community members and health professionals. *J Epidemiol Community Health* 60: 405-411.
17. Afifi ZE (1997) Daily practices, study performance and health during the Ramadan fast. *J R Soc Health* 117: 231-235.
18. Farren C, Naidoo J (1996) Smoking cessation programmes targeted at black and minority ethnic communities. *Br J Cancer* 29: 78-80.
19. Lagrue G, Cormier S (1998) [Ramadan: the problem of tobacco]. *Presse Med* 27: 480.
20. Kadri N, Tilane A, El Batal M, Taltit Y, Tahiri SM, et al. (2000) Irritability during the month of Ramadan. *Psychosom Med* 62: 280-285.
21. Gebhardt R, Cassens S, Liecke F, Rohde G, Gün AK, et al. (2012) [Smoke-free by ramadan: experience with a low-threshold prevention offer on smoking cessation for persons with migration background]. *MMW Fortschr Med* 154: 33-40.
22. Al-Sinawi H, Al-Adawi S, Al-Guedi A (2008) Ramadan fasting triggering koro-like symptoms during acute alcohol withdrawal: a case report from Oman. *Transcult Psychiatry* 45: 695-704.
23. Celen A (2014) Influence of Holy Month Ramadan on Alcohol Consumption in Turkey. *J Relig Health*.
24. Abou-Saleh MT, Younis Y, Karim L (1998) Anorexia nervosa in an Arab culture. *Int J Eat Disord* 23: 207-212.
25. Hankir A, Hankir M, Zaman R (2014) Should Ramadan be prescribed after Christmas? Obesity in the healthcare profession and the health benefits of fasting. *BMJ Case Rep* 2014.
26. Kul S, Savaş E, Öztürk ZA, Karadağ G (2014) Does Ramadan fasting alter body weight and blood lipids and fasting blood glucose in a healthy population? A meta-analysis. *J Relig Health* 53: 929-942.
27. Sadeghirad B, Motaghipisheh S, Kolahtooz F, Zahedi MJ, Haghdoost AA (2014) Islamic fasting and weight loss: a systematic review and meta-analysis. *Public Health Nutr* 17: 396-406.
28. Akgül S, Derman O, Kanbur NO (2014) Fasting during ramadan: A religious factor as a possible trigger or exacerbator for eating disorders in adolescents. *Int J Eat Disord*.
29. Bhadrinath BR (1990) Anorexia nervosa in adolescents of Asian extraction. *Br J Psychiatry* 156: 565-568.
30. Erol A, Baylan G, Yazici F (2008) Do Ramadan fasting restrictions alter eating behaviours? *Eur Eat Disord Rev* 16: 297-301.
31. Savas E, Öztürk ZA, Tanrıverdi D, Kepekçi Y Y (2014) Do Ramadan fasting restrictions alter eating behaviours in obese women? *J Relig Health* 53: 135-140.
32. Lester D (2006) Suicide and islam. *Arch Suicide Res* 10: 77-97.
33. Demirci S, Dogan KH, Koc S (2013) Evaluation of forensic deaths during the month of Ramadan in Konya, Turkey, between 2000 and 2009. *Am J Forensic Med Pathol* 34: 267-270.
34. Daradkeh TK (1992) Parasuicide during Ramadan in Jordan. *Acta Psychiatr Scand* 86: 253-254.
35. Dialmy A (2010) Sexuality and Islam. *Eur J Contracept Reprod Health Care* 15: 160-168.
36. Kadri N, Berrada S, Alami KhM, Manoudi F, Rachidi L, et al. (2007) Mental health of Moroccan women, a sexual perspective. *J Affect Disord* 102: 199-207.

## Chapter 12

# Involvement in Religion and Self-Regulation: Explanations of Muslims' Affects and Behaviors during Ramadan

**Walid Briki**<sup>\*1,2</sup>

<sup>1</sup>University of French West Indies and Guyana, Laboratory ACTES (EA 3596), Pointe-à-Pitre, France

<sup>2</sup>Southern France Montpellier University, Laboratory Epsilon (EA 4556), Montpellier, France

**\*Corresponding author:** Walid Briki, University of French West Indies and Guyana, Laboratory ACTES (EA 3596), Pointe-à-Pitre, France, Tel: +33 604 524 058; E-mail: [walid.briki@univ-ag.fr](mailto:walid.briki@univ-ag.fr) / [briki.w@gmail.com](mailto:briki.w@gmail.com)

## Abstract

The present chapter aims to describe and explain the health-related, psychological, and social outcomes related to Ramadan fasting. Ramadan fasting appears globally related to positive psychosocial outcomes, which could be explained by the fact that Ramadan prescribes the health-promoting behaviors, confers social support, conforms people with Islamic doctrine, and promotes effective coping with stress. However, Ramadan can be also related to negative psychosocial outcomes, suggesting the existence of other factors impacting the fasting-related psychological outcomes. Indeed, while the personal forms of motivation in Islam and a positive God conception (i.e., adaptive religious involvement) seem related to adaptive psychosocial outcomes, the social form of motivation and a negative God conception (i.e., maladaptive religious involvement) seem related to maladaptive psychosocial outcomes. In addition, displaying more adaptive (and less maladaptive) religious involvement, women reveal more adaptive (and less maladaptive) psychosocial outcomes than men during Ramadan. In this perspective, the adaptive (or maladaptive) religious involvement, emerging from internalization processes of religious education, would facilitate self-regulation of affects and behaviors. Moreover, the benefits associated with Ramadan fasting could be explained by increasing self-control during the holy month of Ramadan, which in turn would increase self-regulation.

**Key words:** Internalization; Islam; Ramadan; Self-control; Self-regulation

## Introduction

Ramadan represents one of the widest celebrated religious traditions in the world. As one of the “five pillars” of Islam, Ramadan corresponds to the ninth month of the Islamic lunar calendar during which Muslims fast. Literally, Ramadan fasting (*sawm* in Arabic) means self-refraining: It involves not only abstinence from eating, drinking, sexual intercourse during the daylight hours, but also a high control level of one’s thoughts, attitudes, and behaviors. Concretely, Muslims have to develop a closer relationship with Allah, strengthen

ties with siblings, parents, friends, and restrain from touching, listening, saying, or looking at unlawful things, or going to evil places. From a spiritual standpoint, Ramadan can be considered as a time of self-reflection, because Muslims evaluate themselves in light of Islamic guidance, and a self-reformation time during which Muslims develop patience, humility, compassion, empathy, and generosity [1].

Religion, defined as “...cognition, affect, and behavior that arise from awareness of, or perceived interaction with, supernatural entities that are presumed to play an important role in human affairs” [2], is a psychosocial force capable of modifying human lives trajectories. Adherence in Islam—like in other religions such as Christianity, Judaism, or Buddhism [2]- is globally found to be positively (or negatively) related to positive (or negative) outcomes in terms of health [3,4], subjective well-being [3,5,6], and prosocial behaviors [7]. A few studies, however, stressed that religion can entail deleterious effects on mental and physical health in certain cases, especially when adherence to it is far from one’s personal and deep aspirations [8-11]. Since Quran mentioned that Ramadan fasting can promote individuals’ physical and mental well-being, several recent studies have attempted to examine this issue [12-14]. However, their findings displayed that Ramadan fasting may induce either positive or negative psychological effects according to the existence of specific factors (e.g., religious orientation, religious coping).

The aim of the present chapter is to describe and explain the relationships of Ramadan fasting with health, cognitions, affects, and behaviors. After describing such relationships, we will present the McCullough and Willoughby’s [2] self-regulatory control-process model of religious affects and behaviors, providing keys to understand the relationships between Ramadan fasting and its outcomes.

## Ramadan, Mental Health and Well-Being

While certain studies examined the effects of Ramadan fasting on mental health [12], coping strategies [15-17], and decision making [18], others examined the relationships of Ramadan experiences with other variables such as level of religiosity<sup>1</sup> [7], religious orientation [13,14], religious coping [19], and sex-related differences [13,19].

### Psychological effects of Ramadan fasting

Research examined the relationship of Ramadan and mental health. In their attempt to examine the effects of Ramadan fasting and praying on mental health subscales (i.e., physical symptoms, anxiety and insomnia, social dysfunction, and depression) on Iranian university students, Amirfakhraei and Alinaghizadeh [12] measured self-reported mental health scores before and after the month of Ramadan in participants who (a) fasted almost always, some day (for amusement), or did not fast at all (voluntarily and due to religious or medical reasons), and (b) always, often, sometimes, or never prayed. The findings displayed that participants who fasted the whole month of Ramadan, even for amusement, had higher scores on all the mental health subscales after Ramadan than those who did not fast at all. Additionally, those who often or always prayed reported better mental health scores. Hence, fasting and praying appeared as effective rituals for increasing students’ mental health. The authors explained such findings by the fact that religion may prescribe health-related behaviors, provide social support, promote positive feelings (i.e., optimism, perceived control), and create a meaningful purpose in life.

Research also examined the relationship of Ramadan with the use of coping strategies [15-17]. A coping strategy can be defined as “...the person’s constantly changing cognitive

<sup>1</sup> Even if the terms religiosity and spirituality are sometimes used interchangeably, they represent two distinct (but not exclusive) concepts. Religiosity refers to an adherence to a religion, involving predefined behaviors, rituals, whereas spirituality refers to the subjective relationship with supernatural entity such as a divinity [21]. Spirituality is associated with an existential search of life meaning. Such differences are not trivial since they imply specific psychological consequences. For instance, religious people were found to be highly conscientious, agreeable, self-controlled, and lowly open-minded and extraverted. By contrast, spiritual people appeared to be highly open-minded, and lowly conscientious and self-controlled [2].

and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the person's resources" [20]. Akuchekian et al., [15] evaluated medical students for stress coping strategies before and after the holy month of Ramadan. The results displayed that Ramadan fasting decreased the use of ineffective coping strategies such as superstition, wishful thinking (i.e., kind of denial and maladaptive strategy), and self-medication. However, effective coping strategies, such as problem-solving focus (i.e., strategy directed to the stimulus causing stress response; e.g., plan-full problem solving), emotion focused strategies (i.e., strategy consisting in controlling and removing undesirable affects related to stress; e.g., positive reinterpretation), and other strategies were maintained. Such beneficial effects of Ramadan fasting were explained by the adherence to Islam-related recommendations, inciting Muslims to enhance regulation and control of their personal (e.g., discipline, punctuality) and social life (e.g., correcting one's interpersonal relationships). Considering Ramadan fasting as a coping strategy, the authors also suggested that Ramadan fasting may induce psychological adaptations with stress *via* the secretion of specific hormones (i.e., cortisol, beta-endorphin) rising during fasting.

Focused on elite athletes (archers) engaged in Ramadan fasting during high stake international competitions (e.g., London Olympics 2012), Roy and her colleagues [16,17] observed, through their qualitative investigations, that Muslim athletes developed a diversity of adaptive coping strategies. Concretely, the athletes had to deal with the physiological and psychological constraints of Ramadan fasting (i.e., loss of energy), while they had to prepare for the performance. To do so, they were led to (a) reorganize their training (e.g., decrease of training load) and nutrition (e.g., greater consumption of fluid during non-daylight hours), implement rest time, and control arousal in maintaining calmness, and (b) use psychological skills (e.g., increasing concentration on task) and spirituality. Their spirituality, characterized by their love for God and closeness with Him, served as a means of enhancing their mental strength.

Research did examine the relationship of Ramadan with decision making. Considering the existence of a direct link between the social mood and financial investments, some authors [18,22] attempted to know how Ramadan may influence investor decisions. All suggested the existence of a positive effect of Ramadan on feelings of optimism and happiness of Muslim investors, reflected by the increase of their investments during Ramadan. Moreover, using a specific finance index (i.e., stock market volatility), Al-Hajieh et al., [18] found that the beginning and the end of Ramadan were characterized by a greater synchronization of opinions, decisions, and mood of Muslim investors. This suggests that the ties within the Muslim community are the strongest at the start and the end of Ramadan fasting. More generally, such finding is compatible with the view that Muslim people strengthen their ties during Ramadan.

In this respect, the findings reveal that Ramadan fasting promotes positive psychological patterns including less anxiety, less depression, greater optimism and social identity, and better coping strategies. However, findings of other studies run counter to this view by providing evidence that Ramadan fasting can be associated with negative psychological patterns [23]. Kadri et al., [23] examined the dynamics of objective irritability (i.e., measured through semi-structured interview), subjective irritability (i.e., self-reported measures), self-reported anxiety, consumption of psycho-stimulants (coffee and tea), and duration of sleep during six weeks—from one week before the month of Ramadan (W0) to one week after this month (W5)—in smokers and non-smokers in Morocco. The data were collected one time a week. Different kinds of noteworthy patterns were found. Subjective irritability, objective irritability, and anxiety were globally lower in non-smokers than in smokers during Ramadan fasting, suggesting that smoking outside Ramadan could develop negative affects during Ramadan.

Regarding the dynamics of subjective irritability, objective irritability, and anxiety during Ramadan, differences were found between non-smokers and smokers. In non-smokers, the

variables under study evolved in a stationary way over time, followed by either an increase (for subjective irritability, between W3 and W4) or not (for objective irritability and anxiety). In smokers, all variables increased over time (between W0 and W4). Moreover, a decrease was observed for subjective irritability (in non-smokers and smokers alike), objective irritability (in smokers only), and anxiety (in smokers only) after Ramadan (between W4 and W5). These findings indicate a greater non-stationarity and variability on the variables under study in smokers than in non-smokers, suggesting that smokers are more inclined to feel irritation and anxiety than non-smokers during Ramadan fasting, and that smokers are psychologically more vulnerable to Ramadan.

Along with the dynamics of affects under study, Kadri et al., [23] observed that the consumption of psycho-stimulants also increased over time in both groups, especially in smokers. A decrease of sleep duration was also recorded in both groups. Hence, Kadri et al., [23] attributed the negative effects during the month of Ramadan to the consumption of tobacco and caffeine. However, this explanation in itself is not sufficient since the authors also observed that, for each affective variable under study, non-smokers had a lower mean score than smokers in W0. The higher levels of negative effects in smokers during the rest of the year suggest the existence of other factors than Ramadan fasting, which is known to entail positive effects on psychological aspects [18,22]. Indeed, smoking was found to be positively related to disinterest in religion, a low-level of adaptive religious orientation, lower levels of positive experience of Ramadan, reduction in behaviors of Ramadan, and higher level of negative experience of Ramadan [14]. However, Kadri et al., [23] did not control such critical factors of religiosity in their study.

### **Critical Factors of religiosity implied in the Ramadan experience**

Ramadan could entail either positive or negative effects on mental health and well-being depending on the existence of specific critical factors such as the level of religiosity, religious orientation, style of coping strategies, and sex differences.

### **Religiosity level and the Ramadan experience**

The level of religiosity can influence the Ramadan experience. Akay et al., [7] recently examined the effect of religious festivals and religiosity levels on positional concerns (i.e., level of income and consumption compared to those of other people) of Turkish participants. The authors compared the most important day of Ramadan, the Night of Power (*Laylat al-Qadr* in Arabic), and a day outside Ramadan: They found that the positional concerns were lower during the Night of Power, suggesting that Ramadan could incite Muslim people to erase any social differences and be placed on an equal footing with other people. In addition, the level of positional concerns participants with a low level of religiosity was negatively affected by Ramadan, whereas it remained unaffected by Ramadan for participants with a highly level of religiosity. This suggests that only high religious people would follow the Islamic doctrine during the entire year, because it would be converted into personal values and goals.

Interestingly, the positional concerns are related to a specific emotion: Envy (*al-ghubta* in Arabic), which can be defined as an experience that "...arises when a person lacks another's superior quality, achievement, or possession and either desires it or wishes that the other lacked it" [24]. Envy is explicitly considered as a hostile emotion<sup>2</sup> in most of the major religions, because of its links with immoral thoughts, intentions, affects, or behaviors [25,28]. For instance, Prophet Muhammad stated: "...Keep yourselves far from envy, because it eats up and takes away good actions, like the fire that eats up and burns

<sup>2</sup> Although the envy issue per se is beyond the scope of the present chapter, it is important to note that envy is not the hostile kind (*malicious envy*), which would motivate people to down others' standing in order to level the difference with their superiority [26-29]. Indeed, according Van de Ven and his colleagues [26-29], there would be a more positive form of envy (*benign envy*) encouraging people to pull up their own standing. This type of envy would be related to positive outcomes [29]. Moreover, adhering to the conception that envy is only malicious could lead people to avoid achieving, performing, and reaching success in anticipating the possibility to be envied [25]. In this perspective, a whole society could stay far from any innovation.

wood” (in Abu Dawud). The two findings of Akay et al., [7] could be viewed in the light of this conception: While reducing positional concerns during Ramadan in lowly religious people could be considered as a means of staying far from any feeling of envy, reporting no change in the positional concerns of highly religious people would reflect their effort to live far from envy not only during Ramadan but also during the rest of the year.

### **Religious orientation and the Ramadan experience**

Religious orientation represents the way religious people commit to the religion. Three kinds of religious orientation can be distinguished: Intrinsic personal orientation (i.e., using religion as one’s ultimate motivation), extrinsic personal orientation (i.e., using religion as a means to reach one’s personal well-being), and extrinsic social orientation (i.e., using religion as a means to social ends). Khan and his colleagues [13,14] recently examined the relationships between the religious orientations and the experiences and behaviors of Ramadan of Pakistani students. The Ramadan behaviors correspond to the actions that Muslims should engage in during the month of Ramadan (e.g., reciting the holy Quran). The experience of Ramadan was considered as either a religious development experience (i.e., positive experience of Ramadan) or a difficult experience (i.e., negative experience of Ramadan).

The intrinsic personal orientation was found to be positively related to the positive experience of Ramadan ([13],  $r = .46$ ; [14],  $r = .44$ ), interest in religion ([14],  $r = .43$ ), and Ramadan behaviors ([13],  $r = .25$ ), and negatively related to the negative experience of Ramadan ([13],  $r = -.15$ ). Similarly, the extrinsic personal orientation was found to be associated with the positive experience of Ramadan ([13],  $r = .45$ ; [14],  $r = .25$ ) and Ramadan behaviors ([13],  $r = .25$ ). Concerning the extrinsic social orientation, it was shown to be positively related to the interest in religion ([14],  $r = .28$ ) and the negative experience of Ramadan ([13],  $r = .43$ ; [14],  $r = .40$ ). Further analyses using the multiple regressions showed that the above-mentioned experiences of Ramadan predicted both the type of religious orientation and Ramadan behaviors [13]. More specifically, the positive experience of Ramadan predicted positively the intrinsic and extrinsic personal orientations as well as Ramadan behaviors, and negatively the extrinsic social orientation. The negative experience of Ramadan predicted positively the extrinsic social orientation and negatively the Ramadan behaviors. Moreover, the intrinsic and extrinsic personal orientations predicted positively, yet marginally ( $ps \leq .08$ ), the Ramadan behaviors while the extrinsic social orientation predicted negatively such behaviors.

In sum, the positive experience of Ramadan, intrinsic and extrinsic personal orientations, and Ramadan behaviors could be considered as an adaptive religious psychological pattern, while the negative experience of Ramadan and extrinsic social orientation could correspond to a maladaptive religious psychological pattern. This is compatible with the general view that the intrinsic religious orientation corresponds to an adaptive implication in religion [30,31], but not completely compatible with the view according to which extrinsic religious orientation is maladaptive [30,31]. Khan and his colleagues’ [13,14] findings revealed that the maladaptive religious pattern concerned only the extrinsic social orientation, not the extrinsic personal orientation - even if such orientation was less positively related to positive experiences of Ramadan than the intrinsic personal orientation.

According to Pargament et al., [31], religion could promote the construction of healthier traits of personality through an internalization process, which would have a positive impact on individuals’ capacity to regulate their affects. In this perspective, an intrinsic personal religious orientation would better help deal with negative and stressful events when performing religious rituals such as praying and fasting, which would result in a better mental health and well-being. However, the potential negative effects of the extrinsic social religious orientation could be explained by Festinger’s [32] theory of cognitive inconsistency. When an individual performs religious practices (e.g., praying, fasting) in front of others, or

while imagining being observed by others, she or he inherently faces external reinforcement (i.e., reward), resulting in attributing the religious rituals more to reward than to her or him own attitude. Then, when faced with stressful events, people with extrinsic social religious orientation could not use religious rituals as effective coping strategies. Moreover, the possibility that the extrinsic personal religious orientation generates low positive psychological effects could be due to the fact that such religious orientation combines both a personal interest in religion and an extrinsic form of religious motivation, which may lead people to use religious rituals as effective coping strategies.

### **Coping strategies orientation and the Ramadan experience**

Another critical factor capable of influencing the experiences of Ramadan concerns the stress coping strategies. People are inherently exposed to stressful events and one of the effective ways to deal with stress could be religious coping [16,17].

Recently, Khan, Watson, Chen et al., [19] examined the relationships of Islamic religious coping with the experiences and behaviors of Ramadan in university students. Their findings displayed that positive Islamic coping (i.e., an adaptive religious coping; e.g., looking for a stronger connection with Allah when facing a problem in life) correlated positively with Ramadan behaviors ( $r = .46$ ) and Ramadan experience ( $r = .44$ ), and negatively with negative Ramadan experience ( $r = -.18$ ). Positive Islamic coping appeared to predict Ramadan behaviors. In addition, punishing Allah reappraisal (i.e., maladaptive religious coping; e.g., believing being punished by Allah for bad actions when facing a problem in life) did predict higher levels of negative experience of Ramadan.

However, these findings do not match well the findings of earlier Pakistani investigations with Muslims, which display: (a) a clear relationship between negative religious coping and several indices of maladaptive adjustment [33-35], yet (b) an unclear relationship of positive religious coping with indices of adaptive adjustment [33,34], and (c) a positive relationship of positive religious coping with indices of maladaptive adjustment [35]. Such inconsistencies could be explained by methodological differences. First, contrary to previous studies, Khan, Watson, Chen et al.'s [19] study was conducted during the month of Ramadan, which could have enhanced Muslims' commitment in Islamic recommendations, increasing thus the benefits of positive religious coping. Second, the unexpected positive relationship between positive religious coping and indices of maladaptive adjustment reflected specific psychological mechanisms implying religious patients [35].

Overall, all of the findings are consistent with those of studies run with mainly Christians and Jews showing that positive religious coping was positively associated with happiness and satisfaction with life [36], and negatively associated with anxiety [36] and depression [10,36]. As for negative religious coping, it was found to be positively related to anxiety [36] and depression [10,36]. Similarly, Hebert, Zdaniuk, Schulz, and Scheier [37] observed that negative religious coping predicted worse overall mental health, depressive symptoms, and lower life satisfaction in women with breast cancer.

In sum, given that the religious coping strategies refer to a conception of God, the affective and behavioral consequences associated with the type of religious coping strategies could be influenced by how people view God. In concrete, viewing God as a protector or a punisher could lead to positive or negative psychological outcomes, respectively [10,19]. The consistent links of the type of religious coping strategies with the experiences and behaviors of Ramadan support Pargament et al.'s [31] view according to which religion could foster health-related traits of personality, characterized by a high level of self-regulation.

### **Sex differences and the Ramadan experience**

Some studies examined sex differences in psychological responses to Ramadan fasting [13,19]. All studies showed that women were more religious than men during

Ramadan fasting. More specifically, women revealed a greater tendency to use positive coping strategies [19], to behave in accordance with the Islamic recommendations, and to have more positive feelings during Ramadan [13]. In addition, they reported lower negative experiences of Ramadan and levels of extrinsic social orientation [13]. These findings are compatible with findings of other studies conducted outside the month of Ramadan displaying that women are not only more committed to Islam than men<sup>3</sup> [35,38, 39], but also more open-minded, altruistic, close to God [39], and satisfied with their lives<sup>4</sup> [5]. Consequently, referring to Pargament et al.'s [31] assumption, Muslim women could have developed better self-regulatory skills in internalizing better their religious education.

Finally, the positive relationship of Ramadan with health, well-being, and social behaviors could be *a priori* explained by the fact that Ramadan prescribes (or proscribes) health-promoting (or health-comprising) behaviors, confers social support, conforms people with Islamic doctrine, and promotes effective coping with stress [12,15]. However, such assumptions could explain only a part of the psychological effects of Ramadan because those holy months was also found to be related to negative psychological outcomes, suggesting the existence of other factors. Indeed, research revealed that the way people experience Ramadan and typically behave during this month depended primarily upon their type of religious motivation and conception of God [14,19]. Indeed, the personal (or social) form of religious motivation was related to adaptive (or maladaptive) psychological implications, and viewing God as a protector (or a punisher) was related to better (or worse) adjustment with stressful events. In other words, the religious motivation and conception of God - which could be considered as features of the religious involvement emerging from the internalization process of religious education - may help or hinder self-regulation [31]. McCullough and Willoughby [2] recently argued that the links between religion and its positive outcomes could be partly explained by religion's abilities to foster self-regulation and control of the self.

### **Self-Regulatory control-process of religious affects and behaviors**

Based on Carver and Scheier's [41,42] control-process model of self-regulation, McCullough and Willoughby [2] proposed a model intended to explain the associations between religion and its outcomes. McCullough and Willoughby [2] posit that religion is associated with high self-regulation and self-control.

Self-regulation represents purposive processes involving self-corrective adjustments as needed, so that behavior stays on track for the purpose to which it is directed; such corrective adjustments would originate within the person [41,42]. Human behavior is considered as a continuing process of moving toward or away from goal values, and this process embodies the characteristics of feedback control.

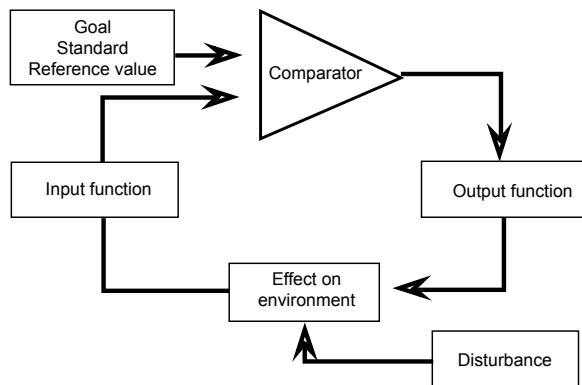
**A feedback loop includes four sub-functions:** An input, a reference value, a comparison, and an output (Figure 1). The input function corresponds to the perception of the current circumstances and situation in which the individual is implied, while the reference value is the goal set by the individual. The comparison function aims to confront the input function with the reference value, following which a discrepancy can be detected. The output function corresponds to the behavioral response to this potential discrepancy in terms of corrective adjustments.

---

<sup>3</sup> It is, however, interesting to note that other studies conducted on Islam in Western countries found that men were more religious than women [35]. This would reflect the tendency of men to maintain a Muslim identity in a non-Islamic society.

<sup>4</sup> The literature is not consistent regarding the fact that Muslim women are related to more positive psychological outcomes than Muslim men. Abdel-Khalek [38] found that Muslim girls reported lower scores of happiness, mental and health, and higher scores of anxiety and depression than boys. Given that the findings involved adolescents only, Abdel-Khalek [38] explained the observed differences in referring to Fakhri El-Islam' [40] argument according to which a son in Arab countries has more freedom, authority, and responsibilities than a daughter.





**Figure 1:** Schematic depiction of a feedback loop (the basic unit of cybernetic control), adapted from Carver and Scheier [41,42].

**Self-regulation processes involve two kinds of feedback loop:** A discrepancy reducing loop (or a negative feedback loop) and a discrepancy enlarging loop (or a positive feedback loop). A negative feedback loop is activated when a desired goal is pursued (e.g., doing good deeds). In this case, the individual is pursuing an approach goal [43] and the output function aims to reduce or eliminate the discrepancy that separates from this goal. By contrast, a positive feedback loop is activated when a non-desired goal or an “anti-goal” is pursued (e.g., avoiding being envious). In this case, the individual is pursuing an avoidance goal [43] and the output function aims to enlarge the discrepancy that separates from this anti-goal. For instance, attempting to follow more strictly the Islamic doctrine during the holy month of Ramadan, Muslim people could change their attitudes and behaviors [7]. More concretely, they could become more helpful with others (activating a negative feedback loop), as well as avoiding any ascending comparisons with similar others to stay far from any envy emotion (activating a positive feedback loop). This example illustrates how both feedback loops can be used concomitantly and complementarily.

**The effectiveness of self-regulation processes would depend on specific abilities:** The capacity of pursuing clear goals, monitoring discrepancies between one’s goals and one’s behaviors, and changing one’s behaviors. First, religion would select some goals and increase the importance of those goals for the self. Through internalization processes of religious teachings, people would develop goal systems hierarchically organized, from the most abstract goals to the most concrete goals. The most abstract goals are called “concept systems”, which refer to one’s ideal self (e.g. being a “good Muslim”). A concept system gives rise to behavioral aspirations called “principles”. A strong adherence to Islam (but also to Christianity and Judaism) was found to lead people both to embrace principles such as being respectful, helpful, responsible, polite, self-disciplined, and honoring elders, and to eschew other principles such as pursuing pleasure, having an exciting and varied life, being free, creative, and independent [44]. Principles suggest behavioral goals called “programs” (e.g. “distract oneself from hostile thoughts”), which lead to actions executed automatically called “sequences” (e.g. reading Quran).

Second, religion would promote monitoring, which involves comparator’ sensitivity to any discrepancy with the goal (Figure 1). Religion would increase such sensitivity in increasing self-monitoring, perceived monitoring by God, and perceived monitoring by other people. Additionally, self-monitoring would be increased by the perception of being monitored by the evaluative audiences (i.e., God, others). The monitoring mechanisms are the components of self-control (i.e., quality of overriding or restraining prepotent impulses), which is a subset of the broader phenomenon of self-regulation. Recently, Carter, McCullough, and Carver [45] examined to which extent the relationship between religiosity and self-control

was mediated by monitoring mechanisms. Results displayed that (a) religiosity predicted self-monitoring, monitoring by God, and monitoring by others, (b) monitoring by God and monitoring by others predicted self-monitoring, and (c) self-monitoring predicted self-control, while monitoring by others negatively predicted self-control. All findings supported authors' expectations, except the last finding displaying a negative relationship between monitoring by others and self-control. The authors explained this unexpected finding could reflect a reactance effect (i.e., reject) regarding the fact to be monitored by others, given that no such effect was related to the perception of being monitored by God.

Third, religion would promote motivation to change behaviors. Perceiving discrepancies between one's standing and one's goals could lead to increase one's religious goal-directed effort [46]. This is compatible with Brehm's [47] reactance theory according to which a loss of control produces an attempt to regain it, as long as control is not viewed as impossible to regain. Moreover, people have many psychological and behavioral tools to change their standing in pursuing their goals: Praying, meditating, imagining, reading could be all potential tools provided by religion. Even if self-regulation refers to both negative and positive events, evidence that religion promotes motivation to self-change by fostering self-regulation could be provided by studies conducted on religious coping strategies [12,15-17,19,31,33]. These studies found the existence of kinds of strategies to cope with stressful events such as engaging in religious activity (e.g., praying, meditating), using a positive (e.g., attempting to resolve one's problem in partnership with God) or a negative religious coping strategy (e.g., attributing one's problem to God's punishment).

Finally, McCullough and Willoughby [2] proposed the view that the physical, psychological, and social benefits associated with religion could be partly explained by self-control, which could improve in turn self-regulation. In line with this perspective, we think that Ramadan could generate positive psychological outcomes by increasing self-regulation. More specifically, the increase of spiritual and social interactions with Allah and other Muslims during Ramadan, respectively, could foster the selection of specific principles (e.g., being respectful, helpful) as well as the increase of sensitivity of monitoring mechanisms, what would increase in turn self-control, and thus self-regulation. Additionally, the motivation to change one's behaviors could be provided by one's spiritual closeness with Allah. However, such efficient self-regulatory mechanisms would need to be based on a positive internalization of religious teachings. Thus, the personal religious orientation, positive religious coping, or positive God conception could be considered as the emerging pattern of personality reflecting a positive integration of one's religious education. This is supported by studies which show that intrinsic motivation regarding Islam were positively associated with self-control [48]. Conversely, the social religious orientation, negative religious coping, or negative God conception would reflect a failure in the integration of religious education.

## Conclusion

This chapter has attempted to describe and explain the health-related, psychological, and social outcomes related to Ramadan fasting. This chapter is composed of two parts. The first displays that Ramadan fasting is globally related to positive psychological and social outcomes, which may be explained by the fact that the holy month would prescribe health-promoting behaviors, confer social support, conform people with Islamic doctrine, and promote effective coping with stress [12,15]. However, Ramadan is also related to negative psychological outcomes [23], suggesting the existence of other factors implied in the relationship of Ramadan fasting with psychological outcomes [13,14,19]. Indeed, the personal forms of motivation in Islam and positive God conception are related to adaptive psychological implications, whereas the social form of motivation and negative God conception are associated with maladaptive psychological implications. The second part of this chapter, based on McCullough and Willoughby's [2] assumptions, shows that the benefits associated with Ramadan fasting may be explained by self-regulation, which was

improved by increasing self-control. The closeness to Allah and social interactions with others, which are enhanced during Ramadan, are considered as key factors potentially responsible for an increase in self-control. The efficiency of such self-regulatory mechanisms would also be based on adaptive religious involvement, emerging from one's internalization of religious education.

The knowledge of psychological self-regulatory processes implied during Ramadan is far from complete. Although Ramadan represents one of the most celebrated religious traditions in the world, only very few studies have been interested in Ramadan in the field of social or cognitive psychology. This chapter has revealed the predominance of quantitative investigations over qualitative investigations, predominance which may have limited our understanding of the complexity of self-regulatory processes in Ramadan. Further research should borrow qualitative methods in order to examine complexity of such processes. Moreover, although the quantitative studies attempted to examine the relationships of Ramadan fasting with psychological outcomes, only Kadri et al.'s [23] study pursued such a goal in borrowing a dynamic approach. Because self-regulation of affects and behaviors is so complex [2], and because any causal mechanism in isolation is inadequate to characterize the resultant phenomenon in all its complexity [49], future research should invest the dynamical approach to examine religious psychology issues [45].

The dynamic systems approach is not new in social psychology since some pioneers displayed how the laws of this approach can be applied to this field [49-51]. The goal of this approach is to describe and explain the change, thereby enabling better understanding of complexity of phenomenon under study. Recent studies conducted in the field of sport social psychology demonstrated the interest in pursuing such an approach [52,53]. Further research should also focus on the influence of Ramadan on the fluctuations of affective, cognitive, and motivational variables in an achievement context such as sport, which has sometimes been considered as a kind of natural laboratory because it implies short contest units that lend themselves well to rigorous investigations [54].

## Acknowledgement

I am grateful to Chiraz Agrebi for her technical assistance.

## References

1. Ismail Büyükçelebi (2005) Living in the shade of Islam. (1<sup>st</sup> edition) The Light Inc., Somerset, NJ, USA.
2. McCullough ME, Willoughby BL (2009) Religion, self-regulation, and self-control: Associations, explanations, and implications. *Psychol Bull* 135: 69-93.
3. Ahmed M Abdel-Khalek (2006) Happiness, health and religiosity: Significant relations. *Mental Health, Religion, & Culture* 9: 85-97.
4. Muhammad Jamal, Jamal Badawi (1993) Job stress among Muslim immigrants in North America: Moderating effects of religiosity. *Stress Medicine* 9: 145-151.
5. Abdel-Khalek Ahmed M, Naceur Farida (2007) Religiosity and its association with positive and negative emotions among college students from Algeria. *Mental Health, Religion, & Culture* 10: 159-170.
6. Kausar Suhail, Haroon Rashid Chaudhry (2004) Predictors of subjective well-being in an Eastern Muslim culture. *Journal of Social and Clinical Psychology* 23: 359-376.
7. Alpaslan Akay, Gökhan Karabulut, Peter Martinsson (2011) The effect of religiosity and religious festivals on positional concerns: An experimental investigation of Ramadan. Discussion Paper series, Forschungsinstitut zur Zukunft der Arbeit, Institute for the Study of Labor.
8. Bart Neyrinck, Maarten Vansteenkiste, WillyLens, Bart Duriez, Dirk Hutsebaut (2006) Cognitive, affective and behavioral correlates of internalization of regulations for religious activities. *Motiv Emot* 30: 323-334.
9. Ryan RM, Rigby S, King K (1993) Two types of religious internalization and their relations to religious orientations and mental health. *J Pers Soc Psychol* 65: 586-596.

10. Smith TB, McCullough ME, Poll J (2003) Religiousness and depression: evidence for a main effect and the moderating influence of stressful life events. *Psychol Bull* 129: 614-636.
11. Williams DR, Sternthal MJ (2007) Spirituality, religion and health: evidence and research directions. *Med J Aust* 186: 47-50.
12. Azita Amirfakhraei, Afsanch Alinaghizadeh (2012) The impact of praying and fasting on the mental health of students attending the Bandar Abbas Branch of Islamic Azad University in Iran in 2012. *Life Science Journal* 9: 2179-2184.
13. Khan ZH, Watson PJ (2010) Ramadan experience and behavior: Relationships with religious orientation among Pakistani Muslims. *Archive for the Psychology of Religion* 32: 149-167.
14. Khan ZH, Watson PJ, Chen Z (2012) Smoking, Muslim religious commitments, and the experience and behavior of Ramadan in Pakistani men. *Mental Health, Religion, & Culture First*: 1-8.
15. Akuchekian S, Ebrahimi A, Alvandian S (2004) Effect of the holy month of Ramadan on coping strategies. *Journal of Research in Medical Sciences* 2: 65-68.
16. Singh R, Hwa OC, Roy J, Jin CW, Ismail SM, et al. (2011) Subjective Perception of Sports Performance, Training, Sleep and Dietary Patterns of Malaysian Junior Muslim Athletes during Ramadan Intermittent Fasting. *Asian J Sports Med* 2: 167-176.
17. Roy J, Singh R, Roy A, Hamidan S (2012) Ramadan fasting and competitive sports: Psychological adaptation within socio-cultural context. *International Journal of Psychological Studies* 4: 55-62.
18. Al-Hajieh H, Redhead K, Rodgers T (2011) Investor sentiment and calendar anomaly effects: A case study of the impact of Ramadan on Islamic Middle Eastern markets. *Research in International Business and Finance* 25: 345-356.
19. Khan ZH, Watson PJ, Chen Z, Iftikhar A, Jabeen R (2011) Pakistani religious coping and the experience and behavior of Ramadan. *Mental Health, Religion, & Culture* 15: 435-446.
20. Folkman S, Lazarus RS, Dunkel-Schetter C, DeLongis A, Gruen RJ (1986) Dynamics of a stressful encounter: cognitive appraisal, coping, and encounter outcomes. *J Pers Soc Psychol* 50: 992-1003.
21. Sawatzky R, Ratner P, Chiu L (2005) A meta-Analysis of the relationship between spirituality and quality of life. *Social Indicators Research* 72: 153-188.
22. Bialkowski J, Etebari A, Wisniewski TP (2012) Fast profits: Investor sentiment and stock returns during Ramadan. *Journal of Banking & Finance* 36: 835-845.
23. Kadri N, Tilane A, El Batal M, Taltit Y, Tahiri SM, et al. (2000) Irritability during the month of Ramadan. *Psychosom Med* 62: 280-285.
24. Parrott WG, Smith RH (1993) Distinguishing the experiences of envy and jealousy. *J Pers Soc Psychol* 64: 906-920.
25. Alberoni F (1991) *Les envieux The envious*. Pocket, Plon, Paris.
26. Van de Ven N, Zeelenberg M, Pieters R (2009) Leveling up and down: the experiences of benign and malicious envy. *Emotion* 9: 419-429.
27. Van de Ven N, Zeelenberg M, Pieters R (2012) Appraisal patterns of envy and related emotions. *Motiv Emot* 36: 195-204.
28. Van de Ven N, Zeelenberg M, Pieters R (2011). The envy premium in product evaluation. *Journal of Consumer Research* 37: 984-998.
29. Van de Ven N, Zeelenberg M, Pieters R (2011) Why envy outperforms admiration. *Pers Soc Psychol Bull* 37: 784-795.
30. Bergin AE (1991) Values and religious issues in psychotherapy and mental health. *Am Psychol* 46: 394-403.
31. Pargament KI, Koenig HG, Perez LM (2000) The many methods of religious coping: development and initial validation of the RCOPE. *J Clin Psychol* 56: 519-543.
32. Festinger L (1957) *A theory of cognitive dissonance*. Row, Peterson and Company, Evanston, Illinois, USA.

33. Khan ZH, Sultana S, Watson PJ (2009) Pakistani Muslims dealing with cancer: Relationships with religious coping, religious orientation, and psychological distress. In : Ralph L. Piedmont, Andrew Village (eds.). *Research in the Social Scientific Study of Religion*. Brill, The Netherlands.
34. Khan ZH, Watson PJ (2006) Construction of the Pakistani Coping Practices Scale: Correlations with religious coping, religious orientation, and reactions to stress among Muslim university students. *The International Journal for the Psychology of Religion* 16: 101-112.
35. Khan ZH, Watson PJ, Chen Z (2011) Differentiating religious coping from Islamic identification in patient and non-patient Pakistani Muslims. *Mental Health, Religion, & Culture* 14: 1049-1062.
36. Ano GG, Vasconcelles EB (2005) Religious coping and psychological adjustment to stress: a meta-analysis. *J Clin Psychol* 61: 461-480.
37. Hebert R, Zdaniuk B, Schulz R, Scheier M (2009) Positive and negative religious coping and well-being in women with breast cancer. *J Palliat Med* 12: 537-545.
38. Abdel-Khalek AM (2007) Religiosity, happiness, health, and psychopathology in a probability sample of Muslim adolescents. *Mental Health, Religion, & Culture* 10: 571-583.
39. Tiliouine H, Cummins RA, Davern M (2009) Islamic religiosity, subjective well-being, and health. *Mental Health, Religion, & Culture* 12: 55-74.
40. Fakh El-Islam M (2000) Mental illness in Kuwait and Qatar. In I. Al-Issa (ed.). *Al-Junun: Mental illness in the Islamic world* (1stedn). International Universities Press, Madison, CT, USA.
41. Carver CS, Scheier MF (1990) Origins and functions of positive and negative affect: A control-process view. *Psychological Review* 97: 19-35.
42. Charles S Carver, Michael F Scheier (1998) *On the self-regulation of behavior*. Cambridge University Press, New York, USA.
43. Elliot AJ, McGregor HA (2001) A 2 X 2 achievement goal framework. *J Pers Soc Psychol* 80: 501-519.
44. Saroglou V, Delpierre V, Dernelle R (2004) Values and religiosity: A meta-analysis of studies using Schwartz's model. *Personality and Individual Differences* 37: 721-734.
45. Carter EV, McCullough ME, Carver CS (2012) The mediating role of monitoring in the association of religion with self-control. *Social Psychological and Personality Science* 0: 1-7.
46. Wenger JL (2007) The implicit nature of intrinsic religious pursuit. *International Journal for the Psychology of Religion* 17: 47-60.
47. Brehm JW (1972) *Responses to loss of freedom: A theory of psychological reactance*. General Learning Press, Morristown, NJ, USA.
48. French DC, Eisenberg N, Vaughan J, Purwono U, Suryanti TA (2008) Religious involvement and the social competence and adjustment of Indonesian Muslim adolescents. *Dev Psychol* 44: 597-611.
49. Andrzej Nowak, Robin R Vallacher (1998) *Dynamical social psychology*. Guilford Press, NewYork, USA.
50. Charles S Carver, Michael F Scheier (2002) Control processes and self-organization as complementary principles underlying behavior. *Personality and Social Psychology Review* 6: 304-315.
51. Stephen J Guastello (1995) *Chaos, catastrophe, and human affairs: Applications of nonlinear dynamics to work, organizations, and social evolution*. Lawrence Erlbaum Associates, Mahwah, NJ, USA.
52. Briki W, RJR Den Hartigh, Keith D Markman, Jean-Paul Micallef, Christophe Gernigon (2013) How psychological momentum changes in athletes during a sport competition. *Psychology of Sport and Exercise* 14: 389-396.
53. Gernigon C, Briki W, Eykens K (2010) The dynamics of psychological momentum in sport: the role of ongoing history of performance patterns. *J Sport Exerc Psychol* 32: 377-400.
54. Briki W, Gernigon C (2009) Momentum psychologique: Le pouvoir de l'élan [Psychological momentum: The power of impetus]. In: Y Paquet (Ed.). *Psychologie du contrôle : aspects théoriques et applications [Psychology of control: Theoretical aspects and applications]* Brussels, De Boeck.

## Chapter 13

# Ramadan Fasting and Biological Biomarkers: the New Opportunities of Systems Biology and Omics Sciences

**Nicola Luigi Bragazzi<sup>1,2\*</sup>**

<sup>1</sup>School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, University of Genoa, Italy

<sup>2</sup>DINO GMI, Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, Genoa, Italy

**\*Corresponding author:** Nicola Luigi Bragazzi, School of Public Health, Department of Health Sciences (DISSAL), Via Antonio Pastore 1, Genoa and DINO GMI and Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health, Section of Psychiatry, University of Genoa, 16132 Genoa, Italy, Tel: +39- 010-353-7664; E-mail: [robertobragazzi@gmail.com](mailto:robertobragazzi@gmail.com)

## Abstract

Ramadan fasting represents the fourth of the five pillars of the Islam creed (*'aqidah*). Even though patients are exempted from observing this religious duty, they may be eager to share this particular moment of the year with their family and peers, by attending the special prayers, social gatherings and other ceremonies. However, there are no guidelines or standardized protocols that can help physicians to properly address the issues and concerns of patients willing to fast in Ramadan and correctly advising them. Despite the extensive body of studies conducted on Ramadan fasting, so far only clinical parameters and analytical chemistry have been used and assessed. There is a dearth of systems biology- and omics-based studies, which investigate biological events from a global perspective, not focusing on single candidate clinical biomarkers but taking into account the entire overall perturbations, by means of high-throughput technologies. Systems biology and omics sciences could assess the metabolic effects of Ramadan fasting, confirming well-known and expected metabolic perturbations, and adding knowledge on both the short-term and long-term effects of Ramadan fasting. Systems biology and omics sciences could undoubtedly constitute a fundamental step further and a crucial advancement in the field of the relationship between religion and health. It can be anticipated that these highly advanced specialties provide a unique, unprecedented opportunity for studying the physiology and physiopathology of fasting, giving personalized counseling and advice to patients willing to fast during Ramadan.

**Keywords:** Biological Pathway and Network; High-Throughput Technologies; Metabolomics; Nutrigenomics; Omics Sciences; Personalized Medicine (P6 Model); Ramadan Fasting; Systems Biology

## Introduction

The Holy month of Ramadan, the ninth month of the Muslim lunar calendar (*Hijra*), is particularly blessed and of great value and significance among Muslims, representing the month of the descent of the *Qur'an*. Ramadan is not only abstinence from food and drinking, but also from smoking, medication and sexual intercourses (*Surat 2 "Al-Baqarah", ayyat 183 and following verses*).

Ramadan fasting is not, however, a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [1]. The fast is broken, taking two traditional meals, pre-dawn meal which is termed as *suhoor*, whilst after-sunset meal is called *iftar*. Ramadan duration is variable; mean fasting duration is usually 12-14 hours, but depending on the place and the year it can last also up to 18 hours [1] or even 22 hours, in the extreme latitudes regions [1].

Patients are exempted from this religious duty (*Surat 2 "Al-Baqarah", ayyat 185-186*). However, they could be willing to fast and share the spirituality of this month with their family and peers, by attending the prayers, social gatherings and other special ceremonies [3].

The effects of Ramadan fasting on human physiology and physiopathology is not a mere academic and speculative topic or of limit interest for only the Arabic countries. It has instead clinically relevant and pragmatic implications: in a globalized society, the physicians have to face with issues like the management of diabetes and Chronic Kidney Diseases (CKDs) in Muslim patients that want to fast during Ramadan [4]. However, information is sparse and no guidelines or standardized protocols exist [4,5].

For these reasons, systems biology and omics sciences could represent a fundamental step further and an advancement in the field of research on Ramadan fasting, exploiting high-throughput technologies [6], and organically linking metabolomics with Genome-Wide-Association studies GWAS (mGWAS) [7-10], as Matthews and collaborators do [6].

## Omics Sciences and Systems Biology

mGWAS indeed offers unique and unprecedented opportunities: GWAS are a tool of genetic epidemiology and enable scholars to analyze and understand the etiopathology of a disease and/or the genetic make-up of a phenotype. GWAS have proven to be highly reproducible identifying reliable and robust genetic associations with hundreds of human diseases and traits. Despite the success of many GWAS, little progress has been made in uncovering the underlying mechanisms for many diseases, since it appears that the computed Odd-Ratios (ORs) for each SNP are very small and do not explain the heritability and heterogeneity of disease. For this reason, GWAS should be complemented with systems biology approaches. For example, in order to overcome these drawbacks, the combination of GWAS with techniques and tools from the field of Molecular Pathological Epidemiology (MPE) has been recently proposed to improve the predictive power and clinical usefulness of GWAS, as well as to simultaneously study the biological make-up of the subjects, their interactions with the environment and the processes leading to the disease [11,12].

The use of metabolomics, which specifically focuses on the systematic study of biochemical processes involving metabolites and other byproducts in a biological cell, tissue, organ or organism, for molecularly characterizing phenotypes or diseases, has enabled the discovery of previously undetected or unsuspected associations between diseases and signaling and metabolic pathways. Most success has been seen in metabolic diseases such as hypertension, diabetes, obesity, dyslipidemia and other endocrinological disorders.

Despite the body of articles on Ramadan fasting, the previous studies have usually used routine clinical chemistry and biochemistry, investigating the effects of few clinical biomarkers.



Only two studies use a broader approach in studying the chemokine network [13] and second-generation biomarkers, such as apelin-13 [14]. In the former study, biochemical and hematological parameters were assessed using routine clinical chemistry, while ELISA was exploited for detection of CXCL1, CXCL10 and CXCL12 chemokines. This systems biology approach showed decreased levels of pro-inflammatory CXC chemokines and unaltered levels of homeostatic ones. The authors concluded that fasting is important in inflammation controlling by finely tuning the chemokines network and pathway. In the latter study, 42 healthy subjects were assessed for serum apelin-13 concentration besides routine analytical chemistry. The authors found that apelin-13 was not affected by the fasting.

## Ramadan as a Complex Metabolic Model

However, Ramadan fasting is a very complex model of fast, since it is not a prolonged or continuous fasting, but consists of alternate fasting and feasting (re-feeding) periods [15]. Ramadan is a concrete example of Intermittent Fasting (IF)/Alternate-Day Fasting (ADF) [16-18] or Alternate-Day Calorie Restriction (ADCR) [19], which means cycles of food intake and cycles of calorie restriction. Among the different models of IF/ADCR Ramadan is particular for the long mean of abstinence from food (usually longer than 12 hours).

Caloric Restriction or Calorie Restriction (CR) is a form of Dietary Restriction (DR) (CR/DR), which is sometimes referred to as Dietary Energy Restriction (DER). Intermittent fasting may have beneficial effects on the health and longevity of animals — including humans — that are similar to the effects of Caloric Restriction (CR). Some studies suggest that benefits could be the result of an overall reduction in caloric intake.

Studies suggest possible benefits: fasting may function as a form of nutritional hormesis [20], having an impact on longevity and ageing, fat metabolism and oxidation [21-23], even though there is not a universal consensus among the scholars.

For all these reasons, Ramadan fasting represents a “*unique metabolic model*”, implying a radical change in lifestyle habits and behaviors, a different eating pattern, as well as a different type of diet consumed respect to the routine diet [15]. Physiological, physiopathological, cultural, and religious variables play interweaving roles.

Since, as we stated above, data concerning physiological and physiopathological parameters are sometimes conflicting in the extant literature, omics sciences could represent an opportunity to confirm, validate or confute these findings, by capturing a global snapshot of the phenomenon.

Omics sciences include specialized specialties and branches such as nutrigenomics [24], which encompasses the study of interactions between genes and nutrients both in healthy and in ill subjects. This kind of investigations could pave the way for personalized medicine, that is to say it may provide a tailored and individualized nutritional advice and counseling, instead of a “one-size-fits-all” [25-27]. This model is known as P6 medicine, where the six Ps stay for predictive, preventive, participatory (or patient-centered), personalized, psycho-cognitive and public. Diseases are not discrete entities but are highly interconnected and interwoven, therefore they should be ecologically thought. Omics sciences are a platform for studying phenotypes and traits from an ecological perspective [28].

Matthew and collaborators collected up to five blood samples for each volunteer. They managed to recruit eleven healthy male subjects. As well-known and expected, they found a post-prandial increase in glucose, insulin and lactate concentration. What the metabolomics-based approach added is the knowledge of the short-term increase in bile acid and amino acid levels and a decrease in long-chain acyl-carnitine and polyamine levels, and the long-term decrease in some phospholipids concentration.

Matthew and co-workers maintain that, since many Muslim patients with diabetes adhere to Ramadan fasting, such a study may also provide information from diseased individuals



under otherwise inaccessible challenge conditions and also help to better understand how individuals with common metabolic diseases can be best managed under Ramadan fasting conditions. This is true not only for patients suffering from diabetes but also for those suffering from CKDs, as well as other kinds of disease.

## Conclusions

Ramadan fasting is a complex, multifaceted model of fasting. Even though highly studied, no standardized guidelines and evidence-based protocols exist; moreover, data taken from the extant literature are sometimes contrasting and so far only clinical parameters and analytical chemistry have been assessed. Omics sciences would be extremely useful in capturing this complexity and potentially translate into clinical practice, by advising patients and giving them personalized and tailored recommendations.

## References

1. Berbari AE, Daouk NA, Mallat SG, Jurjus AR (2012) Ramadan Fasting in Health and Disease. In: Berbari AE, Mancia G (Eds.). "Special Issues in Hypertension".
2. Günaydin GP, Dogan NO, Çevik Y, Korkmaz H, Savrun A, et al. (2013) Evaluation of patients with renal colic that present to an emergency department during the month of Ramadan.[Ramazan Ayinda Renal Kolikle Acil Servise Basvuran Hastalarin Degerlendirilmesi]. The Journal of Academic Emergency Medicine. 12: 24-26.
3. Budak A (2005) Fasting in Islam and the month of Ramadan (Islam in practice). The Light Inc Editor.
4. Al Wakeel J, Mitwalli AH, Alsuwaida A, Al Ghonaim M, Usama S, et al. (2013) Recommendations for fasting in Ramadan for patients on peritoneal dialysis. Perit Dial Int 33: 86-91.
5. Bragazzi NL (2014) Ramadan fasting and Chronic Kidney Disease (CKD): a systematic review. Journal of research in medical science.
6. Mathew S, Krug S, Skurk T, Halama A, Stank A, et al. (2014) Metabolomics of Ramadan fasting: an opportunity for the controlled study of physiological responses to food intake. J Transl Med 12: 161.
7. Adamski J, Suhre K (2013) Metabolomics platforms for genome wide association studies--linking the genome to the metabolome. Curr Opin Biotechnol 24: 39-47.
8. Dharuri H, Demirkan A, van Klinken JB, Mook-Kanamori DO, Van Duijn CM, et al. (2014) Genetics of the human metabolome, what is next? Biochim Biophys Acta 1842: 1923-1931.
9. Adamski J (2012) Genome-wide association studies with metabolomics. Genome Med 4: 34.
10. Dumas ME (2012) Metabolome 2.0: quantitative genetics and network biology of metabolic phenotypes. Mol Biosyst 8: 2494-2502.
11. Ogino S, Lochhead P, Chan AT, Nishihara R, Cho E, et al. (2013) Molecular pathological epidemiology of epigenetics: emerging integrative science to analyze environment, host, and disease. Mod Pathol 26: 465-484.
12. Ogino S, Chan AT, Fuchs CS, Giovannucci E (2011) Molecular pathological epidemiology of colorectal neoplasia: an emerging transdisciplinary and interdisciplinary field. Gut 60: 397-411.
13. Akrami Mohajeri F, Ahmadi Z, Hassanshahi G, Akrami Mohajeri E, Ravari A, et al. (2013) Dose Ramadan Fasting Affects Inflammatory Responses: Evidences for Modulatory Roles of This Unique Nutritional Status via Chemokine Network. Iran J Basic Med Sci. 16:1217-1222.
14. Celik A, Saricicek E2, Saricicek V3, Sahin E4, Ozdemir G1, et al. (2014) Effect of Ramadan fasting on serum concentration of apelin-13 and new obesity indices in healthy adult men. Med Sci Monit 20: 337-342.
15. El-Wakil HS, Desoky I, Lotfy N, Adam AG (2007) Fasting the month of Ramadan by Muslims: could it be injurious to their kidneys? Saudi J Kidney Dis Transpl 18: 349-354.
16. Azevedo FR, Ikeoka D, Caramelli B (2013) Effects of intermittent fasting on metabolism in men. Rev Assoc Med Bras 59: 167-173.
17. Shephard RJ (2012) The impact of Ramadan observance upon athletic performance. Nutrients 4: 491-505.
18. Varady KA, Hellerstein MK (2007) Alternate-day fasting and chronic disease prevention: a review of human and animal trials. Am J Clin Nutr 86: 7-13.

19. Johnson JB, Laub DR, John S (2006) The effect on health of alternate day calorie restriction: eating less and more than needed on alternate days prolongs life. *Med Hypotheses* 67: 209-211.
20. Hayes DP (2007) Nutritional hormesis. *Eur J Clin Nutr* 61: 147-159.
21. Michalsen A, Li C (2013) Fasting therapy for treating and preventing disease - current state of evidence. *Forsch Komplementmed* 20: 444-453.
22. Trepanowski JF, Bloomer RJ (2010) The impact of religious fasting on human health. *Nutr J* 9: 57.
23. Trepanowski JF, Canale RE, Marshall KE, Kabir MM, Bloomer RJ (2011) Impact of caloric and dietary restriction regimens on markers of health and longevity in humans and animals: a summary of available findings. *Nutr J* 10: 107.
24. Bragazzi NL (2013) Situating Nutri-Ethics at the Junction of Nutrigenomics and Nutriproteomics in Postgenomics Medicine. *Curr Pharmacogenomics Person Med* 11: 162-166.
25. Nicolini C, Bragazzi N, Pechkova E (2012) Nanoproteomics enabling personalized nanomedicine. *Adv Drug Deliv Rev* 64: 1522-1531.
26. Bragazzi NL (2013) From P0 to P6 medicine, a model of highly participatory, narrative, interactive, and "augmented" medicine: some considerations on Salvatore Iaconesi's clinical story. *Patient Prefer Adherence* 7: 353-359.
27. Bragazzi NL (2013) Children, adolescents, and young adults participatory medicine: involving them in the health care process as a strategy for facing the infertility issue. *Am J Bioeth* 13: 43-44.
28. Bragazzi NL (2013) Rethinking psychiatry with OMICS science in the age of personalized P5 medicine: ready for psychiatome? *Philos Ethics Humanit Med* 8: 4.

## Chapter 14

# Ramadan Fasting and Lipid Profile

**Hadi AR HadiKhafaji\*<sup>1</sup> and Jassim M Al Suwaidi<sup>2</sup>**

<sup>1</sup>Toronto Western Hospital, Toronto University, Canada

<sup>2</sup>Hamad Medical Corporation, Weill Cornell Medical College, Qatar

**\*Corresponding author:** Hadi AR HadiKhafaji, (FRCP Glasgow), Internal medicine Department, Toronto Western Hospital, Toronto University, Canada; E-mail: [Hadi968@hotmail.com](mailto:Hadi968@hotmail.com); [hadiarhadi@yahoo.com](mailto:hadiarhadi@yahoo.com)

**Abbreviations:** BUN: Blood Urea Nitrogen; CAD: Coronary Artery Disease; CKD: Chronic Kidney Disease; e-GFR: estimated Glomerular Filtration Rate; HDL: High Density Lipoprotein; HSP: Heat Shock Protein; LDL: Low Density Lipoprotein; NICU: Neonatal Intensive Care Unit; NIDDM: Non-Insulin Dependent Diabetes Mellitus; TC: Total Cholesterol; TG: TriGlyceride

## Introduction

Since the influential effort of Mc Cay et al., ample interest has been shown in caloric restriction's aptitude to perk up health and to spread lifespan. Caloric constraint has been shown to increase permanence, reduces the morbidity of a host of diseases, including autoimmune diseases, atherosclerosis, cardiomyopathies, cancer, diabetes, renal diseases, neurodegenerative diseases, and respiratory diseases [1-3]. Fasting is demarcated as a partial or total refraining from all foods, or a select abstention from prohibited foods. Fasting has been the subject of abundant scientific soundings.

In Islam, the fasting period is one lunar month. During which Muslims fast and do not eat or drink anything from dawn to sunset. For the reason that lunar month is shorter than calendar one and lunar year is 10 days shorter than calendar year Ramadan can be in any of the four season of the year, it can be in winter or in summer. If it was corresponding to summer season, the fasting people should cease food and drinking in long days equated to winter season in which fasting intermission is short. During Ramadan, all healthy adult Muslims are forbidden from overwhelming any food or water from sunrise to sunset. Food and fluid intake become nocturnal during Ramadan, and the shared repetition is to eat one large meal after sunset and one lighter meal before dawn [4]. Ramadan is clearly the most commonly sought religious fast.

The formerly believed that Ramadan fasting often led to a bridged energy intake and weight loss [5], but recent studies have brought about that caloric intake really increases in the face of the decreased meal occurrence [6]. In relation to macronutrient composition, meals are often calm of more fat and less carbohydrate during Ramadan than during the rest of the year [5-8]. The intermittent fasting of Ramadan could affect various aspects of body physiology and biochemistry important to athletic success. Performance of repeated anaerobic exercise is impaired, but aerobic power and muscular strength show little change during Ramadan. Ratings of fatigue are increased, and vigilance and reaction times are impaired, particularly during the afternoon. Athletes with diabetes mellitus should seek

a medical exemption from fasting, and prescribed drug schedules should be carefully maintained. There is no major increase of injury rates, but competitors may have difficulty in producing urine for doping controls [9]. Ramadan fasting had a small to moderate, negative impact on quality of performance during an acute high-intensity exercise session, particularly during the period of the daytime fast. Fatigability is higher in the afternoon during Ramadan; therefore, training and competition should be scheduled at the time of day when physical performance is less affected. The optimal time to conduct an acute high-intensity exercise session during the Ramadan fasting month is in the evening, after the breaking of the day's fast. Athletes who maintain their total energy and macronutrient intake, training load, body composition, and sleep length and quality are unlikely to suffer any substantial decrements in performance during Ramadan [10-12]. Ramadan fasting has elicited mixed results in relation to cardiovascular wellbeing, particularly concerning lipid profiles. In this chapter we will incite the state of the art regarding the effect of Ramadan fasting on lipid profile in relation to different health aspect which has been subjected to investigation.

## Ramadan Fasting and Lipid Profile in Healthy Population

Inconsistent results concerning the effect of Ramadan fasting on serum lipid levels [5,13-18]. Physicians working in Muslim countries should be attentive that Ramadan may affect some laboratory findings. Fasting serum cholesterol, triglycerides, thyroxine, triiodothyronine, uric acid, gastrin, and insulin were measured in a group of 24 Muslims at the beginning and end of Ramadan. There was a significant increase in the levels of total serum cholesterol, thyroxine, and uric acid and a significant fall in body weight with no significant change in the levels of total serum triglycerides, triiodothyronine, gastrin, fasting insulin, or in the in gastrin or insulin escalation 30 minutes after food. These changes, although unlikely to affect normal healthy people, may be significant in some patients [13]. A cohort study on 81 healthy volunteers (41 male, mean age of 22.7 years) indicated that Ramadan fasting result in a decrease in glucose and weight. Although there was a significant discount in meal frequency, a significant increase in LDL and decrease in HDL was noted during Ramadan. No significant changes in total cholesterol and Triglycerides after Ramadan fasting with no association with sex, body weight changes, number of meals. There was negative correlation between primary triglycerides and cholesterol levels before Ramadan and its change during Ramadan such negative correlation was stronger in females than males. TG level showed significant increase in subjects with normal BMI, though it decreased in over weights. Such finding bounces the imprint that the effect of Ramadan fasting on serum lipid levels may be closely related to the nutritional diet or biochemical response to starvation [16]. Ramadan fasting may increases serum HSP70 and improves serum lipid profile [17] and increase in blood cholesterol levels with either increasing or decreasing level of energy intake in correlation to the quantitative and qualitative dietary intake and may be the physical activity [18,19].

Author	Country/ study	Population included	Age	Effect on lipid profile
Fedail et al., 1982 [13]	England/ prospective	24 volunteers (20 males, 4 females)	Mean age = 30 yrs. (range 21-40)	<p>↑ Significant in the levels of TC.</p> <p>↓ Thyroxin&amp; uric acid significant, ↓ in body weight.</p> <p>→ in TG, T3, gastrin, fasting insulin level.</p>
Aldouni et al., 1997 [14]	Morocco/ prospective	32 healthy adult male volunteers	25-50 yrs.	<p>↓ TC (7.9%, p &lt; 0.001) during Ramadan vs. pre-fasting period.</p> <p>↓ TG (30%, p &lt; 0.001).</p> <p>The ↓ of both TG and TC maintained 1 month after Ramadan.</p>

Afrasiabi et al., 1997 [15]	Iran/ prospective	38 healthy men volunteers	age group 27-62 (42 ± 10) years	↓ In energy intake & nutrient materials during Ramadan (P<0.05). ↓ TC, LDL-C, TG levels towards the end of Ramadan (P<0.01).
Ziaee V et al., 2006 [16]	Iran cohort study	81 healthy volunteers	22.7 yrs (range: 18-29 yrs, SD 2.3)	↓ In glucose & weight. ↓ In meal frequency significantly. ↑ In LDL significantly. ↓ In HDL significantly.
Haghdoost AA, Poorranjbar M 2009 [19]	Iran/ randomized trial	93 healthy students	Mean (SD) 19.25 (3.5) 20.4 (3.2) yrs.	↓ TG in both gps during Ramadan. ↓ TC during & after Ramadan in subject who engaged in physical activity & fasted (-12.24 and -8.4 mg/dL, respectively). The patterns of changes in the HDL, LDL & HDL/ LDL values comparable in both groups (p > 0.5).
Zare A et al., 2011 [17]	Iran/ prospective	32 male volunteers	Mean age of 28.5 (range 23-37) years	↑ HSP 70 & HDL significantly on day 3 & 25 <sup>th</sup> day of Ramadan vs 1 day before Ramadan. ↓ Mean serum TG, TC, LDL, LDL /HDL & TC/ HDL ratios on the 25 <sup>th</sup> day of Ramadan significantly vs. one day before & 3 <sup>rd</sup> day Ramadan.
Shehab A et al., 2012 [18]	UAE/ prospective	102 (68% male) multi-ethnic volunteers;	Mean age ± SD (38.76 10.5 ± 6yrs)	Significant improvements in HDL-C and LDL-C levels even after 4 weeks post Ramadan.
Kul S et al., 2013 [20]	Turkey/ meta-analysis	1,476 healthy (923 men, 553 women)	-----	↓ LDL & fasting blood glucose levels after Ramadan fasting, both sex groups & in the entire group in contrast to levels prior to Ramadan.

↑: Increase, ↓: Decrease, TC: Total Cholesterol, TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; HSP: Heat Shock Protein; →: No Change. ----- Information Not accessible

**Table 1:** Ramadan fasting and lipid profile in healthy population.

A meta-analysis of self-controlled cohort studies comparing body weights, lipids levels and fasting blood glucose before and after Ramadan bearing in mind the gender differences. The primary finding of this meta-analysis was that after Ramadan fasting, low-density lipoprotein (95% CI = -2.48 to -0.86) and fasting blood glucose levels (95% CI = -1.62 to -0.58) were decreased in both sex groups. On top, body weight, total cholesterol and triglyceride levels (95% CI = -0.31, 0.36) remained unchanged in females, despite the fact HDL levels increased (95% CI = 0.11 to 1.61, p = 0.03). Ramadan fasting resulted in weight loss (p = 0.001). Also, a substantial reduction in total cholesterol (95% CI = -0.77 to -0.11) and LDL levels (95% CI = -3.47 to -0.96) and a small decrease in triglyceride levels (95% CI = -0.67 to -0.02) in males [20]. In this meta-analysis, combining all results of all studies, it can be clinched that Ramadan fasting leads to decreased LDL levels, nonetheless no increases in HDL and triglycerides. FBG levels were also significantly abridged after Ramadan fasting. Ramadan fasting may have some positive effects on a number of health outcomes in a healthy Muslim population. Keeping in consideration the limitations of such analysis while interpreting the results, more investigations are necessary to show sustainability of this positive effect.

## Ramadan and Lipid Profile in Association to Nutritional Style, Physical Activity, Changes in Sleep Pattern

Ramadan fasting investigations have shown that despite the increase in the level of

calorie consumption in Ramadan, the body weight, TC, TG and C-LDL decreased at the end of the holy month. The reduction of both serum TG and TC was maintained one month after Ramadan. This has been anticipated to the changes in the dietary habit during Ramadan. While fasting is accompanied with an increase of anti-atherogenic biochemical parameters (HDL-cholesterol) and apolipo protein A1 and/or a decrease of atherogenic parameters [triglycerides, total cholesterol, apoprotein (apo) B, and LDL-cholesterol] in certain practicing Islamic fasting populations, this influential effect may not be evident in other Muslim fasting population. Such incongruity could be attributed to different ethnic groups, alimentary products consumption, different level of physical activity and almost certainly to different physio-pathological conditions and geographical zones, or seasonal variation in which Ramadan takes place as a lunar calendar month [8,15,17,21-28].

Ramadan fasting have shown that striking changes in nutritional habits during Ramadan may be useful in reducing LDL levels and in increasing HDL levels. The young Muslim's diet during Ramadan may contribute to auspicious alterations of the serum lipoprotein profile related to cardiovascular protection. In a study of 48 Healthy volunteers (22 men & 24 women) in North Africa showed higher total energy intake during Ramadan (13 and 11 MJ/day) equated to before and after Ramadan (11 and 9 MJ/day) in both genders, correspondingly. In the second week of Ramadan, carbohydrate intake was elevated by 22% and 24% in men and women, respectively, compared to before and after Ramadan. At the end of Ramadan, the low density lipoproteins decreased by 20% in women and 55% in men compared to the values obtained before Ramadan. In both groups, high density lipoproteins increased by 1.4-fold (on day 28 of Ramadan vs. before and after Ramadan). A progressive decrease in LDL-C perceived in females. HDL-C displayed 30 % increment on day 15 of Ramadan, compared to before Ramadan [29].

Later study in which Ramadan month conforming to the winter season (included 38 healthy men volunteers) clinched that Islamic fasting in Ramadan with low fat, low calorie diet leads to plasma lipids reduction in hyper lipidemic men. In this study population, the fat diet was high in polyunsaturated fatty acid in disparity to saturated fatty acid. After Ramadan total energy intake increased but as compared with the pre fasting period totals energy level is delimited. The reduction of mean body weight one month after Ramadan in comparing with the first day of holy month could be donated to a reduction in energy intake and increase in physical activity after Ramadan. Relating to the short term of the fasting days and the occurrence of fasting in the winter season, the fasting population likely had not changed their daily feeding habits after Ramadan. These finding suggest that continuing nourishing behavior and aerobic exercise could lead to maintain lipid profile levels and to increase HDL level one month after Ramadan [15].

Keeping in mind that different Islamic populations have dissimilar eating habits, conspicuously during Ramadan, the change of diet, lipids, and lipoproteins produced during Ramadan in 36 (22 males and 14 females) Tunisian volunteers. During Ramadan, the study subjects consumed more proteins, cholesterol, vitamin E ( $p < 0.01$ ), and polyunsaturated fatty acids ( $p < 0.05$ ). Simultaneously, they displayed an increase in total cholesterol, low-density lipoprotein-cholesterol ( $p < 0.01$ ) and apoprotein B ( $p < 0.05$ ) and a decrease in the ratio of apoprotein A1 to apoprotein B ( $p < 0.01$ ). All assayed saturated fatty acids were not altered during fasting while three unsaturated fatty acids (C18:1cis9, C18:2n-6, and C30:4n-6) increased significantly. Habitual diet was not sufficient to restore the pre-fasting patterns [30]. Ramadan is associated with a change of diet and biochemical profile with unclear influence on atherosclerosis risk; perhaps, considering other non-alimentary changes, such as sleep and physical activity, might be useful to elucidate the influence of dietary change in the observed reform of biological profile.

Author	Country/ study	Study sample	age	Effect on lipid profile
Chaouachi A et al., 2008 [34]	Tunisia/ prospective	15 elite judo players	-----	<p>↑ HDL-C and LDL-C increased by 0.12 (p &lt; 0.01) &amp; 0.20 mmol. l (-1) (p &lt; 0.05), respectively.</p> <p>↓ mean non-esterified fatty acid levels from 0. (p &lt; 0.01) in first week, then ↑ (p &lt; 0.05) to 1.22 mmol. ↓ (-1) over the middle of Ramadan &amp; recovered to pre-Ramadan level for the end &amp; the post-Ramadan periods.</p> <p>↑ Apolipoprotein A1 levels significantly at the end (p &lt; 0.01) &amp; post-Ramadan p (p &lt; 0.05).</p>
Bouhlel E et al., 2008 [33]	Tunisia/ prospective	9 male rugby players	(age 19 +/- 2 yr)	↑ Plasma triglycerides and HDL cholesterol concentrations.
Lamri-Senhadj M Y 2009 [29]	Algeria/ prospective	46 Healthy volunteers (22 men, 24 women)	mean age = 24 ± 3 years	Higher total energy intake during Ramadan (13 and 11 MJ/day) than before and after Ramadan (11 and 9 MJ/day) in men and women.
Haghdoust AA et al., 2009 [19]	Iran/ randomized trial	93 students	Group I :19.25 (3.5) yrs group II:20.4 (3.2) yrs	<p>↓ Body weight by 1.2 kg (p = 0.03) in Fasting grp with physical activity.</p> <p>↓ TG in both groups during Ramadan.</p> <p>↓ TC during &amp; after Ramadan for those who concurrently engaged in physical activity &amp; fasted. Comparable changes in the HDL, LDL &amp; HDL/LDL in both groups (p &gt; 0.5).</p>
Barkia A et al., 2011 [30]	Tunisia/ prospective	36 healthy volunteers (22 males & 14 females)	Mean age 42 (range :22-55) years	<p>↑ In TC, LDL-C (p &lt; 0.01) &amp; Apo protein B (p &lt; 0.05).</p> <p>↓ Apo protein A1/ Apo protein B ratio (p &lt; 0.01).</p> <p>→ Saturated fatty acids by fasting.</p> <p>↑ 3 unsaturated fatty acids significantly.</p>
Trabelsi K et al., 2011[35]	Tunisia/ prospective	18 physically active men	Mean 26.6 ( ± SD 3.0) yrs.	↑ High-density lipoprotein cholesterol by 27.3% (P < 0.001).
Mirzaei B et al., 2012 [32]	Iran/ prospective	14 male collegiate wrestlers	(age, 20.12 ± 2.5 yrs)	<p>↓ TC &amp; LDL after Ramadan vs. pre-Ramadan (P = 0.011, P = 0.001).</p> <p>↑ TG &amp; VLDL at the end of Ramadan vs. before &amp; after Ramadan.</p> <p>↓ Glucose Significantly.</p> <p>↑ HDL (P = 0.001, P = 0.045).</p> <p>↓ Body weight, body fat % &amp; aerobic power at 4<sup>th</sup> wk of Ramadan vs. pre-Ramadan (P = 0.05).</p>

↑: increase, ↓: decrease, TC: Total Cholesterol; TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; →: No Change; ----- : Information Not Accessible

**Table 2:** Ramadan, nutritional style, physical activity, athletics, changes in sleep pattern and lipid profile.

Habitually, people are less physically active during Ramadan; nonetheless such assumption may not explain the disparities in the lipid profile. Other factors, such as changes in the diet and sleeping hours, may have more important starring role. A randomized trial, which included 93 students who took a physical education course who were divided into two groups – those who had regular physical activity after Ramadan and those who had physical activity during Ramadan, assessing fasting glucose sugar and lipid profile from venous blood sample before, at the end, and 40 days after Ramadan. In this study Fasting with physical activity decreased body weight by 1.2 kg (p = 0.03). Fasting blood sugar decreased by 7 mg/dL, triglyceride decreased in both groups during Ramadan, nevertheless cholesterol levels dropped noticeably during and after Ramadan for those who concurrently engaged in physical activity and fasted (-12.24 and -8.4 mg/dL, respectively). The outlines of fluctuations in the high-density lipoprotein, low-density lipoprotein and HDL/ LDL values were more or less comparable in both groups (p>0.5) [19]. Due to the long duration of diurnal fasting in Ramadan, hunger and dehydration levels increase beyond those experienced at other times of the year, food intake is restricted to the night hours within a short time distance, which delays and reduces the duration of sleep. Furthermore, if the period of

daytime fasting is disjointed by spells of sleeping, the normal sleep-wake cycle associated with the solar day is disturbed [15,16]. These effects suggest that Ramadan fasting can be considered as a period when the human body is exposed to different mild strains, and hence, fasting may induce stress tolerance and heat shock protein. A profitable effect of Ramadan fasting may increase serum HSP70 and improves serum lipid profile [17]. In a study included 102 multi-ethnic volunteers (68% male; mean age  $\pm$  SD (38.76 $\pm$ 10.5 years) from the middle east correlating lipid profile changes and body weight and waist circumference found significant and beneficial changes in systolic blood pressure, body weight, waist circumference, triglyceride, high-density lipoprotein and low-density lipoprotein, at the end of Ramadan, but not in total cholesterol. Likewise, a significant progressive increase in high-density lipoprotein and decrease in low-density lipoprotein levels were found four weeks after Ramadan. At the end of Ramadan both total cholesterol and triglyceride were slightly lower before and 4 week after Ramadan [18]. This is in contrast to results from Morocco [14], where a significant reduction in total cholesterol and triglyceride levels up to four weeks after fasting season. Such findings are associated with increased feasting of monounsaturated and polyunsaturated fatty acids along with decreased consumption of saturated fatty acids during fasting period the significant differences between the classical Mediterranean dietary habits and the diet enriched in saturated fat, in the Middle East [18] may be the elucidation.

## Ramadan, Lipid Profile and Athletes Performance

Ramadan fasting has little effect on the performance of experienced Judokas, but Muslim athletes who train during Ramadan should carefully timetabled their training load and scrutinize their food intake and fatigue levels to avoid performance decrements [31]. Correlating physical activity and fitness to the Muslims fasting season. Ramadan fasting appears to have significant effect on body composition, aerobic power and lipid profile in 14 male wrestlers (age, 20.12  $\pm$  2.5 yrs.) who were tested one week before the beginning of Ramadan, last week of Ramadan and the 4<sup>th</sup> week after Ramadan results showed that body weight, body fat percentage and aerobic power at 4<sup>th</sup> week of Ramadan were significantly lower than pre-Ramadan values ( $P = 0.05$ ). Total cholesterol and low density lipoprotein levels decreased after Ramadan compared to pre-Ramadan ( $P = 0.011$ ,  $P = 0.001$  respectively), however, it touched to higher levels month after Ramadan vs. Pre-Ramadan levels, significant decrease and increase were consequently witnessed in glucose and high density lipoprotein ( $P = 0.001$ ,  $P = 0.045$ ). Triacylglycerol and VLDL increased at the end of vs. before and after Ramadan [32]. In a study involved 9 male rugby players (age 19  $\pm$  2 yr, height 1.78  $\pm$  0.74 m) showed that Ramadan fasting was associated with a reduction of body mass and body fat ( $p < 0.01$ ) without significant change in leptin or adiponectin levels but increased plasma triglycerides and HDL cholesterol concentrations [33].

The effect of Ramadan intermittent fasting on blood lipid markers in 15 elite judo athletes during a period when they were maintaining their training load without competing Mean energy intake (12.9 MJ/d) remained similar throughout the study as did the macronutrient constituents of the diet. Mean body mass was slightly reduced (2%;  $p < 0.01$ ) by the end of Ramadan due mainly to a 0.65  $\pm$  0.68 kg decrease in body fat ( $p < 0.05$ ). Ramadan fasting produced significant changes in some of the blood lipid levels: both HDL-C and LDL-C increased by 0.12 ( $p < 0.01$ ) and 0.20 mmol/L ( $p < 0.05$ ), respectively. During Ramadan, mean non-esterified fatty acid levels decreased from 0.73 to 0.28 mmol. L (-1) ( $p < 0.01$ ) during the first week, then increased ( $p < 0.05$ ) to 1.22 mmol/L over the middle of Ramadan and recovered to pre-Ramadan concentrations for the end and the post-Ramadan periods. Apolipoprotein A1 (Apo-A1) levels were significantly elevated at the end ( $p < 0.01$ ) and the post-Ramadan periods ( $p < 0.05$ ). Three weeks after Ramadan, blood levels of glucose, non-esterified fatty acid, Apo-A1, and Apo-B did not return to the values observed before Ramadan. The amalgamation of the change in diet pattern during Ramadan, along with intense exercise training, induced a significant decrease in body mass associated with a reduction in body fat and changes in some of the serum lipids and



lipoproteins. Nevertheless, all the measured serum parameters remained within normal levels for young and active individuals [34].

In a study encompassed 18 physically active men showed that fasting Ramadan resulted in an increase urea by 8.7% ( $P < 0.001$ ), creatinine by 7.5% ( $P < 0.001$ ), uric acid by 12.7% ( $P < 0.001$ ), serum sodium by 1.9% ( $P < 0.001$ ), serum chloride by 2.6%; ( $P < 0.001$ ) and high-density lipoprotein cholesterol by 27.3% ( $P < 0.001$ ) [35].

## Ramadan Fasting, Lipid Profile and Cardiovascular Health

Ramadan fasting has elicited diverse results in relation to cardiovascular health, above all regarding lipid profiles. As discussed in above section that nutritional habits, sleeping patterns and frequency of meals have reflective effects on human health. Whether such alterations affect the lipid profile in association to homocysteine and coagulation profile were studied in 24 healthy fasting volunteers with assumption of intermittent fasting led to some profitable changes in serum HDL and plasma homocysteine levels, and the coagulation rank. These changes may be due to omitting at least one meal when the body was particularly metabolically active and possibly had a low blood viscosity level at the same time [36]. Subclinical inflammation is a risk factor for cardiovascular diseases [37] and further more elevated concentrations of CRP (C-reactive protein), mediated by cytokines (especially IL-6) produced by adipose and other tissue are shown to be associated with obesity, insulin resistance and metabolic syndrome [38-40]. Prolonged intermittent fasting in a model like Ramadan has some affirmative effects on the inflammatory status of the body and on the risk factors for cardiovascular diseases such as homocysteine, CRP and TC/HDL ratio. Such result bring into being in a study in 40 healthy volunteers of normal weight (20 females aged 20 - 38 years, 20 males aged 23 - 39 years, body mass index (BMI)<25 kg/m<sup>2</sup>) found no significant changes in serum total cholesterol, triglycerides and LDL levels. TC/HDL ratio decreased during and after Ramadan in both genders in the fasting group even though no changes perceived in the non-fasting group measure up to pre-fasting levels. IL-6 ( $p < 0.001$ ), CRP ( $p < 0.001$ ) and homocysteine ( $p < 0.01$ ) levels were significantly low during Ramadan in both fasting genders, keeping in mind that the average daily energy, water intake and working hours were akin in both the fasting and non-fasting groups [41].

Author	Country/study	Study sample	Age	Effect on lipid profile
Aksungar FB et al 2005 [36]	Turkey/ prospective	24 healthy volunteers (12 females, 12 males)	21-35 years	→ InTC TG and LDL levels. ↑ HDL levels during Ramadan ( $p < 0.001$ ) & 20 days after ( $p < 0.05$ ). ↓ D -dimer at the end of Ramadan vs. pre- & post-fasting levels ( $p < 0.001$ ). ↓ Homocysteine levels during Ramadan ( $p < 0.05$ ) reached pre-fasting levels after Ramadan.
Aksungar FB et al 2007 [41]	Turkey/ prospective	40 healthy volunteers	23- 39 years	→ in TC, TG& LDL levels. ↓ TC/HDL ratio during & after Ramadan in both genders in the fasting grp. → In the non-fasting group. ↓ IL-6 ( $p < 0.001$ ), CRP ( $p < 0.001$ ) & homocysteine ( $p < 0.01$ ) levels during Ramadan in the fasting genders.
Nematy M et al 2012 [42]	Iran/ a prospective observational study	in 82 volunteers (38 male , 44 female,	29–70 y, (mean 54.0 ± 10 y)	Improvement in 10 years CAD risk score (Framingham risk score) ( $13.0 \pm 8$ before Ramadan & $10.8 \pm 7$ after Ramadan, $P < 0.001$ , t test) & other cardiovascular risk factors; lipids profile, systolic BP, weight, BMI & waist circumference.
Khafajihadi et al 2012 [46]	Qatar/ prospective study	56 patients with stable cardiac illnesses	67.9% aged >50 years	↓ HDL-C significantly during vs. before fasting ( $P = 0.012$ ). ↑ LDL-C during fasting vs. before fasting ( $P = 0.022$ ). No significant changes TC, TG, serum leptin, or hs-CRP. Significant correlation between TC & hs-CRP during fasting ( $P = 0.036$ ), but not with TG, LDL-C, or HDL-C ( $P > 0.05$ ). Neither of these correlated with serum leptin ( $P > 0.05$ ).

↑: increase; ↓: decrease; TC: Total Cholesterol; TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; →: No Change

**Table 3:** Ramadan fasting lipid profile and cardiovascular health.

Ramadan fasting has beneficial effects on cardiovascular risk factors, nevertheless there are disputes. prospective observational study carried out in 82 volunteers (38 male , 44 female, mean age  $54.0 \pm 10$  y), with a previous history of either coronary artery disease, metabolic syndrome or cerebro-vascular disease with at least one cardiovascular risk factor (including history of documented previous history of either Coronary Artery Disease (CAD), metabolic syndrome or cerebro-vascular disease in past 10 y) shows a significant improvement in 10 years coronary heart disease risk score (based on Framingham risk score) and other cardiovascular risk factors including lipids profile, systolic blood pressure, weight, BMI and waist circumference in subjects with a previous history of cardiovascular disease. HDL-c, WBC, RBC and platelet count are significantly higher and lower plasma cholesterol, triglycerides, LDL, VLDL, systolic blood pressure, body mass index and waist circumference after Ramadan ( $P < 0.05$ ). With no significant changes in fasting blood sugar, insulin, Homeostasis Model Assessment Insulin Resistance (HOMA-IR), homocysteine, hs-CRP and diastolic blood pressure before and after Ramadan ( $P > 0.05$ ) [42].

Leptin have multiple roles in the cardiovascular system as a vaso active substance in regulation of myocardial blood flow and it may have a pro-thrombotic effect [43,44]. Serum CRP is significantly associated with other cardiovascular risk factors [45]. We have reported before That Ramadan fasting in stable cardiac patients has no effect on their clinical status, serum leptin, or hs-CRP, but results in decrease in HDL, increase in LDL such finding my controversial to what elicited above, but we found significant correlation between TC and hs-CRP during Ramadan, but not with TG, LDL-C, or HDL-C, we also reported a significant correlation between hs-CRP and serum leptin before, during, and after fasting season [46].

## Ramadan Fasting and Lipid Alteration in Diabetics and Pre-Diabetics

Diabetes is known to be associated with alterations in metabolic parameters. Whether Ramadan fasting can affect these metabolic parameters in diabetics has been investigated in many studies most of which were on NIDDM patients. Physiological adaptations during the month of fasting lead to an increase in reliance on fat as a source of energy during fasting hours [47].

During Ramadan obese patients with type 2 diabetes, consume more dietary fat (35.84 versus 25.36%), particularly the saturated fats (231 kcal/day or 43.25% of total fat) [48]. Total cholesterol intake, in addition to total cholesterol and low-density lipoprotein cholesterol concentrations, increased significantly in non-obese patients with type 2 ( $n = 57$ ) ( $p < 0.03$ ) [49] and in NIDDM patients with hyperlipidemia whether on diet, fibrates or statins also go through changes in the apo A-1 level and its ratio to HDL and apo B but TC and apo B levels increased ( $P < 0.05$ ). These divergent effects in diabetic patients could inconsistently influence coronary artery disease risk liability [26]. In diabetic obese woman Ramadan fasting may have a beneficial effect on glucose homeostasis; but an unbalanced profile on lipids. [29].

Results from more recent study showed that fasting during Ramadan deteriorated the glycemic control in Type 2 diabetes patients. This is more evident in patients using oral hypoglycemic medication than diet- controlled patients. However, Ramadan fasting had small positive effects on lipid profile and body weight. This was found in a prospective cohort clinical trial on 88 Type 2 diabetes patients (45 male, 43 female, age  $51 \pm 10$  yr) who opted to fast for at least 10 days during the month of Ramadan. There was a significant deterioration in fasting blood sugar and HbA (1c) ( $p = 0.002$  and  $p \leq 0.001$ , respectively) and significant improvements in HDL and LDL cholesterol and body mass index after Ramadan ( $p < 0.001$ ). Captivatingly, HbA (1c) showed a reduction 1 month after Ramadan [50].

However, the pre-Ramadan existed dyslipidemia was sustained or even worsened following Ramadan fasting in a study conducted in 44 NIDDM male (mean age were 52 ± 9 years, range 35-75) volunteers who fasted the month of Ramadan with metabolic parameters recorded. The total daily energy intake (qualitative components of nutrients) unchanged. NIDDM patients showed a trend towards better glycemic control following Ramadan fasting. Pre-Ramadan existed dyslipidemia was sustained or even worsened following Ramadan fasting with statistically significant body weight reduction, FBS, HbA1c, and TG levels by the end of Ramadan (1.57 kg, 31 mg/dl, 0.85%, and 35 mg/dl). No changes seen in other parameters such as TC, LDL-C, and HDL-C were not affected [51].

Evaluating the effect of Ramadan fasting on insulin sensitivity in subjects with the metabolic syndrome in 55 Males (age 34.1 (SD 8.9) years) with the metabolic syndrome showed that total daily energy intake was decreased by 234.6 (SD 88.2) kJ/d in the fasting period (P = 0.005). 1/HOMA-IR, QUICKI and HDL-C were significantly increased (P = 0.005, P = 0.001 and P = 0.004 respectively) and Fasting glucose level significantly decreased (P < 0.005) after fasting. The combined change in the number and timing of meals and portioning of the entire intake into only two meals per day may increase insulin sensitivity in subjects with the metabolic syndrome [52].

Author	Country/ study	Study sample	Age	Effect on lipid profile
Laajam MA 1990 [54]	Saudi Arabia/ Prospective	39 NIDDM overweight pts-29 F+10 M	mean age of 51.5 +/- 1.65 years	↑ TC significantly but not TG at the end of Ramadan → in body weight, fasting plasma glucose, HbA1, C-peptide & insulin blood levels at the end of fasting.
Akanji AO et al., 2000 [23]	Kuwait / Prospective	64 adult hyperlipidemic diabetic patients	Mean aged 47.9±10.6 yrs	→ Apo A-1 level & its ratio to HDL & apo B in diabetics. ↑ TC & Apo B levels (P < 0.05)-more consistent in men vs. women, in subjects on fibrate or statins, may variably influence CHD risk liability.
Bouguerra R et al., 2003 [56]	Tunisia / Prospective	25 NIDDM controlled/ diet/ oral agents	-----	→ fasting glucose, serum fructosamine & haemoglobin A1c. Negative relation between cholesterol intake during Ramadan and the change of HDL-cholesterol.
Yarahmadi S et al., 2003 [49]	Iran/ Observational non interventional study	57 NIDDM	-----	↑ in daily cholesterol intake in all subjects (p < 0.03). ↑ Body mass index in women (p < 0.03). ↓ BMI & waist-hip ratio in men (p < 0.01). → Blood pressure, fasting blood glucose & serum fructosamine. ↓ Plasma insulin (p < 0.05), C-peptide (p < 0.01) & insulin resistance (p < 0.01) in male. ↑ TC and LDL significantly in all subjects.
Khatib FA et al., 2004 [51]	Jordan/ Prospective	44 NIDDM male patients	mean age =52 ± 9 yrs (35-75 yrs)	→ TC, LDL-C, HDL-C during Ramadan fasting. ↓ Body weight, FBS, HbA1c, & TG levels by the end of Ramadan (1.57 kg, 31 mg/dl, 0.85%, and 35 mg/dl) Significant.
Sari R et al., 2004 [59]	Turkey/ Prospective	52 NIDDM patients	Group 1 = 59 ± 6yrs, Group 2 = 57 ± 5yrs, Group 3 = 58 ± 8yrs	→ TC. ↓ TG after Ramadan in patient taking sulfonylurea (p = 0.002) and 3 (p = 0.024). ↑ HDL-cholesterol level in group 3 (p = 0.022). (See reference).

Gustaviani R et al., 2004 [55]	Indonesia/ prospective controlled study	24 NIDDM (10 males vs. 14 females)	(median 52.6yrs) range of 34 – 68 yrs	→ in TC compared week -1 & week 4 of Ramadan. ↑ in LDL cholesterol level significantly.
Bouguerra R 2006 [57]	Tunisia/ Prospective	38 NIDDM pts (20 males & 18 females)	Mean age = 51.4±10.5 yrs	↓ HDL-cholesterol (p < 0.01). ↑ LDL-cholesterol (p < 0.003). → in glycemic control.
Khaled BM et al., 2006 [26]	Algeria/ Prospective	60 obese diabetic women (BMI = 35.41 +/- 3.64 kg/m <sup>2</sup> ),	aged 51 +/- 10 years	↓ in fasting B. glucose (16.72%, p < 0.001), in HbA1c (11.3%, p < 0.005), HDL-C (26.81%, p < 0.001) rates. ↑ TC (13.85%, p<0.001), TGs (16.9%, p<0.003), the LDL-C (22.39 %, p < 0.0001) levels significantly.
Shariatpanahi ZV et al., 2008 [52]	Iran/ Prospective	55 Males	Mean age =34.1 (SD 8.9) years	↑ In HDL-C levels after the intervention (P = 0-004). ↑ Insulin sensitivity in subjects with metabolic syndrome. ↓ total daily energy intake by 234.6 (SD 88.2) kJ/d in the fasting period (P = 0.005). ↓ Fasting glucose (P < 0.005) after fasting.
M'guil M et al., 2008 [53]	Morocco/ prospective	120 pts (62 F + 58 M) well controlled NIDDM.	48-60 yrs	Fluctuations in some lipid and hematological parameters, creatinine, urea, uric acid, total protein, bilirubin, and electrolytes; however, all values stayed within the proper physiological range.
Norouzy A et al., 2012 [58]	Iran /Prospective	45 male, 43 female, with NIDDM	age 51 ± 10 yr	significant deterioration in FBG & HbA (1c) (p = 0.002, p ≤ 0.001, respectively), significant improvements in HDL & LDL cholesterol & body mass index after Ramadan (p<0.001)

↑: Increase; ↓: Decrease; TC: Total Cholesterol; TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; →: No Change; -----: Information Not Accessible; FBG: Fasting Blood Glucose; NIDDM: Non-Insulin Dependent Diabetes Mellitus

**Table 4:** Ramadan fasting and lipid alteration in pre-diabetics and diabetics.

Unique physiologic and metabolic changes occur during Ramadan fasting which also requires adjustments of diabetes therapy to prevent complications. Although managing diabetes during Ramadan is challenging but successful fasting can be accomplished if proper pre-Ramadan assessment and education is provided to the patient. While some studies found no changes in body weight and blood pressure mean plasma fasting glucose, serum fructosamin and haemoglobin A1c or any metabolic complications [53-55]. A negative relation between cholesterol intake during Ramadan and the change of HDL-cholesterol were found. When cholesterol intake was lower than 400 mg/day, plasma HDL-cholesterol increased by 13% at the end of Ramadan and by 23% 3 weeks after Ramadan [56]. Ramadan fasting was safe in patients with type 2 diabetes mellitus in a study in Morocco included 120 with well controlled DM with oral agent and or diet .Ramadan fasting had no major effect on energy intake, body weight, body mass index, blood pressure, and liver enzymes. Fasting and post-prandial glucose levels decreased, while insulin levels increased. Diabetes was well controlled, as indicated by HbA1c, fructosamine, C-peptide, HOMA-IR, and IGF-1 values, with some fluctuations within the physiological range in some lipid and hematological parameters, creatinine, urea, uric acid, total protein, bilirubin, and electrolytes. [53]. Ramadan fasting seems to trigger slight effects on glycemia and lipoprotein levels when previous metabolic control is quite good but more corrosion when previous control is poor and hypoglycemia should be kept in mind especially in patients using sulfonylurea treatment [57-59].

## Ramadan Fasting Lipid Profile and Renal Patients

Muslim patients with Chronic Kidney Disease (CKD) usually fast Ramadan, the studies

on this group of patient are very scarce regarding fasting and lipid profile changes with a gain of diverse result, but good number of studies has shown that Ramadan fasting is safe in these patient even those with mild to moderate renal impairment such result may need further investigation and should be taken cautiously by the treating physician for these patients and insofar diabetes were the sole cause of renal impairment in the fasting age group, a prospective study of 31 patients fasted the whole month of Ramadan (19 males (mean age  $54 \pm 14.2$  years)) 14 patients were in stage III CKD, 12 in stage IV and 5 had stage V. patients shows tendency to weight reduction, and lower systolic and diastolic blood pressure. In this study Diabetes was the main cause of CKD (19 (61%) patients (e-GFR) =  $29 \pm 16.3$  mL/min). Clinical assessment and renal function tests performed one month prior to fasting then during and a month later. Patient continued taking medications two divided doses at sunset and pre-dawn. eGFR showed a significant improvement during the fast and the month after. With deterioration of the glycemic control with an increase in the HbA1c, there was better lipid profile, reduction of the proteinuria and urinary sodium fasting is well tolerated by patient studied [60].

Author	Country/study	Study sample	Age	Effect on lipid profile
Bernieh B et al., 2010 [60]	UAE/ prospective	31 patients	mean age $54 \pm 14.2$ years	Better lipid profile, significant improvement in e-GFR during the fast & month after. ↓ proteinuria & urinary sodium. ↑ Hb A1c.
Boobes Y 2009 [66]	UAE/ prospective	22 kidney RTX for 1 yrs. with stable kidney functions	mean age of $47 \pm 11.6$ years	→ Body weight, blood pressure, kidney function tests, blood sugar, lipid profile, and cyclosporine levels. None of the patients experienced any undue fatigue, or symptoms.
Argani H et al., 2003 [69]	Iran / prospective	30 stable renal transplant recipients	mean age of $39 \pm 4$ years	VLDL ( $33 \pm 7$ mg/dL vs $28.5 \pm 5$ mg/dL, $P = 0.019$ ) significantly ↓ during fasting in vs. non-fasting periods. ↑ Levels of HDL ( $47 \pm 5$ mg/dL vs. $54 \pm 4$ mg/dL, $P = 0.001$ ).

↑: Increase; ↓: Decrease; TC: Total Cholesterol; TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein

**Table 5:** Ramadan fasting lipid profile and renal patients.

Nonetheless Patients and physicians fear fasting in renal transplant patients primarily due to thirst and dehydration [61] however Ramadan fasting may have no effect on GFR and other urine parameters in renal transplant patients [62,63]. Immunosuppressive effects persuaded by anti-rejection drugs persevere during fasting, as well in the non-fasting period although the threshold for suspicion of infections should be lower in this period as over immune suppression due to alteration in pharmacokinetic and dynamics may predispose patients to infection [64-65] but Ramadan fasting can be safe in this group of patient with even no alteration in immunosuppressive serum level even in patients with mild to moderate renal impairment [66-68]. For stable renal transplant patients Ramadan fasting is not harmful at least in seasons with a fasting period of 12 hours. It can have some positive effects, if the patients are observed carefully by their physician. In a study of 30 stable renal transplant recipients who displayed serum creatinine values less than 1.8 mg/dL under triple immune suppression the investigators observed lower levels of VLDL, and higher HDL. IgG and C4 levels increased moderately but not significantly. T cells, IgA level, total WBC counts, serum electrolytes, serum creatinine, BUN, and relation of urine protein to urine creatinine were relatively constant during the fasting period. Clinically, BP and urine volume did not change during fasting. In addition there are lower levels B cells, IgM, C3 [69].

## Ramadan Fasting Lipid Profile and Gestation

Many studies have focused on the effect of fasting during pregnancy on maternal and fetal health; nonetheless inconsistent but maybe advantageous results have been conveyed [70-80]. Changes in lipid profile during Ramadan have been described by Kiziltan et al.,

reported a significant increase in the HDL concentrations of 12 healthy fasting women with pregnancy of the first trimester. They also reported a decrease in the levels of plasma LDL in 37 fasting healthy women with pregnancies of the second or third trimester [81]. Eating one large daily meal leads to a significant increase in serum HDL levels, while decreasing the LDL/HDL ratio in healthy subjects during Ramadan, such increase in the HDL levels was due to post-prandial lipemia and the magnitude of the post-prandial lipemia was suggested to be important for the metabolism and plasma levels of HDL [8,82].

On the other hand, elevated levels of serum triglyceride in fasting subjects have been reported and attributed to the lipolytic effect of prolonged fasting [72,80,81,83]. On the other hand, Ziaee et al., [16] reported a negative correlation between primary triglyceride levels before and during Ramadan, i.e., subjects with higher triglyceride levels had a lesser increase in triglyceride levels during Ramadan. Fasting of healthy women during pregnancy seems to have no adverse effects on amniotic fluid index, fetal Doppler and delivery parameters. In one study recruited 110 women (56 fasting vs. 54 non-fasting). No statistical difference detected between the groups in regards to fetal Doppler parameters, amniotic fluid index, and gestational age at delivery, cesarean section rate, birth weight or NICU admission. However, lower levels of VLDL, triglyceride and higher incidence of ketonuria were detected in the fasting group ( $p < 0.05$ ) [84].

Author	Country/study	Study sample	age	Effect on lipid profile
Malhotra A et al., 1989 [79]	UK/ prospective	11 pregnant women	Child bearing age ---	↑ triglyceride, non-esterified fatty acid and 3-hydroxybutyrate. ↓ in glucose, insulin, lactate & carnitine significantly.
Prentice AM et al., 1983 [80]	West African village/ prospective	22 fasting pregnant, 10 lactating & 10 non-pregnant, non-lactating	Child bearing age	↑ free fatty acid and beta-hydroxybutyrate levels significantly ( $P < 0.05$ ). ↓ Alanine values significantly ( $P < 0.05$ ) in late than in early pregnancy.
Kiziltan G et al., 2005 [81]	Turkey/ prospective	49 fasting & 49 non-fasting (control) pregnant women	Child bearing age	↑ in the fasting blood glucose slightly. ↑ serum TC, HDL, TG ( $p < 0.05$ for first trimester) concentrations slightly in the fasting group during Ramadan. ↓ levels of urea, TC, TG, LDL & total protein & albumin levels of the fasting group vs. control group.
Dikensoy E et al., 2009 [83]	Turkey/ prospective	36 healthy women with uncomplicated pregnancies	Child bearing age	↑ in TC&TG levels non-significantly in the fasting group, but higher than in the control group ( $p < 0.05$ ). ↓ LDL & VLDL levels non-significantly at the end of Ramadan. ↑ HDL levels showed a slightly. ↓ LDL/HDL ratios in fasting group ( $p < 0.05$ ).
D. Hizli et al., 2012 [84]	Turkey/ prospective	110 women 56 fasting group & 54 non-fasting	Mean age 26.4 (range 18–37) yrs	↓ levels of VLDL, TG. ↑ Incidence of ketonuria were detected in the fasting group ( $p < 0.05$ ). No statistical difference between the groups according to fetal Doppler parameters, amniotic fluid index, gestational age at delivery, cesarean section rate, birth weight or NICU admission.

↑: increase; ↓: decrease; TC: Total Cholesterol; TG: Triglyceride; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; VLDL: Very Low Density Lipoprotein; HSP: Heat Shock Protein

**Table 6:** Ramadan fasting lipid profile in pregnancy.

In summary fasting had no adverse effect on pregnant ladies, it may have beneficial effect on atherogenic lipid profile, the value of which need more investigations which in turn is difficult to apply from the clinical and may be the ethical point of view and short duration



of Ramadan fasting season but in general the available evidence from the above bundle of investigations at least can accomplish that Ramadan fasting have neutral or no adverse significances.

## Conclusion

Till the date of writing this subject summarizing the effect of Ramadan fasting in different Islamic communities who are diverse in their eating behavior and constitution these communities have different social nutritional and physical activity sketch all of which may have great influence on the investigations results concerning the effect of fasting on lipid profile in these communities , in general we can determine that most of the studies that have discussed above and categorizes in the above chapter subtitles have at least shown neutral and mostly encouraging effect of Muslims fasting season on the general health in correlation to impact of fasting on the lipid fractions in correlation atherogenic risk but it may have advantageous effect at least in healthy general population and the stable cardiac , renal patients and normal pregnancies, finally physicians should be always on cautious side when taking this conclusion in consideration and each patient should be managed on their disease entities.

## References

1. McCay CM, Crowell MF, Maynard LA (1989) The effect of retarded growth upon the length of life span and upon the ultimate body size. 1935. *Nutrition* 5: 155-171.
2. Imai S (2009) SIRT1 and caloric restriction: an insight into possible trade-offs between robustness and frailty. *Curr Opin Clin Nutr Metab Care* 12: 350-356.
3. Vaquero A, Reinberg D (2009) Calorie restriction and the exercise of chromatin. *Genes Dev* 23: 1849-1869.
4. Ibrahim WH, Habib HM, Jarrar AH, Al Baz SA (2008) Effect of Ramadan fasting on markers of oxidative stress and serum biochemical markers of cellular damage in healthy subjects. *Ann Nutr Metab* 53: 175-181.
5. Hallak MH, Nomani MZ (1988) Body weight loss and changes in blood lipid levels in normal men on hypocaloric diets during Ramadan fasting. *Am J Clin Nutr* 48: 1197-1210.
6. Lamine F, Bouguerra R, Jabrane J, Marrakchi Z, Ben Rayana MC, et al. (2006) Food intake and high density lipoprotein cholesterol levels changes during ramadan fasting in healthy young subjects. *Tunis Med* 84: 647-650.
7. el Ati J, Beji C, Danguir J (1995) Increased fat oxidation during Ramadan fasting in healthy women: an adaptative mechanism for body-weight maintenance. *Am J Clin Nutr* 62: 302-307.
8. Maislos M, Khamaysi N, Assali A, Abou-Rabiah Y, Zvili I, et al. (1993) Marked increase in plasma high-density-lipoprotein cholesterol after prolonged fasting during Ramadan. *Am J Clin Nutr* 57: 640-642.
9. Shephard RJ (2013) Ramadan and Sport: Minimizing Effects Upon the Observant Athlete. *Sports Med*.
10. Aloui A, Chaouachi A, Chtourou H, Wong del P, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated-sprint performances. *Int J Sports Physiol Perform* 8: 254-262.
11. Aziz AR, Chia MY, Low CY, Slater GJ, Png W, et al. (2012) Conducting an acute intense interval exercise session during the Ramadan fasting month: what is the optimal time of the day? *Chronobiol Int* 29: 1139-1150.
12. Chaouachi A, Leiper JB, Chtourou H, Aziz AR, Chamari K (2012) The effects of Ramadan intermittent fasting on athletic performance: recommendations for the maintenance of physical fitness. *J Sports Sci* 30: 53-73.
13. Fedail SS, Murphy D, Salih SY, Bolton CH, Harvey RF (1982) Changes in certain blood constituents during Ramadan. *Am J Clin Nutr* 36: 350-353.
14. Adlouni A, Ghalim N, Benslimane A, Lecerf JM, Saile R (1997) Fasting during Ramadan induces a marked increase in high-density lipoprotein cholesterol and decrease in low-density lipoprotein cholesterol. *Ann Nutr Metab* 41: 242-249.
15. Afrasiabi A, Hassanzadeh S, Sattarivand R, Nouri M, Mahbood S (2003) Effects of low fat and low calorie diet on plasma lipid levels in the fasting month of Ramadan. *Saudi Med J* 24: 184-188.

16. Ziaee V, Razaei M, Ahmadinejad Z, Shaikh H, Yousefi R, et al. (2006) The changes of metabolic profile and weight during Ramadan fasting. *Singapore Med J* 47: 409-414.
17. Zare A, Hajhashemi M, Hassan ZM, Zarrin S, Pourpak Z, et al. (2011) Effect of Ramadan fasting on serum heat shock protein 70 and serum lipid profile. *Singapore Med J* 52: 491-495.
18. Shehab A, Abdulle A, El Issa A, Al Suwaidi J, Nagelkerke N (2012) Favorable changes in lipid profile: the effects of fasting after Ramadan. *PLoS One* 7: 47615.
19. Haghdooost AA, Poorranjbar M (2009) The interaction between physical activity and fasting on the serum lipid profile during Ramadan. *Singapore Med J* 50: 897-901.
20. Kul S, Savaş E, Oztürk ZA, Karadağ G (2013) Does Ramadan Fasting Alter Body Weight and Blood Lipids and Fasting Blood Glucose in a Healthy Population? A Meta-analysis. *J Relig Health*.
21. Adlouni A, Ghalim N, Saïle R, Hda N, Parra HJ, et al. (1998) Beneficial effect on serum apo AI, apo B and Lp AI levels of Ramadan fasting. *Clin Chim Acta* 271: 179-189.
22. Sarraf-Zadegan N, Atashi M, Naderi GA, Baghai AM, Asgary S, et al. (2000) The effect of fasting in Ramadan on the values and interrelations between biochemical, coagulation and hematological factors. *Ann Saudi Med* 20: 377-381.
23. Akanji AO, Mojiminiyi OA, Abdella N (2000) Beneficial changes in serum apo A-1 and its ratio to apo B and HDL in stable hyperlipidaemic subjects after Ramadan fasting in Kuwait. *Eur J Clin Nutr* 54: 508-513.
24. Saleh SA, El-Kemery TA, Farrag KA, Badawy MR, Sarkis NN, et al. (2004) Ramadan fasting: relation to atherogenic risk among obese Muslims. *J Egypt Public Health Assoc* 79: 461-483.
25. Qujeq D, Bijani K, Kalavi K, Mohiti J, Aliakbarpour H (2002) Effects of Ramadan fasting on serum low-density and high-density lipoprotein-cholesterol concentrations. *Ann Saudi Med* 22: 297-299.
26. Khaled BM, Bendahmane M, Belbraouet S (2006) Ramadan fasting induces modifications of certain serum components in obese women with type 2 diabetes. *Saudi Med J* 27: 23-26.
27. Al-Hourani HM, Atoum MF (2007) Body composition, nutrient intake and physical activity patterns in young women during Ramadan. *Singapore Med J* 48: 906-910.
28. Beltaifa L, Bouguerra R, Ben Slama C, Jabrane H, El-Khadhi A, et al. (2002) [Food intake, and anthropometrical and biological parameters in adult Tunisians during fasting at Ramadan]. *East Mediterr Health J* 8: 603-611.
29. Lamri-Senhadj MY, El Kebir B, Belleville J, Bouchenak M (2009) Assessment of dietary consumption and time-course of changes in serum lipids and lipoproteins before, during and after Ramadan in young Algerian adults. *Singapore Med J* 50: 288-294.
30. Barkia A, Mohamed K, Smaoui M, Zouari N, Hammami M, et al. (2011) Change of diet, plasma lipids, lipoproteins, and fatty acids during Ramadan: a controversial association of the considered Ramadan model with atherosclerosis risk. *J Health Popul Nutr* 29: 486-493.
31. Chaouachi A, Coutts AJ, Chamari K, Wong del P, Chaouachi M, et al. (2009) Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. *J Strength Cond Res* 23: 2702-2709.
32. Mirzaei B, Rahmani-Nia F, Moghadam MG, Ziyaolhagh SJ, Rezaei A (2012) The effect of ramadan fasting on biochemical and performance parameters in collegiate wrestlers. *Iran J Basic Med Sci* 15: 1215-1220.
33. Bouhlel E, Denguezli M, Zaouali M, Tabka Z, Shephard RJ (2008) Ramadan fastings effect on plasma leptin, adiponectin concentrations, and body composition in trained young men. *Int J Sport Nutr Exerc Metab* 18: 617-627.
34. Chaouachi A, Chamari K, Roky R, Wong P, Mbazaa A, et al. (2008) Lipid profiles of judo athletes during Ramadan. *Int J Sports Med* 29: 282-288.
35. Trabelsi K, El Abed K, Trepanowski JF, Stannard SR, Ghilisi Z, et al. (2011) Effects of ramadan fasting on biochemical and anthropometric parameters in physically active men. *Asian J Sports Med* 2: 134-144.
36. Aksungar FB, Eren A, Ure S, Teskin O, Ates G (2005) Effects of intermittent fasting on serum lipid levels, coagulation status and plasma homocysteine levels. *Ann Nutr Metab* 49: 77-82.



37. Magliano DJ, Liew D, Ashton EL, Sundararajan V, McNeil JJ (2003) Novel biomedical risk markers for cardiovascular disease. *J Cardiovasc Risk* 10: 41-55.
38. Yudkin JS, Stehouwer CD, Emeis JJ, Coppack SW (1999) C-reactive protein in healthy subjects: associations with obesity, insulin resistance, and endothelial dysfunction: a potential role for cytokines originating from adipose tissue? *Arterioscler Thromb Vasc Biol* 19: 972-978.
39. Festa A, D'Agostino R Jr, Howard G, Mykkanen L, Tracy RP, et al. (2000) Chronic subclinical inflammation as part of the insulin resistance syndrome: the Insulin Resistance Atherosclerosis Study (IRAS). *Circulation* 102: 42-47.
40. Ridker PM, Wilson PW, Grundy SM (2004) Should C-reactive protein be added to metabolic syndrome and to assessment of global cardiovascular risk? *Circulation* 109: 2818-2825.
41. Aksungar FB, Topkaya AE, Akyildiz M (2007) Interleukin-6, C-reactive protein and biochemical parameters during prolonged intermittent fasting. *Ann Nutr Metab* 51: 88-95.
42. Nematy M, Alinezhad-Namaghi M, Rashed MM, Mozhdehifard M, Sajjadi SS, et al. (2012) Effects of Ramadan fasting on cardiovascular risk factors: a prospective observational study. *Nutr J* 11: 69.
43. Sundell J, Huupponen R, Raitakari OT, Nuutila P, Knuuti J (2003) High serum leptin is associated with attenuated coronary vasoreactivity. *Obes Res* 11: 776-782.
44. Bodary PF, Westrick RJ, Wickenheiser KJ, Shen Y, Eitzman DT (2002) Effect of leptin on arterial thrombosis following vascular injury in mice. *JAMA* 287: 1706-1709.
45. Rutter MK, Meigs JB, Sullivan LM, D'Agostino RB Sr, Wilson PW (2004) C-reactive protein, the metabolic syndrome, and prediction of cardiovascular events in the Framingham Offspring Study. *Circulation* 110: 380-385.
46. Khafaji HA, Bener A, Osman M, Al Merri A, Al Suwaidi J (2012) The impact of diurnal fasting during Ramadan on the lipid profile, hs-CRP, and serum leptin in stable cardiac patients. *Vasc Health Risk Manag* 8: 7-14.
47. Khaled BM, Belbraouet S (2009) Effect of Ramadan fasting on anthropometric parameters and food consumption in 276 type 2 diabetic obese women. *Int J Diabetes Dev Ctries* 29: 62-68.
48. Reilly T, Waterhouse J (2007) Altered sleep-wake cycles and food intake: the Ramadan model. *Physiol Behav* 90: 219-228.
49. Yarahmadi SH, Larijani B, Bastanhigh MH, Pajouhi M, Baradar Jalili R, et al. (2003) Metabolic and clinical effects of Ramadan fasting in patients with type II diabetes. *J Coll Physicians Surg Pak* 13: 329-332.
50. Norouzy A, Mohajeri SM, Shakeri S, Yari F, Sabery M, et al. (2012) Effect of Ramadan fasting on glycemic control in patients with Type 2 diabetes. *J Endocrinol Invest* 35: 766-771.
51. Khatib FA, Shafagoj YA (2004) Metabolic alterations as a result of Ramadan fasting in non-insulin-dependent diabetes mellitus patients in relation to food intake. *Saudi Med J* 25: 1858-1863.
52. Shariatpanahi ZV, Shariatpanahi MV, Shahbazi S, Hossaini A, Abadi A (2008) Effect of Ramadan fasting on some indices of insulin resistance and components of the metabolic syndrome in healthy male adults. *Br J Nutr* 100: 147-151.
53. M'guil M, Ragala MA, El Guessabi L, Fellat S, Chraibi A, et al. (2008) Is Ramadan fasting safe in type 2 diabetic patients in view of the lack of significant effect of fasting on clinical and biochemical parameters, blood pressure, and glycemic control? *Clin Exp Hypertens* 30: 339-357.
54. Laajam MA (1990) Ramadan fasting and non-insulin-dependent diabetes: effect on metabolic control. *East Afr Med J* 67: 732-736.
55. Gustaviani R, Soewondo P, Semiardji G, Sudoyo AW (2004) The influence of calorie restriction during the Ramadan fast on serum fructosamine and the formation of beta hydroxybutyrate in type 2 diabetes mellitus patients. *Acta Med Indones* 36: 136-141.
56. Bouguerra R, Belkadhi A, Jabrane J, Hamzaoui J, Maâtki C, et al. (2003) [Metabolic effects of the month of Ramadan fasting on type 2 diabetes]. *East Mediterr Health J* 9: 1099-1108.
57. Bouguerra R, Jabrane J, Maâtki C, Ben Salem L, Hamzaoui J, et al. (2006) [Ramadan fasting in type 2 diabetes mellitus]. *Ann Endocrinol (Paris)* 67: 54-59.

58. Norouzy A, Mohajeri SM, Shakeri S, Yari F, Sabery M, et al. (2012) Effect of Ramadan fasting on glycemic control in patients with Type 2 diabetes. *J Endocrinol Invest* 35: 766-771.
59. Sari R, Balci MK, Akbas SH, Avci B (2004) The effects of diet, sulfonylurea, and Repaglinide therapy on clinical and metabolic parameters in type 2 diabetic patients during Ramadan. *Endocr Res* 30: 169-177.
60. Bernieh B, Al Hakim MR, Boobes Y, Abu Zidan FM (2010) Fasting Ramadan in chronic kidney disease patients: clinical and biochemical effects. *Saudi J Kidney Dis Transpl* 21: 898-902.
61. Jamison RL, Maffly RH (1976) The urinary concentrating mechanism. *N Engl J Med* 295: 1059-1067.
62. Ghalib M, Qureshi J, Tamim H, Ghamdi G, Flaiw A, et al. (2008) Does repeated Ramadan fasting adversely affect kidney function in renal transplant patients? *Transplantation* 85: 141-144.
63. Qurashi S, Tamimi A, Jaradat M, Al Sayyari A (2012) Effect of fasting for Ramadan on kidney graft function during the hottest month of the year (August) in Riyadh, Saudi Arabia. *Exp Clin Transplant* 10: 551-553.
64. Moussavi D, Kadri N (1997) *Symposia Neurology* 123.
65. Al-Khader AA, Al-Hasani MK, Dhar JM, et al (1991) *Saudi Med J* 12: 30.
66. Boobes Y, Bernieh B, Al Hakim MR (2009) Fasting Ramadan in kidney transplant patients is safe. *Saudi J Kidney Dis Transpl* 20: 198-200.
67. Einollahi B, Lessan-Pezeshki M, Simforoosh N, Nafar M, Pour-Reza-Gholi F, et al. (2005) Impact of Ramadan fasting on renal allograft function. *Transplant Proc* 37: 3004-3005.
68. Einollahi B, Lessan-Pezeshki M, Pourfarziani V, Aghdam B, Rouzbeh J, et al. (2009) Ramadan fasting in kidney transplant recipients with normal renal function and with mild-to-moderate renal dysfunction. *Int Urol Nephrol* 41: 417-422.
69. Argani H, Mozaffari S, Rahnema B, Rahbani M, Rejaie M, et al. (2003) Evaluation of biochemical and immunologic changes in renal transplant recipients during Ramadan fasting. *Transplant Proc* 35: 2725-2726.
70. Robinson T, Raisler J (2005) "Each one is a doctor for herself": Ramadan fasting among pregnant Muslim women in the United States. *Ethn Dis* 15: 99-103.
71. Joosop J, Abu J, Yu SL (2004) A survey of fasting during pregnancy. *Singapore Med J* 45: 583-586.
72. Cross JH, Eminson J, Wharton BA (1990) Ramadan and birth weight at full term in Asian Moslem pregnant women in Birmingham. *Arch Dis Child* 65: 1053-1056.
73. Hefni M, Fikry SAH, Abdalazim M, Abdelkhalik MA (1993) Fasting in Ramadan and preterm labour. *Saudi Med J* 14: 130-132.
74. Naderi T, Kamyabi Z (2004) Determination of fundal height increase in fasting and non-fasting pregnant women during Ramadan. *Saudi Med J* 25: 809-810.
75. Kamyabi Z, Naderi T (2004) The effect of Ramadan fasting on amniotic fluid volume. *Saudi Med J* 25: 45-46.
76. Rabinerson D, Dicker D, Kaplan B, Ben-Rafael Z, Dekel A (2000) Hyperemesis gravidarum during Ramadan. *J Psychosom Obstet Gynaecol* 21: 189-191.
77. Fowler H, Griffin E, Lawton F, Buxton J, Luesley D (1990) Antenatal attendance and fasting of pregnant Muslims during Ramadan. *Br J Obstet Gynaecol* 97: 861-862.
78. Salleh H (1989) Ramadan fasting among pregnant women in Muar district, Malaysia and its association to health outcomes. *Malays J Reprod Health* 7: 69-83.
79. Malhotra A, Scott PH, Scott J, Gee H, Wharton BA (1989) Metabolic changes in Asian Muslim pregnant mothers observing the Ramadan fast in Britain. *Br J Nutr* 61: 663-672.
80. Prentice AM, Prentice A, Lamb WH, Lunn PG, Austin S (1983) Metabolic consequences of fasting during Ramadan in pregnant and lactating women. *Hum Nutr Clin Nutr* 37: 283-294.
81. Kiziltan G, Karabudak E, Tuncay G, Avsar F, Tuncay P, et al. (2005) Dietary intake and nutritional status of Turkish pregnant women during Ramadan. *Saudi Med J* 26: 1782-1787.

82. El-Migdadi F, El-Akawi Z, Abudheese R, Bashir N (2002) Plasma levels of adrenocorticotrophic hormone and cortisol in people living in an environment below sea level (Jordan Valley) during fasting in the month of Ramadan. *Horm Res* 58: 279-282.
83. Dikensoy E, Balat O, Cebesoy B, Ozkur A, Cicek H, et al. (2009) The effect of Ramadan fasting on maternal serum lipids, cortisol levels and fetal development. *Arch Gynecol Obstet* 279: 119-123.
84. Hizli D, Yilmaz SS, Onaran Y, Kafali H, DaniÅŸman N, et al. (2012) Impact of maternal fasting during Ramadan on fetal Doppler parameters, maternal lipid levels and neonatal outcomes. *J Matern Fetal Neonatal Med* 25: 975-977.

## Chapter 15

# Body Composition, Hematological and Biochemical Modifications during Ramadan Fasting

**Khaled Trabelsi<sup>1\*</sup>, Stephen R. Stannard<sup>2</sup>, Roy J Shephard<sup>3</sup>, Kamel Jamoussi<sup>4</sup> and Ahmed Hakim<sup>1</sup>**

<sup>1</sup>Laboratory of Pharmacology, Faculty of Medicine, 3029 Sfax, University of Sfax, Tunisia

<sup>2</sup>School of Sport and Exercise, Massey University, Palmerston North, New Zealand

<sup>3</sup>Faculty of Kinesiology & Physical Education, University of Toronto, Toronto, ON

<sup>4</sup>Department of Biochemistry of the Hedi Chaker University Hospital, 3029 Sfax, Tunisia

**\*Corresponding author:** Khaled Trabelsi, Laboratory of Pharmacology, Faculty of Medicine, 3029 Sfax, University of Sfax, Tunisia, Tel: (+216) 22 935 747, E-mail: [trabelsikhaled@gmail.com](mailto:trabelsikhaled@gmail.com)

## Abstract

During the observance of Ramadan, food and fluid intake is concentrated into the hours between sunset and the following sunrise. Food choices, the sleep/waking cycle, and energy expenditures are among other habits that are often altered throughout this month. Many active individuals who observe Ramadan endeavor to maintain their normal patterns of physical activity during Ramadan, but all of the many consequences of superimposing a daily fast upon a program of vigorous physical activity have yet to be described. Body composition, metabolic markers, electrolytes, hematological parameters, and health-related indices such as blood lipids may all be altered. This chapter summarizes such effects, and explores training tactics that may help to conserve a normal body composition and counter potential changes in hydration status, renal function, immune function and inflammatory markers when active individuals engage in the intermittent fasting of Ramadan.

## Introduction

Ramadan lasts between 29 and 30 days. During this month, Muslims abstain from food and fluid intake from dawn (*el fajr*) to sunset (*el moghreb*). Ramadan occurs eleven days earlier every year, and thus rotates through each of the four seasons over a 33 year cycle [1]. When it occurs during the summer, the daily fast in some countries can exceed 15 hours, and the hours of darkness may then provide insufficient time for glucose and insulin concentrations to be restored to basal levels [2].

Individuals who are observing Ramadan may change the frequency of their meals [3], the quantity of food eaten [4] and fluid intake [1,5-7]. Not only is the timing of meals altered during Ramadan, but the type of food eaten often differs substantially from that consumed during the rest of the year [8]. One commonly reported trend is an increased preference for fatty foods [1,5,9,10]. Such dietary changes can in turn influence both the utilization and

the storage of substrates, and lead to modifications of body composition [5,6,11,12]. There may also be changes in hydration status, renal function, and the behavior of immune and inflammatory systems [5,6,11-14].

Those who are observing Ramadan often try to maintain a normal level of physical activity for recreational and health purposes. Likewise, many athletes seek to continue their normal pattern of training throughout Ramadan, particularly if they are competing at an international level. However, if Ramadan falls during the summer, maintenance of training places a heavy additional stress on mechanisms for the delivery of energy and maintenance of fluid/electrolyte balance [6]. With these issues in mind, recent investigations [1,7] have explored training tactics to maintain and even improve body composition and to prevent dehydration and the impairment of renal function in physically active individuals who are observing Ramadan.

This chapter reviews published research examining the effects of Ramadan fasting on body composition, hematological and biochemical parameters in physically active individuals. It also describes novel approaches to training during Ramadan, examining how far these new tactics influence body composition, lipid profile, and immune and inflammatory markers. The relevant literature was reviewed using PubMed and Google Scholar databases, adopting the search terms of Ramadan fasting, fed versus fasted, hematological, biochemical, renal function, hydration status, immune system, inflammatory markers, lipid profile and sport.

## **Body Mass and Body Composition**

### **Body mass**

Body mass commonly decreases over the course of the day during Ramadan [15,16]. This reflects progressive dehydration, at a rate influenced by environmental conditions, the intensity of physical activity and the resultant rate of sweating. Thus, the body mass of both soccer players [15] and martial arts practitioners [16] were lower during the afternoon than during the morning during Ramadan. Discrepancies in or lack of information on the time of measurement plainly limit the ability to make comparisons between studies.

Empirical findings among participants in regular physical activity are quite heterogeneous. Many reports note a decrease in total body mass during Ramadan, for instance in subjects practicing general aerobic training [1,6,17-19] soccer players [20,21], various types of elite athlete [22], judokas [12] and rugby players [5,11]. Several factors have been invoked to explain the decrease in body mass, including not only dehydration [1,5,11] but also a negative energy balance [5,6], an increased use of body fat stores both at rest and during exercise [1,2,5,6,11,12], the use of lean tissue in gluconeogenesis or a combination of these factors [1,5,6,11].

In contrast, several authors have reported no significant change of body mass during Ramadan; the groups studied have included soccer players [23,24], middle-distance runners [25,26], elite power athletes [27] and recreational bodybuilders [7,14]. Activity levels seem to have been as high as in the studies where body mass decreased; possibly, these groups followed a better dietary plan to maximize the intake of food and fluids during Ramadan.

### **Body composition**

Several methods have been used to determine changes of body composition during Ramadan. The commonest approach has been to measure skin fold thicknesses and thus to predict the body's fat mass, using a two-compartment model [5-7,11,14,20]. Unfortunately, if body mass decreases due to dehydration, changes in the difference between total body mass and fat mass may give an erroneous impression that lean tissue has been lost. One of the studies cited applied the supposed "gold standard" of hydro densitometry to physically active men during the month of fasting [28]. This method is difficult to implement during Ramadan, since full submersion is required, and no water must pass through the mouth

of participants while they are fasting. Moreover, although an accurate estimate of fat mass is obtained, the difference between total and fat mass remains vulnerable to the effects of dehydration, just as with the simpler skinfold methodology. Determinations of bioelectrical impedance have occasionally been used to estimate body fatness [24,29], but this method, like the previous two, can be affected by changes in hydration status [30].

Published data on changes in body fat content during Ramadan have yielded conflicting results, presumably reflecting differences in dietary tactics. The percentage of body fat decreased in judokas [12], and rugby players [5,11], but remained unchanged in physically active men [28], middle-distance runners [25,26], elite power athletes [26], or soccer players [20]. Recently, Trabelsi and co-workers [1] compared a group of physically active men who were practicing aerobic exercise (running, rowing, and cycling at least 3 times/week) before breaking their Ramadan fast (between 4:00 and 6:00 PM) with another group who were practicing an equivalent amount of aerobic exercise after breaking their fast (between 9:30 and 10:30 PM). The percentage of body fat decreased in the first group, but not in the second [1]. It appears that if aerobic exercise is practiced when fasting, the resulting energy deficit stimulates the use of stored body fat as the substrate for exercise [1].

A parallel study evaluated the effects of a muscle-building program on the body composition of sixteen Tunisian recreational body builders [7]. These again were randomized to two equal groups of subjects training daily either before (between 4:00 and 6:00 PM) or after the break of fast (between 9:00 and 10:00 PM) during Ramadan for a total of four training sessions/week. The results showed that an equivalent amount of resistance training practiced either before or after the break of fast did not reduce fat or lean tissue mass, possibly because the total energy costs of training were lower.

Table 1 summarizes empirical data on the changes of body fat content in active subjects during Ramadan.

Authors	Subjects	Training Program	Effect
Trabelsi et al., [14]	9 male recreational bodybuilders	Resistance training program 3 times/week	↔
Trabelsi et al., [14]	12 male recreational rugby sevens players	120 min/day, 4 times/week	↓
Meckel et al., [23]	10 young male soccer players	90 min/day 3 times/week plus one competition/week	↑
Trabelsi et al., [1]	10 physically active men	40-60 min/day of aerobic training in fasted state at least 3 times/week	↓
	9 physically active men	40-60 min/day of aerobic training in fed state at least 3 times/week	↔
Karli et al., [27]	10 elite male power athletes	120 min/day, 6 times/week	↔
Bouhlef et al., [5]	9 elite male rugby players	120 min/day, 5 times/week	↓
Chaouachi et al., [12]	15 elite male judokas	120 min/day, 6 times/week	↓
Chennaoui et al., [25]	8 male middle - distance runners	6 to 10 times/week = total of 8 hours/week	↔
Maughan et al., [20]	59 young male soccer players	60 min/session, 6 to 8 session /week	↔
Brisswalter et al., [26]	9 well-trained runners	specific training program, 3 times/week	↔
Ramadan et al., [17]	6 physically active men	jogging or brisk walking exercise with a duration of 30-60 min/day (after dusk), 3 to 5 times/week	↔
Stannard and Thompson [28]	8 physically active men	2 to 5 times /week in the weight training gymnasium	↔
Racinais et al., [29]	11 recreational soccer players	-	↔
Güvenç [24]	16 amateurs soccer players	120 min/day, 3 times/week	↔
	8 recreational bodybuilders	Resistance training program in fasted state, 4 times/week	↔
Trabelsi et al., [7]	8 recreational bodybuilders	Resistance training program in fed state, 4 times/week	↔

↔: no-significant; ↓: significant decrease; ↑: significant increase

**Table 1:** Changes in the percentage of body fat in physically active individuals during Ramadan.

## Hematological Parameters

Measurements of hematocrit and blood hemoglobin concentration are commonly used to evaluate hydration status [31,32]. The reported effects of Ramadan fasting on these two parameters in physically active individuals have not been consistent. One issue has been the timing of blood sampling, since dehydration is more likely in the late afternoon than early in the morning. Increases of hematocrit and hemoglobin have been noted in rugby union [5], seven players [11] and physically active men [6]. Dehydration was attributed to a decrease in the 24-hour water intake during Ramadan [5,6,11].

In contrast, a decrease in these parameters was seen in one group of soccer players during Ramadan [20]; possibly, they had a higher night-time water intake, but a further factor is that blood samples were collected in the mornings in some of the subjects.

Aloui and colleagues [15] found that the hematocrit and hemoglobin values of twelve amateur soccer players were higher during Ramadan than in a control period, whether samples were collected in the morning (07:00 AM) or in the afternoon (05:00 PM). However, values were also higher in the afternoon than the morning during Ramadan, pointing to both a daily dehydration and a cumulative loss of body fluids over the month. Tayebi and colleagues [33] evaluated the effect of a 3 sessions/week resistance training program on weightlifters. Their results showed no changes in hematocrit, hemoglobin, red blood cell count, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration or distribution index of red blood cells during Ramadan, relative to data measured before Ramadan. Similarly, blood platelet counts did not change during Ramadan [6,33]. However, micronutrient deficiencies (particularly a lack of iron and vitamins) may sometimes decrease blood platelet counts in physically active men during Ramadan [17].

## Biochemical Parameters

### Plasma and serum electrolytes

Serum sodium concentration is another potential indicator of hydration status [31,34]. Values increase in sedentary men during Ramadan, but interestingly such a change is not duplicated in physically active men [17] or soccer players [20]. Possibly, athletes, pay greater attention to maximizing their fluid intake during the hours of darkness. However, if Ramadan falls during a hot and humid month, the daily fluid losses may be such that an increase in serum sodium and chloride concentrations is difficult to avoid. Increased sodium concentrations have been reported in rugby sevens players [13] and in rugby union players [5].

During Ramadan, dehydration develops progressively over the day [35]. Amateur soccer players thus show higher plasma sodium and potassium concentrations in the afternoon (05:00 PM) than in the morning (07:00 AM) during Ramadan [15].

During Ramadan, some physically active men opt to train at night, few hours after the *Iftar*, in order to minimize their fluids losses. This strategy appears to be effective from the viewpoint of fluid balance; thus, Trabelsi and co-workers [1] noted that serum electrolytes concentrations (sodium, potassium and chloride) did not change during Ramadan if aerobic training was undertaken after breaking the fast, whereas sodium and chloride concentrations increased if aerobic training was performed before breaking the fast.

Surprisingly, bodybuilders experience some increase in some serum electrolytes towards the end of Ramadan, whether they train at night or during the day [7]. These results seem in conflict with the findings during aerobic training. However, the total water intake of the bodybuilders decreased during Ramadan, even if they trained at night, whereas the men who were practicing aerobic exercise at night succeeded in maintaining their water

intake. Possibly, athletes who engage in resistance training receive less guidance on the maintenance of fluid balance than those who are involved in aerobic activities.

Regardless of the time of day when training is undertaken, subjects should drink some 600 mL/h of fluid (the normal gastric emptying rate) from the breaking of fast until bedtime, and an additional 1L at the *Sahour* meal in order to minimize chronic dehydration [36].

### **Renal function markers**

Creatinine clearance, and the plasma/serum concentrations of creatinine, urea and uric acid are all potential measures of renal function [37-39], although an increased breakdown of tissue protein could compromise the use of these indices during Ramadan. Increases of serum urea and creatinine have been observed in sedentary men during Ramadan [17]. However, possibly because of adaptations of renal function, the serum uric acid concentration is lower in physically active than in sedentary men [17]. Likewise, creatinine clearance values for elite rugby union players did not change during Ramadan [40].

In contrast, serum urea, creatinine and uric acid concentrations were all increased in one recent study of rugby sevens players when Ramadan occurred in a hot and humid summer month [13]. Moreover, an increase in serum creatinine concentration and a decrease in creatinine clearance were seen in subjects who performed aerobic exercise during Ramadan, whether they trained before or after breaking their fast [1]. Likewise, resistance training performed either before or after breaking the fast increased the serum creatinine levels of bodybuilders who continued training during Ramadan [7].

### **Glycemia**

The daily fast of Ramadan can induce a progressive drop in blood glucose concentration over the course of the day, even in healthy sedentary subjects [41,42]. A greater capacity for gluconeogenesis may prevent the drop in blood glucose levels in athletes, even if their energy intake is decreased during Ramadan [5,13]. However, in most studies where this has been measured, there has been no significant decrease of lean tissue mass over the month of intermittent fasting, and thus not much gluconeogenesis from the breakdown of tissue protein. Other studies of physically active men [1,6] and recreational bodybuilders [7,14] also found no significant change of blood glucose during Ramadan. However, decreased blood glucose levels have been seen in those performing more sustained aerobic activities, including runners [19,43,44] and participants in team sports (soccer and basketball) [18].

Glucose levels are certainly affected by the time of day when blood samples are taken [45]; for instance, martial arts practitioners show lower glucose concentrations in the afternoon (04:00 PM) than in the morning (09:00 AM) during Ramadan [16]. Such observations suggest that an athlete's ability to complete an intensive physical training session or perform at his or her maximum may be compromised by the falling blood glucose concentration during the afternoon. Unfortunately, athletes sometimes cannot avoid training during the hours of daylight. One useful tactic for such individuals might be to consume foods with a low glycemic index at the *Sahour* meal, in order to prolong the release of sugars into the blood stream [46].

Little is known regarding possible changes in the action of insulin and other mechanisms of glycemic control during Ramadan. Nevertheless, some improvement of regulation might be anticipated, since intermittent starvation similar to that experienced in Ramadan can increase insulin sensitivity and improve glucose tolerance in both humans and animals [2].

### **Lipid profile**

The lipid profile is an important indicator of cardiovascular health, and it is instructive to examine the changes in this profile that develop during the observance of Ramadan. Empirical data are conflicting, perhaps because findings are influenced not only by the



timing of blood samples and any changes of diet, but also by the initial body fat content, and possible changes in physical activity during Ramadan.

The serum concentration of total cholesterol increased in judokas [12], but not in middle-distance runners [25], rugby union players [40], physically active men [6,11] or bodybuilders [7,14]. An increase serum High Density Lipoprotein Cholesterol concentration (HDL-C) seen in judokas [12] and rugby union players [40] have been attributed to a mobilization of body fat stores during Ramadan. Supporting this view is an increase of HDL-C in subjects practicing aerobic exercise before breaking their fast [1], and in those undertaking resistance training in either a fed or a fasted state [7].

Low Density Lipoprotein (LDL) cholesterol concentrations also increase in judokas during Ramadan [12], perhaps due to an increased consumption of saturated fatty acids [47] associated with altered food choices.

Chaouachi and co-workers [12] noted that although the serum triglyceride values of judokas were increased sixteen days after the beginning of Ramadan, values had returned to pre-Ramadan levels towards the end of the month. In contrast, in a group of rugby players, Bouhleb and colleagues [40] found increased triglyceride values at the end of Ramadan. Others have reported no significant change of triglycerides concentrations during Ramadan [1,7,48].

The altered feeding behavior seen during Ramadan may increase apolipoprotein A1 levels, with a resulting increase in protection of the cardiovascular system [12,49]. On the other hand, the apolipoprotein B levels in judokas remained unchanged during Ramadan [12].

### **Immune markers**

There is as yet only limited information on changes of immune function during Ramadan. If a negative energy balance develops, this might depress immune function, but as yet no evidence has been seen of such a change. The total leucocyte count of soccer players during Ramadan was increased when blood samples were collected in the morning (09:00 AM), but was unchanged for subjects whose blood samples were collected the afternoon (01:30 PM) [20]. No change in either the total or the differential leucocyte count was seen in judokas during Ramadan [50]; however, one problem in interpreting data from these subjects is that any tissue trauma sustained during training is likely to induce an inflammatory response, with consequent slight increases in immunoglobulin A and immunoglobulin G [50]; this makes it difficult to discern the effects of Ramadan alone. Likewise, no changes of total leucocytes or leucocyte subsets were seen in Muslims bodybuilders practicing resistance training, whether before or after breaking their fast [7]. It is worth emphasizing that in the several studies completed to date, all values for immune markers have remained well within normal clinical limits. Thus, there is no evidence that the combination of physical activity and Ramadan fasting has affected immunocompetence. Nevertheless, further tests are needed in long distance events such as marathon and ultra-marathon runs, the type of situation where impairment of immune function is most commonly observed even in the absence of Ramadan fasting.

### **Inflammatory markers**

Findings regarding the effect of training and Ramadan observance upon inflammatory markers are inconsistent. C-reactive protein concentrations increased in judokas [50], decreased in a sample of soccer players who were tested in the morning [20], and did not change in either middle-distance runners [24] or recreational bodybuilders training either before or after breaking their fast [7]. Serum transferrin concentrations increased in soccer players [20], but did not change in judokas during Ramadan [50]. The prealbumin, albumin, haptoglobin and homocysteine concentrations of judokas also remained unchanged during

Ramadan [50], and ferritin concentrations remained unchanged in soccer players [20]. Although some observers have reported statistically significant changes in inflammatory markers values, it must again be emphasized that values have remained within the normal laboratory reference range.

## Conclusions

Athletes who maintain predominantly aerobic-based training during Ramadan may expect to see some decrease in their body fat stores. In addition, if training is conducted during daylight under hot and humid conditions, changes in hematological and biochemical parameters reflect a progressive dehydration and possibly some impairment of renal function. However, information obtained to date does not suggest that the immune and inflammatory systems are adversely affected by Ramadan. Moreover, changes in hematological and biochemical parameters are usually relatively small, with values remaining within the normal reference range. The implication seems that intensive physical training can be maintained with safety during Ramadan.

Recent studies have helped in defining optimal tactics to maintain homeostasis and conserve or enhance body composition while continuing rigorous training during Ramadan. If aerobic training is practiced before the night-time break in fasting, it may stimulate lipid mobilization, thus reducing body fat stores and improving the lipid profile. However, cumulative dehydration may develop over four weeks of aerobic training in a fasted state, so that care must be taken if this training plan is adopted. In contrast, it seems that resistance-based training can be performed safely either before or after breaking the fast. Lean body mass seems well maintained, and the immune and inflammatory systems do not appear to be adversely affected by Ramadan. Mild dehydration and an improvement of lipid profile are likely with resistance training, whether the exercise is performed in a fed or a fasted state.

## References

1. Trabelsi K, el Abed K, Stannard SR, Jammoussi K, Zeghal KM, et al. (2012) Effects of fed- versus fasted-state aerobic training during Ramadan on body composition and some metabolic parameters in physically active men. *Int J Sport Nutr Exerc Metab* 22: 11-18.
2. Stannard SR (2011) Ramadan and its effect on fuel selection during exercise and following exercise training. *Asian J Sports Med* 2: 127-133.
3. Ba Hammam A (2005) Assessment of sleep patterns, daytime sleepiness, and chronotype during Ramadan in fasting and nonfasting individuals. *Saudi Med J* 26: 616-622.
4. Husain R, Duncan MT, Cheah SH, Ch'ng SL (1987) Effects of fasting in Ramadan on tropical Asiatic Moslems. *Br J Nutr* 58: 41-48.
5. Bouhlel E, Salhi Z, Bouhlel H, Mdella S, Amamou A, et al. (2006) Effect of Ramadan fasting on fuel oxidation during exercise in trained male rugby players. *Diabetes Metab* 32: 617-624.
6. Trabelsi K, El Abed K, Trepanowski JF, Stannard SR, Ghlissi Z, et al. (2011) Effects of ramadan fasting on biochemical and anthropometric parameters in physically active men. *Asian J Sports Med* 2: 134-144.
7. Trabelsi K, Stannard SR, Ghlissi Z, Maughan RJ, Kallel C, et al. (2013) Effect of fed- versus fasted state resistance training during Ramadan on body composition and selected metabolic parameters in bodybuilders. *J Int Soc Sports Nutr* 10: 23.
8. Leiper JB, Molla AM, Molla AM (2003) Effects on health of fluid restriction during fasting in Ramadan. *Eur J Clin Nutr* 57: 30-38.
9. Frost G, Pirani S (1987) Meal frequency and nutritional intake during Ramadan: a pilot study. *Hum Nutr Appl Nutr* 41: 47-50.
10. el Ati J, Beji C, Danguir J (1995) Increased fat oxidation during Ramadan fasting in healthy women: an adaptive mechanism for body-weight maintenance. *Am J Clin Nutr* 62: 302-307.

11. Trabelsi K, Rebai H, El-Abed K, Stannard SR, Khannous H, et al. (2011) Effect of ramadan fasting on body water status markers after a rugby sevens match. *Asian J Sports Med* 2: 186-194.
12. Chaouachi A, Chamari K, Roky R, Wong P, Mbazaa A, et al. (2008) Lipid profiles of judo athletes during Ramadan. *Int J Sports Med* 29: 282-288.
13. Trabelsi K, Rebai H, el Abed K, Stannard S, Kallel C, et al. (2012) Effect of ramadan fasting on renal function markers and serum electrolytes after a rugby sevens match. *IOSR J Pharm* 2: 42-50.
14. Trabelsi K, Stannard SR, Maughan RJ, Jammoussi K, Zeghal K, et al. (2012) Effect of resistance training during Ramadan on body composition and markers of renal function, metabolism, inflammation, and immunity in recreational bodybuilders. *Int J Sport Nutr Exerc Metab* 22: 267-275.
15. Aloui A, Chaouachi A, Chtourou H, Wong del P, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated-sprint performances. *Int J Sports Physiol Perform* 8: 254-262.
16. Tian HH, Aziz AR, Png W, Wahid MF, Yeo D, et al. (2011) Effects of fasting during ramadan month on cognitive function in muslim athletes. *Asian J Sports Med* 2: 145-153.
17. Ramadan J, Telahoun G, Al-Zaid NS, Barac-Nieto M (1999) Responses to exercise, fluid, and energy balances during Ramadan in sedentary and active males. *Nutrition* 15: 735-739.
18. Haghdoust AA, Poorranjbar M (2009) The interaction between physical activity and fasting on the serum lipid profile during Ramadan. *Singapore Med J* 50: 897-901.
19. Aziz AR, Slater GJ, Hwa Chia MY, Teh KC (2012) Effects of Ramadan fasting on training induced adaptations to a seven-week high-intensity interval exercise programme. *Science & Sport* 27: 31-38.
20. Maughan RJ, Leiper JB, Bartagi Z, Zrifi R, Zerguini Y, et al. (2008) Effect of Ramadan fasting on some biochemical and haematological parameters in Tunisian youth soccer players undertaking their usual training and competition schedule. *J Sports Sci* 26: 39-46.
21. Memari AH, Kordi R, Panahi N, Nikookar LR, Abdollahi M, et al. (2011) Effect of ramadan fasting on body composition and physical performance in female athletes. *Asian J Sports Med* 2: 161-166.
22. Kordi R, Abdollahi M, Memari AH, Najafabadi MG (2011) Investigating Two Different Training Time Frames during Ramadan Fasting. *Asian J Sports Med* 2: 205-210.
23. Meckel Y, Ismaeel A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *Eur J Appl Physiol* 102: 651-657.
24. Güvenç A (2011) Effects of ramadan fasting on body composition, aerobic performance and lactate, heart rate and perceptual responses in young soccer players. *J Hum Kinet* 29: 79-91.
25. Chennaoui M, Desgorces F, Drogou C, Boudjemaa B, Tomaszewski A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Appl Physiol Nutr Metab* 34: 587-594.
26. Brisswalter J, Bouhler E, Falola JM, Abbiss CR, Vallier JM, et al. (2011) Effects of Ramadan intermittent fasting on middle-distance running performance in well-trained runners. *Clin J Sport Med* 21: 422-427.
27. Karli U, Güvenç A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *J Sports Sci Med* 6: 490-497.
28. Stannard SR, Thompson MW (2008) The effect of participation in Ramadan on substrate selection during submaximal cycling exercise. *J Sci Med Sport* 11: 510-517.
29. Racinais S, Périard JD, Li CK, Grantham J (2012) Activity patterns, body composition and muscle function during Ramadan in a Middle-East Muslim country. *Int J Sports Med* 33: 641-646.
30. Pialoux V, Mischler I, Mounier R, Gachon P, Ritz P, et al. (2004) Effect of equilibrated hydration changes on total body water estimates by bioelectrical impedance analysis. *Br J Nutr* 91: 153-159.
31. Oppliger RA, Bartok C (2002) Hydration testing of athletes. *Sports Med* 32: 959-971.
32. Hackney AC, Coyne JT, Pozos R, Feith S, Seale J (1995) Validity of urine-blood hydrational measures to assess total body water changes during mountaineering in the sub-Arctic. *Arctic Med Res* 54: 69-77.

33. Tayebi SM, Hanachi P, Niaki AG, Ali PN, Ghaziani F (2010) Ramadan Fasting and Weight-Lifting Training on Vascular Volumes and Hematological Profiles in Young Male Weight-Lifters. *Global J health Sci* 2: 160-166.
34. Shirreffs SM (2000) Markers of hydration status. *J Sports Med Phys Fitness* 40: 80-84.
35. Maughan RJ, Shirreffs SM (2012) Hydration and performance during Ramadan. *J Sports Sci* 30: 33-41.
36. Shephard RJ (2012) The impact of Ramadan observance upon athletic performance. *Nutrients* 4: 491-505.
37. Cockcroft DW, Gault MH (1976) Prediction of creatinine clearance from serum creatinine. *Nephron* 16: 31-41.
38. Kakadiya J, Shah N (2010) Renal function markers: a short review. *JITPS* 1: 270-273.
39. Gowda S, Desai PB, Kulkarni SS, Hull VV, Math AA, et al. (2010) Markers of renal function tests. *N Am J Med Sci* 2: 170-173.
40. Bouhlel E, Denguezli M, Zaouali M, Tabka Z, Shephard RJ (2008) Ramadan fastings effect on plasma leptin, adiponectin concentrations, and body composition in trained young men. *Int J Sport Nutr Exerc Metab* 18: 617-627.
41. Fakhrzadeh H, Larijani B, Sanjari M, Baradar-Jalili R, Amini MR (2003) Effect of Ramadan fasting on clinical and biochemical parameters in healthy adults. *Ann Saudi Med* 23: 223-226.
42. Larijani B, Zahedi F, Sanjari M, Amini MR, Jalili RB, et al. (2003) The effect of Ramadan fasting on fasting serum glucose in healthy adults. *Med J Malaysia* 58: 678-680.
43. Aziz AR, Wahid MF, Png W, Jesuvadian CV (2010) Effects of Ramadan fasting on 60 min of endurance running performance in moderately trained men. *Br J Sports Med* 44: 516-521.
44. Faye J, Fall A, Badji L, Cisse F, Stephan H, et al. (2005) [Effects of Ramadan fast on weight, performance and glycemia during training for resistance]. *Dakar Med* 50: 146-151.
45. Hammouda O, Chtourou H, Chahed H, Ferchichi S, Chaouachi A, et al. (2012) High intensity exercise affects diurnal variation of some biological markers in trained subjects. *Int J Sports Med* 33: 886-891.
46. Jeukendrup AE, McLaughlin J (2012) Carbohydrate ingestion during exercise: Effects on performance, training adaptations and trainability of the gut. In: Maughan RJ, Burke LM (eds.). *Sports Nutrition: More than Just Calories - Triggers for Adaptation*. Karger Publications, Basel, Switzerland.
47. Mattson FH, Grundy SM (1985) Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *J Lipid Res* 26: 194-202.
48. Tayebi SM, Niaki AG, Hanachi P, Ghaziani FG (2010) The Effect of Ramadan Fasting and Weight-Lifting Training on Plasma Volume, Glucose and Lipids Profile of Male Weight-Lifters. *Iran J Basic Med Sci* 13: 57-62.
49. Adlouni A, Ghalim N, Saïle R, Hda N, Parra HJ, et al. (1998) Beneficial effect on serum apo AI, apo B and Lp AI levels of Ramadan fasting. *Clin Chim Acta* 271: 179-189.
50. Chaouachi A, Coutts AJ, Wong del P, Roky R, Mbazza A, et al. (2009) Haematological, inflammatory, and immunological responses in elite judo athletes maintaining high training loads during Ramadan. *Appl Physiol Nutr Metab* 34: 907-915.

## Chapter 16

# Maintaining Fluid Balance during Day Fasting in the Month of Ramadan

**Roy J. Shephard\***

\*Faculty of Kinesiology & Physical Education, University of Toronto, Canada

\***Corresponding author:** Roy J. Shephard, Faculty of Kinesiology & Physical Education, University of Toronto, P.O. Box: 521, Brackendale, BC V0N 1H0, Toronto Ontario, Canada, Tel: 604-898-5527; Fax: 604-898-5724; E-mail: [royjshep@shaw.ca](mailto:royjshep@shaw.ca)

## Introduction

The observance of Ramadan requires complete abstinence from oral intake of any food or any fluid from before dawn to just after sunset on each day throughout the full month of Ramadan (29 or 30 days, depending on the Moon Hijri Calendar Year). For trained athletes, who are engaged in professional team or endurance sports, the abstinence from fluids intake from the early morning hours is a severe challenge to their body and internal organs. In many categories of trained athletes, such day-long fasting can lead to adverse effects upon their competitive performance [1]. Although some 3000 Muslims participated in the 2012 London Olympics, there was surprisingly little comment concerning the impact of Ramadan fasting; possibly, competitors were helped by the cloudy and relatively mild weather that is typical of an English summer, and some may have also benefited from a recent *Fatwa* that offered athletes the option of deferring their fast until they had completed competition. The FIFA World Cup competitions in Brazil (June/July 2014) will also coincide with the month of Ramadan, and the focus upon a team sport may make this a greater issue in terms of the performance and health of the players.

This chapter looks specifically the hydration status of individuals who observe the intermittent fasting required by Ramadan. The maintenance of hydration, particularly by long-distance runners and those involved in team sports have to date received surprisingly little discussion [2].

## Effects of Dehydration upon Health and Physical Performance

A safe level of dehydration is still debated, but losses of 7-8% of body mass (i.e. as much as 5 L) can be tolerated in a temperate climate [3], although performance is then sub-optimal. Saltin argued that during the performance of sustained aerobic exercise in a hot environment (a situation where the water of hydration of glycogen is likely to be mobilized), decreases of maximal oxygen intake and cardiac output develop when fluid losses exceeded 5% of body mass (about 3.5 L) [4]. Armstrong and associates tested the effect of 10-12% reduction in plasma volume (produced experimentally by administration of the diuretic furosemide). Although subjects sustained a 1.6-2.1% decrease of body mass, their maximal oxygen intake remained unchanged. Nevertheless, track times were increased for 1500 m, 5000 m and 10,000 m events [5].

Wrestlers who have undergone deliberate dehydration have also shown decrease in maximal isometric strength and circulatory function if rehydration has been incomplete prior to competition. Performance has been impaired with quite small fluid deficits (2% of body mass, perhaps 2L in a heavy wrestler) [6-9]. Likewise, under conditions where soccer players are sweating heavily, physical performance and skills have sometimes been enhanced by the provision of fluids at half time, although performance gains have been slight when correcting fluid losses of up to 2.5% of body mass (1.5 L) [10]; indeed, where benefit has been seen, this may have come as much from the glucose as from the water content of the beverage that was provided [11,12].

### **Theoretical considerations**

The body normally loses about 2.5 L of water per day, due to the excretion of 1.2-1.5 L of urine, an “insensible” loss of some 0.5 L of water at the skin surface, the addition of 0.4 L to expired air, and the 150-200 mL of water found in feces of normal consistency. An increased secretion of the anti-diuretic hormone and aldosterone can reduce the output of urine somewhat if fluids are in short supply, but the fluid intake needed to accommodate the minimum urinary flow and losses in the lungs and skin is around 1.5 L/day [13]. In exercising athletes, this figure can be substantially boosted by sweat losses of up to 2 L/h. Depending upon the humidity of the inspired air, respiratory water losses can also increase greatly during exercise.

Hydration is normally maintained by the ingestion of fluids (at least 1 L/day), the water content of food (about 1.2 L/day), and the production of water during the metabolism of food (about 0.3 L/day). A significant additional resource is the water of hydration associated with glycogen (about 2.7 g/g, or given a total store of 500g some 1.35 L). The total water volume includes also water molecules associated with stored glycogen, osmolytes such as sodium in the extracellular space and organic osmolytes within cells [14]. As glycogen is broken down during prolonged physical activity, the associated water molecules are added to the functional water volume. This is a more important variable than the gross body water [15]; during vigorous exercise, there can be a decrease of both body mass and total body water, but no change in the functional water volume.

Ramadan may induce some changes of dietary composition, but the total energy intake generally shows little change [1], so that the amount of water derived from food and its metabolism (1.5 L/day) shows little change; it is in itself almost enough to meet the minimum fluid requirements of a sedentary person. Furthermore, it is quite possible for a sedentary person to ingest the normal fluid intake of 1 L/day during the hours of refeeding [16], leaving 500 mL or more of fluid in the stomach at daybreak. Because the night-time intake of fluid is large, many people think (usually erroneously) that their fluid intake has increased during Ramadan [17]. Certainly, there seems no fundamental reason why a sedentary person should develop a cumulative fluid deficit during the month of Ramadan.

The fluid requirements of the distance athlete or team competitor are much larger, given a tenfold increase of respiratory minute volume and the potential to lose 3-4 L of sweating during 2 hours of activity. One laboratory comparison of sedentary middle-aged men with their peers who were running an average of 14.8 km/d concluded that the additional fluid requirements of the runners were even greater than suggested by respiratory and sweat losses [13]. Although they probably derived up to 2 L of functional water from the breakdown of glycogen [3], they would likely have incurred a fluid deficit of 1-2 L by the end of a match or distance race.

### **Empirical Evidence on the Extent of Dehydration during Ramadan**

In theory, observance of Ramadan fasting could cause either a short-term dehydration (developing progressively over the course of a day of fasting), or cumulative effects incurred

over the month when the daytime ingestion of fluid was prohibited. Methods of examining hydration have included studies of body mass, haemoglobin and haematocrit, urinary volume and composition. Body mass changes in body mass observed over the course of Ramadan (Table 1) could reflect not only a progressive dehydration, but also the breakdown of body fat and lean tissue to meet metabolic needs, or (particularly in sedentary individuals) a deliberate restriction of food intake in order to reduce body fat content.

Author	Subjects	Methodology	Changes during Ramadan
<b>Sedentary individuals</b>			
Aybak et al., [43]	20 non-smoking males	Body mass	No change in body mass
Bakhotmah [18]	173 Saudi families	Body mass	20% show weight gain during Ramadan, 60% show increase after Ramadan
Born et al., [44]	12 males	Body mass	1.8 kg (2.6%) decrease of body mass
Fedail et al., [45]	20 males, 4 females	Body mass	1.8 kg (2.6%) loss of body mass
Hallack & Nomani [19]	16 male university students	Body mass	2.4 kg (3.6%) loss of body mass, associated loss of subcutaneous fat
Husain et al., [20]	12 sedentary males, 9 sedentary females	Body mass, body fat, fluid balance chart	Decreased body mass (M 2.5%, F 3.2%) and fat, No significant change of fluid intake or urinary output
Muazzam & Khaleque [38]	13 male & female	Body mass	1.4 kg (2.5%) decrease of body mass, with some associated decrease of urinary output
Ramadan et al., [41]	7 sedentary males	Body mass and serum osmolality	1.3% decrease of body mass
Schmall et al., [46]	27 males	Body mass	3.6 kg decrease of body mass
Siddiqui et al., [47]	46 Sedentary Pakistani males	Body mass	Increase in body mass
Sweileh et al., [21]	7 males, 1 female	Body mass	1.9 kg decrease of body mass, but also 2.7% decrease of body fat
Zebidi et al., [36]	15 males	Body mass	Decreased body mass (2.6 kg, 3.5%), daytime urinary concentration close to maximal
<b>Active/athletic individuals</b>			
Bigard et al., [25]	11 male fighter pilots	Body mass and haematocrit	2 kg (2.7%) decrease of body mass over Ramadan
Fall et al., [48]	20 physically active Senegalese, ?male	Body mass	No change of body mass
Ramadan et al., [41]	6 active males	Body mass and serum osmolality	1.4% decrease of body mass
Stannard & Thompson [49]	10 physically active males	Body mass and body fat	0.8% decrease of body mass
Chennaoui et al., [22]	8 middle-distance runners	Body mass and body fat	No change of body mass or fluid volumes, sweat secretion unchanged
Meckel et al., [23]	19 junior soccer players	Body mass	No change of body mass

**Table 1:** Changes in body mass during Ramadan observance.

A decrease in body mass, commonly in the order of 2-3 kg, was seen in 8 of 11 studies of sedentary subjects, and 3 of 6 studies of active individuals. However, no change of body mass was observed in 1 study of sedentary people and 3 studies of active groups. Two sedentary groups actually showed an increase of body mass during and following Ramadan; this was attributed to an increased consumption of carbohydrates and fats during Ramadan [18], and possibly to group festivities such as large communal meals.

Even where there was a progressive decrease of body mass during Ramadan, this cannot necessarily be attributed to chronic dehydration. In some cases there has been documentation of associated fat loss [19-21], and in one study a quite large change of body mass occurred without any change in urinary output [20]. The two studies specifically concerned with athletes saw no changes of body mass, fluid volumes or sweat rates [22,23].

## Haemoglobin and haematocrit

Changes in haemoglobin and haematocrit provide more reliable evidence of dehydration, particularly on a short term basis, but findings must still be interpreted with caution, since the overall social environment of Ramadan can create changes in the blood picture even among those who do not observe the fast [24]. Unfortunately, few studies about Ramadan fasting have included matched control groups. Of 5 haemoglobin and haematocrit studies in sedentary individuals, five have indicated no significant change in plasma volume during Ramadan fasting. There is only one exception reported, which concerned a group of fighter pilots [25], who probably lived a more active life than subjects in the remaining investigations. Among the 6 haemoglobin/haematocrit studies of active individuals, 4 found an increase of the afternoon readings during Ramadan, suggesting that some dehydration developed over the course of the day [26-29]. Bouhlel et al., observed an additional haemoconcentration following a rugby match, as might be expected [27], but in the study of Aloui et al., haemoconcentration was, surprisingly, not increased by exercise [26]. A group of judoka showed no consistent changes of daily water intake over Ramadan, and (probably because blood samples were collected in the morning), changes of haematocrit and haemoglobin were also inconsistent [30]. Maughan et al., tested some of their subjects in the morning and others in the afternoon; perhaps because of changes in the overall community living environment during Ramadan they saw decrease in haemoglobin and haematocrit levels in both fasting and non-fasting subjects during Ramadan [2,31] (Table 2).

Author	Subjects	Methodology	Effects of Ramadan
<b>Sedentary individuals</b>			
Al Hourani et al., [50]	57 healthy females	Haematocrit	No change of haematocrit
Bigard et al., [25]	11 male fighter pilots	Haematocrit	7% decrease of plasma volume over Ramadan
Chiha [28]	9 sedentary subjects	Body mass, body fat and haematocrit	No significant decrease of plasma volume at rest or after lab exercise; but volume of water ingested decreased by 0.46 L/d
Farshidfar et al., [51]	62 M & F students	Haematocrit & haemoglobin	No significant change of haematocrit, but decrease of haemoglobin; also decrease of body mass
Furuncuoglu et al., [52]	7 males, 32 females	Body mass, haematocrit and blood chemistry	No significant changes (but trend to decrease of haematocrit)
<b>Active/Athletic individuals</b>			
Aloui et al., [26]	12 active males	Haematocrit and haemoglobin	Readings for both haematocrit and haemoglobin increased in afternoon during Ramadan, implying decrease of plasma volume
Bouhlel et al., [27]	9 male rugby players	Body mass, body fat, haematocrit	Increase of haematocrit, decrease of afternoon plasma volumes both early and late during Ramadan, similar effect upon post-exercise values
Chaouachi et al., [30]	15 male Tunisian Judokus	Body mass, body fat and haematocrit	Variable changes in morning plasma volumes over course of Ramadan (-4% to +4%)
Chiha [28]	12 male soccer players	Body mass, body fat and haematocrit	Increase of haemoglobin at rest and post-exercise, non-significant trend to increase of haematocrit during Ramadan. Volume of water ingested decreased by 1.07L/d
Maughan et al., [53]	79 male soccer players	Body mass, body fat, haematocrit	Loss of body mass, no loss of fat; no significant change in haematocrit but puzzling decrease in haemoglobin, particularly during 4 <sup>th</sup> week of Ramadan



Shireffs and Maughan [31]	55 observant male soccer players, 37 non-observant	Body mass, haemoglobin and haematocrit	Decrease of haemoglobin and haematocrit during Ramadan, seen also in controls. Study appears to overlap with [53]
Trabelsi et al., [29]	12 male recreational rugby players	Haematocrit, haemoglobin	Increase of resting haematocrit and haemoglobin, with decrease of blood volume but not total body water, particularly at beginning of Ramadan; not exacerbated by Rugby match.

**Table 2:** Changes of haemoglobin and/or haematocrit during Ramadan.

## Urinary Volumes and Composition

Most published studies of urinary volumes and composition have involved sedentary subjects (Table 3). During Ramadan, there has usually been some decrease of daytime urinary volumes, but little [32] or no significant change of urinary output on a 24-hour basis [16,20,33-36]. Any overall decrease in urinary volume has been insufficient to have an adverse effect on health [37]. One report found daytime urinary concentrations rose close to the maximal concentrating ability of the kidneys, but unfortunately this study included no data on the osmolality of night urine specimens [36], so that cumulative effects cannot be assessed. Another study noted a small decrease in the daily output of urine, although this apparently began before there had been a significant change in body mass [38].

Some reports have noted substantial decreases of fluid intake during Ramadan [28,39]. Nevertheless, there has often been a tendency for an adjustment of fluid balance as Ramadan continued, possibly through a combination of altered behavior (particularly drinking more at night), a reduction in non-renal water loss [34], and increases in the secretion of antidiuretic hormone and aldosterone leading to greater retention of water and salt by the kidneys [21,39].

Author	Sample	Method	Effects of Ramadan
<b>Sedentary individuals</b>			
Cheah et al., [33]	13 sedentary Malaysians	Urinary volume, osmolality and solute excretion	No change in total daily urine volume, although during daytime tendency to decrease during Ramadan, with more concentrated urine
Chiha [28]	9 sedentary subjects	Body mass, body fat and haematocrit, water ingestion	No significant decrease of plasma volume at rest or after lab. exercise; but volume of water ingested decreased by 0.46 L/d (16%) during Ramadan
Husain et al., [20]	12 sedentary males	Body mass, body fat, fluid balance chart	Weekly observations; No significant change of fluid intake or urinary output during Ramadan
Leiper & Prastowow [34]	Sedentary Muslims	Isotope tracer	No change of water turnover; decrease of non-renal water loss
Miladipour et al., [32]	57 males aged 30 to 55 yr, including 37 with recurrent calculi	Urinary volume and urinary composition	0.16 L/d (10%) decrease of urinary volume during Ramadan
Mustafa et al., [39]	16 Sedentary Sudanese men	Body mass, fluid intake, urinary volume and electrolytes	2.7% decrease of body mass at beginning of 2 <sup>nd</sup> week, recovery by 4 <sup>th</sup> week of Ramadan; 2 L/d fluid balance deficit at beginning of Ramadan, compensated by end of month by urinary concentration and salt retention
Prentice et al., [16]	20 lactating Gambian women	Body mass, body fat, urine volume and osmolality	7.6% depletion of total body water over the day, but made good at night; no chronic loss

Sweileh et al., [21]	7 males, 1 female	Body mass, body fat, serum electrolytes	Decrease of body mass and fluids in first week, with no change of body fat. Recovery by end of Ramadan, but water intake reduced 0.8 L (36%)
Waterhouse et al., [35]	20 healthy males	Urinary osmotic pressure	Afternoon rise of osmotic pressure during Ramadan, not seen on control days
<b>Athletic individuals</b>			
Chiha [28]	12 soccer players	Body mass, body fat and haematocrit	No significant decrease of plasma volume at rest or after laboratory exercise, but volume of water ingested decreased by 1.07 L/d (31%) during Ramadan
Karli et al., [40]	10 power athletes	Body mass, Urinary specific gravity, bio-impedance	No change of body mass, but increase of afternoon urinary specific gravity during Ramadan.
Shirreffs et al., [31]	55 junior soccer players	Body mass, serum biochemistry and urinary specific gravity	2% change of body mass during training session, not seen in controls, but no chronic effect on body mass or urinary specific gravity (some of urine samples collected in the morning?)

**Table 3:** Urinary volume and composition, fluid balance.

Two urinary studies of athletes involved soccer players, and the third power athletes [40]. There were no chronic changes in body mass [31,40] or plasma volume [28]. During Ramadan, the power athletes showed an increase of urinary specific gravity in the afternoon samples. This was not seen in the soccer players [31], although apparently the samples were collected from some subjects during the morning rather than the afternoon. Sessions of soccer training caused a temporary 2% decrease of body mass not seen in the same players during control periods when they had free access to fluids [31], and one study also noted a substantial 1.07 L/d decrease of water ingestion during Ramadan [28].

### Other measures of fluid balance during Ramadan

Other investigators have looked for changes in body impedance and serum electrolyte concentrations during Ramadan (Table 4).

Author	Sample	Method	Effects of Ramadan
<b>Sedentary individuals</b>			
Ramadan et al., [41]	7 sedentary Kuwaitis	Body mass, serum osmolarity, serum sodium	Decrease of body mass <1.3% Increased plasma sodium concentration
Sweileh et al., [21]	7 healthy men, 1 healthy woman	Body mass, body fat, serum electrolytes	Decrease of fluids in first week, increase of plasma sodium, but recovery by end of Ramadan
<b>Athletic individuals</b>			
Karli et al., [40]	10 elite power athletes	Toe-to-toe body impedance	No change in this measure of total body water
Ramadan et al., [41]	6 active Kuwaitis	Body mass, serum osmolarity, serum sodium	Decrease of body mass <1.4% Trend to increase of plasma sodium not significant
Shirreffs et al., [31]	55 junior soccer players	Body mass, serum biochemistry and urinary specific gravity	2% change of body mass during exercise, but no chronic effect; plasma sodium did not differ from controls throughout (but some samples collected in the morning?)

**Table 4:** Other measures of fluid balance during Ramadan.

Afternoon foot-to-foot bio-impedance data were obtained on a small group of elite power athletes (2 wrestlers, 7 sprinters and 1 thrower) [40]. No significant change was seen in this estimate of total body water during Ramadan. However, most studies both of sedentary individuals [21,41] and active individuals [41] tended to show increased sodium ion concentrations during Ramadan. In the one study where this was not seen (based on pre-training evaluations of soccer players), it appears that blood samples were collected on some subjects in the morning rather than the afternoon [31].

## Conclusions

Both theoretical considerations and empirical data support the view that the restrictions on fluid intake imposed by Ramadan observance have little effect upon sedentary individuals. If the fluid intake is increased during the hours of darkness, such individuals show little if any evidence of either short-term afternoon dehydration or accumulation of a fluid deficit over the course of Ramadan. Even individuals with clinical problems such as repeated episodes of urinary calculi do not seem to be adversely affected [42].

There have been relatively few studies of fluid balance in athletes, but available data support the view that acute fluid deprivation can develop, particularly for competitors who engage in sustained periods of aerobic activity. Observations in power athletes [40], rugby [27,29] and soccer [28] players all show evidence of afternoon haemoconcentration, although in general this has been corrected by ingesting large volumes of fluid during the hours of darkness. Further, weight loss seen during training is not duplicated under normal conditions [31]. No observations have yet been made on participants in events such as a marathon or ultra-marathon run; it seems likely that effects will be greatest in such sports, and there is an urgent need to determine the effects upon health and performance in such competitions.

The temporary decrease of blood volume during afternoon competitions seems likely to reduce maximal cardiac output, thus impairing both aerobic performance and thermoregulation. A lesser blood flow to the brain could also reduce various aspects of cognitive performance, particularly vigilance. Potential tactics to minimize these effects of Ramadan include maximizing the night-time intake of fluid, beginning the fast with at least 500 ml. of fluid in the stomach, maximizing glycogen stores (with their associated store of bound water), remaining in a cool room away from sunlight until the time of competition, and possibly wetting the clothing, so that body cooling comes from the drying of the clothing rather than sweating.

Athletes who plan to fast during a period of training or competition should seek professional advice to develop a personal strategy to maintain hydration. Those charged with the care of athletes should be prepared to offer such advice, and take account of personal circumstances, including gender, age, experience, environment and the demands of the sport itself [54]. In non-Muslim majority environments, especially in team sports, coaches and athletes should be sensitive to the needs of their team-mates who may be fasting and abstaining from fluids. Where possible, event organizers should also take account of the needs of Muslim athletes when scheduling the dates and timings of sports competitions [55].

## References

1. Shephard RJ (2012) The impact of Ramadan observance upon athletic performance. *Nutrients* 4: 491-505.
2. Maughan RJ, Shirrefs SM (2012) Hydration and performance during Ramadan. *Journal of Sports Sciences* 30: 33-41.
3. Howald H, Poortmans J (1975) *Metabolic adaptations to prolonged exercise*. Birkhauser Verlag, Basel, Switzerland.
4. Saltin B (1964) Circulatory response to submaximal and maximal exercise after thermal dehydration. *Journal of Applied Physiology* 19: 1125-1132.
5. Armstrong LE, Costill DL, Fink WJ (1985) Influence of diuretic-induced dehydration on competitive running performance. *Medicine & Science in Sports & Exercise* 17: 456-461.
6. American College of Sports Medicine (1976) American College of Sports Medicine Position stand on weight loss in wrestlers. *Medicine & Science in Sports* 8: 11-13.
7. Herbert WG, Ribisl PM (1972) Effect of dehydration upon physical working capacity of wrestlers under competitive conditions. *Research Quarterly* 43: 416-422.

8. Opplinger RA, Case HD, Horswell CA, Landry GL, Shelter AC (1996) American College of Sports Medicine Position Stand. Weight loss in wrestlers. *Medicine & Science in Sports & Exercise* 28: 9-12.
9. Sproles CB, Smith DP, Byrd RJ, Allen TE (1976) Circulatory responses to submaximal exercise after dehydration and rehydration. *Journal of Sports Medicine & Physical Fitness* 16: 98-105.
10. Owen JA, Kehoe SJ, Oliver SJ (2013) Influence of fluid intake on soccer performance in a temperate environment. *Journal of Sports Sciences* 31: 1-10.
11. Guerra I, Chaves R, Barros T, Tirapegui J (2004) The influence of fluid ingestion on performance of soccer players during a match. *Journal of Sports Science and Medicine* 3: 198-202.
12. McGregor SJ, Nicholas CW, Lakomy HKA, Williams C (1999) The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *Journal of Sports Sciences* 17: 895-903.
13. Leiper JB, Carnie A, Maughan RJ (1996) Water turnover rates in sedentary and exercising middle aged men. *British Journal of Sports Medicine* 30: 24-26.
14. Bauernschmitt HG, Kinne RK (1993) Metabolism of the 'organic osmolyte' glycerophosphocholine in isolated rat inner medullary collecting duct cells. II. Regulation by extracellular osmolality. *Biochimica Biophysica Acta* 1150: 25-34.
15. Strasser H, K Kluth K, Rausch H, Bub H (2003) *Quality of Work and Products in Enterprise of the Future*. Ergonomia verlag ohg, Stuttgart, Germany.
16. Prentice AM, Lamb WH, Prentice A, Coward WA (1984) The effect of water abstinence on milk synthesis in lactating women. *Clinical Science* 66: 291-298.
17. Singh R, Hwa OC, Roy J, Jin CW, Ismail SM, et al. (2011) Subjective Perception of Sports Performance, Training, Sleep and Dietary Patterns of Malaysian Junior Muslim Athletes during Ramadan Intermittent Fasting. *Asian Journal of Sports Medicine* 2: 167-176.
18. Bakhotmah B (2011) The puzzle of self-reported weight gain in a month of fasting (Ramadan) among a cohort of Saudi families in Jeddah, Western Saudi Arabia. *Nutrition Journal* 10: 84.
19. Hallack MH, Nomani MZ (1988) Body weight loss and changes in blood lipid levels in normal men on hypocaloric diets during Ramadan fasting. *American Journal of Clinical Nutrition* 48: 1197-1210.
20. Husain R, Duncan MT, Cheah SH, Ch'ng SL (1987) Effects of fasting in Ramadan on Tropical Asiatic Moslems. *British Journal of Nutrition* 58: 41-48.
21. Sweileh N, Schnitzler A, Hunter GR, Davis B (1992) Body composition and energy metabolism in resting and exercising muslims during Ramadan fast. *Journal of Sports Medicine and Physical Fitness* 32: 156-163.
22. Chennaoui M, Desgorces F, Drogou C, Boudjemaa B, Tomaszewski A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Applied Physiology Nutrition & Metabolism* 34: 587-594.
23. Meckel Y, Ismael A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *European Journal of Applied Physiology* 102: 651-657.
24. Dewanti L, Watanabe C, Sulistiawati, Ohtsuka R (2006) Unexpected changes in blood pressure and hematological parameters among fasting and nonfasting workers during Ramadan in Indonesia. *European Journal of Clinical Nutrition* 60: 877-881.
25. Bigard AX, Boussif M, Chalabi H, Guezennec CY (1998) Alterations in muscular performance and orthostatic tolerance during Ramadan. *Aviation, Space, and Environmental Medicine* 69: 341-346.
26. Aloui A, Chaouchi A, Chtourou H, Wong DP, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated sprints performances. *International Journal of Sports Physiology and Performance* 8: 254-262.
27. Bouhlel E, Salhi Z, Bouhlel H, Mdella S, Amamou A, et al. (2006) Effect of Ramadan fasting on fuel oxidation during exercise in trained male rugby players. *Diabetes & Metabolism* 32: 617-624.
28. Chiha F. (2008/2009) Variations du métabolisme énergétique à l'effort des footballeurs lors du jeûne de Ramadan. Algeria: University of Algiers.
29. Trabelsi K, Rebai H, el-Abed K, Stannard SR, Khannous H, et al. (2011) Effect of Ramadan fasting on body water status markers after a Rugby sevens match. *Asian Journal of Sports Medicine* 2: 186-194.

30. Chaouachi A, Chamari K, Roky R, Wong P, Mbazza A, et al. (2008) Lipid profiles of judo athletes during Ramadan. *International Journal of Sports Medicine* 29: 282-288.
31. Shirreffs SM, Maughan RJ (2008) Water and salt balance in young male football players in training during the holy month of Ramadan. *Journal of Sports Sciences* 26: 47-54.
32. Miladipour AH, Shakhssalim N, Parvin M, Azadvari M (2012) Effect of Ramadan fasting on urinary risk factors for calculus formation. *Iranian Journal of Kidney Diseases* 6: 33-38.
33. Cheah SH, Ch'ng SL, Huisain R, Duncan MT (1990) Effects of fasting during Ramadan on urinary excretion in Malaysian Muslims. *British Journal of Nutrition* 63: 329-337.
34. Leiper JB, Prastowow SM (2000) Effects of fasting during Ramadan on water turnover in men living in the tropics. *Journal of Physiology* 528: 43.
35. Waterhouse J, Alabed H, Edwards B, Reilly T (2009) Changes in sleep, mood and subjective and objective responses to physical performance during the daytime in Ramadan. *Biological Rhythms Research* 40: 367-383.
36. Zebidi A, Rachel S, Dhidah M, Sadraoui M, Tabka Z, et al. (1990) The effect of Ramadan fasting on various blood and urinary parameters. *Tunisie Médecine* 68: 367-372.
37. Leiper JB, Molla AM, Molla AM (2003) Effects on health of fluid restriction during fasting in Ramadan. *European Journal of Clinical Nutrition* 57: 30-38.
38. Muazzam MG, Khaleque KA (1959) Effect of fasting in Ramadhan. *Journal of Tropical Medicine & Hygiene* 62: 292-294.
39. Mustafa KY, Mahmoud NA, Gumaa KA, Gader AM (1978) The effects of fasting in Ramadan. 2. Fluid and electrolyte balance. *British Journal of Nutrition* 40: 583-589.
40. Karli U, Guvenc A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *Journal of Sport Science & Medicine* 6: 490-497.
41. Ramadan J, Telahoun G, Al-Zaid NS, Barac-Nieto M (1999) Responses to exercise, fluid, and energy balances during Ramadan in sedentary and active males. *Nutrition* 15: 735-739.
42. Al-Hadramy MS (1997) Seasonal variations of urinary stone colic in Arabia. *Journal of the Pakistani Medical Association* 47: 281-284.
43. Auybak M, Turkoglu A, Sermeyt A, Denli O (1996) Effect of Ramadan fasting on platelet aggregation in healthy male subjects. *European Journal of Applied Physiology* 73: 552-556.
44. Born M, Elmfada. I, Scmal FW (1979) Effects of periodical fluid and food withdrawal. An inquiry conducted during the lenten month Ramadan on foreign workers. *Muenchen medische Wochenschrift* 121: 1569-1572.
45. Fedail SS, Murphy D, Salih SY, Bolton CH, Harvey RF (1982) Changes in certain blood constituents during Ramadan. *American Journal of Clinical Nutrition* 36: 350-353.
46. Schmall FW, Metzler B, Born M, Elmadfa I. Ramadan (1988) Ramadan health hazard education during the month of fasting. *Deutsches Ärzteblatt* 85: 842-844.
47. Siddiqui QA, Sabir S, Subhan MM (2005) The effect of Ramadan fasting on spirometry in healthy subjects. *Respirology* 10: 525-528.
48. Fall A, Sarr M, Mandengue SH, Badji L, Samb A, et al. (2007) Effets d'une restriction hydrique et alimentaire prolongée (Ramadan) sur la performance et les réponses cardiovasculaires au cours d'un exercice incrémental en milieu tropical chaud. *Science et Sports* 22: 50-53.
49. Stannard SR, Thompson MW (2008) The effect of participation in Ramadan on substrate selection during submaximal cycling exercise. *Journal of Science and Medicine in Sports* 11: 510-517.
50. Al-Hourani HM, Atoum MF (2007) Body composition, nutrient intake and physical activity patterns in young women during Ramadan. *Singapore Medical Journal* 48: 906-910.
51. Farshidfar G, Yousfi H, Vakili M, Noughabi A (2006) The effect of Ramadan fasting on hemoglobin, hematocrit and blood biochemical parameters. *Journal of Research in Health Science* 6: 21-27.

52. Furuncuoglu Y, Karaca E, Aras S, Yonem A (2007) Metabolic, biochemical and psychiatric alterations in healthy subjects during Ramadan. *Pakistan Journal of Nutrition* 6: 209-211.
53. Maughan RJ, Bartagi Z, Dvorak J, Zerguini Y (2008) Dietary intake and body composition of football players during the holy month of Ramadan. *Journal of Sports Sciences* 26: 29-38.
54. Maughan RJ, Al-Kharusi W, Binnett MS, Budgett R, Burke LM, et al. (2012) Fasting and sports: a summary statement of the IOC workshop. *British Journal of Sports Medicine* 46: 457.
55. Maughan RJ, Zerguini Y, Chalabi H, Dvorak J (2012) Achieving optimum sports performance during Ramadan: some practical recommendations. *Journal of Sports Sciences* 30: 109-117.

## Chapter 17

# Circadian Rhythm and Sleep Disturbances during Ramadan: Implications on Sports Performance

**Herrera Christopher Paul<sup>1</sup>, Berrichi Houria<sup>2</sup>, Chamari Karim<sup>1</sup> and Davenne Damien<sup>2,3\*</sup>**

<sup>1</sup>Research and Education Centre, Aspetar – Qatar Orthopaedic & Sports Medicine Hospital, Doha, Qatar

<sup>2</sup>Inserm, U1075 COMETE, Caen, 14032, France

<sup>3</sup>NormandieUniv, France

**\*Corresponding author:** Davenne Damien, UFR STAPS / UCBN, 2, bd du Marechal Juin, F-14032 CAEN cedex, France, Tel: +33 6 87 98 42 65; E-mail: [damien.davenne@unicaen.fr](mailto:damien.davenne@unicaen.fr)

## Abstract

The sleep-wake cycle is the most discernible human circadian rhythm. Regulation of the sleep-wake state is by the interplay of specialized neurons located in the suprachiasmatic nucleus of the lateral hypothalamus in the brainstem. Evidence shows that sleep is required to maintain health and psychophysiological functioning and therefore sleep is tightly linked to daytime functioning. Ramadan, which involves a one-month period of intermittent fasting during daylight hours, is associated with alterations sleep. Specifically, eating and drinking, as well as social and physical activities are delayed into the night which promotes a delay in bedtime, reductions in total sleep time and sleep quality during Ramadan. These changes, although not ubiquitous, have consequences on daytime functioning, including reduced alertness, impaired psychomotor performance, mood disturbances, and increased for injury (e.g. car crash). For athletes, these lifestyle changes combined with partial sleep loss can negatively influence sports performance. Evidence shows a link between partial sleep loss and increased reaction times, reduced alertness and limitations on components of both aerobic and anaerobic performance. Moreover, the timing of peak physical functioning may be delayed. Although, the observance of Ramadan carries religious significance, the ability for athletes (and general population alike), to schedule adequate time for sleep is important. In most cases, sleep loss during Ramadan is self-imposed, and therefore a modifiable risk-factor for daytime consequences. Thus, sleep education in combination with behavioral management of sleep problems can positively influence human health and performance.

## Circadian Rhythms

The cycling of day and night, caused by the earth's rotation around its axes, has far reaching effects on our physiology. Regular fluctuations of biological processes in function of time are a fundamental characteristic of life, from unicellular to complex organisms such as humans. Biological function that fluctuates with a period of about 24 hours is referred to as a circadian rhythm, and thus chronobiology is therefore the study of circadian rhythms.

There are a myriad of circadian rhythms, though core body temperature and the sleep-wake cycle are most clearly understood [1]. Both internal and external factors influence circadian rhythms. Studies have shown that when an individual is completely removed from time cues of the outside environment (exogenous components), many biological markers still fluctuate with a period of about 24 hours [2]. These results indicate that there are internal (endogenous) components that regulate circadian rhythms. Indeed, the Suprachiasmatic Nucleus (SCN) serves as the master clock to control all circadian rhythms, including temperature control, regulation of the pineal gland and melatonin secretion, food intake and the sleep-wake cycle [3,4]. The SCN is located within the hypothalamus and is comprised of approximately 20,000 specialized neurons. The electrical activity of the SCN is primarily driven and synchronized by light via the retino-hypothalamic axis which involves both afferent fibers from ganglion cells of the retina and efferent fibers projected to the nuclei of the periventricular zone to control various other rhythms. The circadian clock also has a molecular oscillator which consists of several genes, among them CLOCK, BMAL1, Period (Per 1, Per2, Per3), and Cryptochrome (Cry1 and Cry2), which interact to form a retro negative loop which last about 24 hours [5].

To perform optimally during physical activity, many physiological and psychomotor factors are involved. Each of these factors is likely to show specific time-of-day fluctuations and the optimal state to reach performances is expected when most of these factors are synchronized and on the positive phase of their sinusoids [6]. Core body temperature, a key circadian rhythm, has a minimum, or nadir, between 04:00 -06:00 AM and a maximum, or acrophase, between 04:00 – 06:00 PM. Muscular efficiency, joint stiffness, and flexibility, and pain thresholds are known to peak near the acrophase. Cardiovascular function, ventilator capacity, and recovery from aerobic exercise are at their lowest capacity between 02:00 and 05:00 AM. Within the body, metabolism and humoral regulation (insulin, glucagon, growth hormone, cortisol, prolactin, etc.) are also linked to different phases of the circadian rhythm [1]. For instance, higher serum levels of growth hormone occur around midnight, during the first period of deep sleep [7]. In addition, biological processes involved in the adaptation to physical stress, such as the amount of water and electrolyte in the body, plasma volume, fluid distribution, and perspiration threshold, show a wide range of acrophase [8]. As a result of these fluctuating biological rhythms, optimum physical efficiency is observed in the late afternoon or early evening. Indeed, it is at this time that many athletes reach their best sports performances [6]. In contrast, it is usually at the early morning, around 04:00 AM, that mental acuity and physical performances are worst.

Individual differences in circadian rhythms are well known [9]. Generally, there are two types of individual circadian preference, or chronotypes: morning- and evening- type [10]. Morning types tend to go to bed earlier in the evening and wake up earlier in the morning. Besides sleep; all other biological rhythms are also in advanced phase. This internal state dictates that morning types are more effective earlier during the daytime. In contrast, evening types usually fall asleep and wake up late, and their biological rhythms are in delayed phase. Optimal functioning occurs later in the afternoon among evening types. Finally, an individual may be considered neither morning- nor evening type, and thus has a more flexible circadian rhythm system.

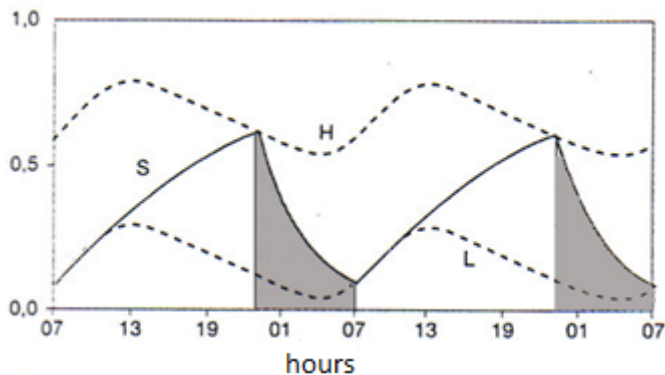
## **The sleep-wake rhythm**

The human sleep-wake rhythm is among one of the most extensively studied circadian rhythms [9,11,12]. Schematically, the propensity to sleep is regulated by two mechanisms: a circadian process (C) and a homeostatic process (S). Process C helps to organize the timing of sleep at night and is tightly controlled by the body's "master clock", located in the SCN [9]. The fundamental adaptive advantage of a temporal organization is that it allows for predictive, rather than reactive, homeostatic regulation of sleep. For example, several hours before the end of sleep, sympathetic autonomic tone and plasma cortisol levels rise



in anticipation of energetic demands for wakefulness. Process S is an accumulative process that originates at awaking and whose evolution depends on the duration and the quality of prior wakefulness. In other words, the homeostatic drive for sleep increases as wakefulness continues and decreases after sleep in proportion to sleep duration [13]. Research shows that the accumulation of adenosine at the neuronal synapse during wakefulness and as a result of active metabolism may mediate sleepiness [14-18]. The action of adenosine is mediated by cytokines such as Interleukins 1 and 6 (IL-1 and IL-6) and Tumor Necrosis Factor  $\alpha$  (TNF $\alpha$ ) which are sleep inducers [19].

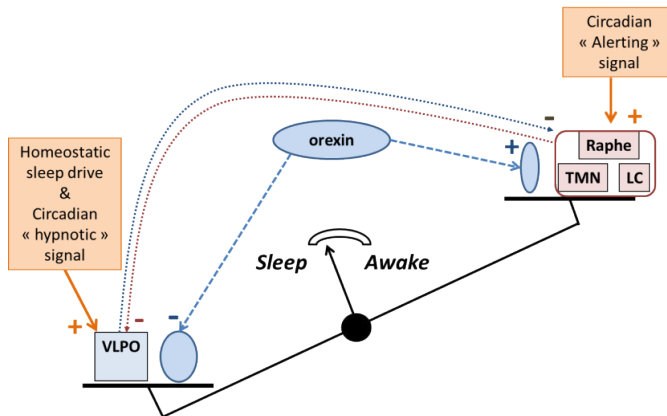
To illustrate the interplay between the circadian and homeostatic regulation of sleep, Borbely et al., [13] established the “two-opponent process” model to which [20] added a high threshold for sleep and awakening (Figure 1). This model predicts both the quantity and the quality of sleep. During wakefulness the strength of process S, the homeostatic drive for sleep, increases. As Process C fluctuates in time, episodes of sleep shown by grey shading, occurs when the circadian regulation decreases. At that time the difference between the two processes increases and the sleep drive also increases. In other terms, this difference reflects the strength of the sleep need.



**Figure 1:** Two-opponent process model of sleep regulation [20].

Strength of circadian drive H and L. H: high circadian threshold of the falling asleep; L: low circadian threshold of the awakening; S: strength of homeostatic drive. The grey zones indicate the periods of sleep.

Notably, sleep is a periodic and immediately reversible suspension of wakefulness. Changes between wakefulness and sleep occur in the hypothalamus by means of the “flip-flop switch” [21]. The change from wakefulness to sleep (or sleep to wakefulness) depends on the activity and interplay of surrounding neurons (Figure 2). The neurons of the Ventrolateral Preoptic Nucleus (VLPO) are sleep promoters and their inhibition causes insomnia and sleep fragmentation. Alternatively, activity within the Tuberomammillary Nuclei (TMN), the Locus Coeruleus (LC) and the dorsal median raphe nuclei (raphe) promote arousal and wakefulness. At any given moment, brain wave activity within a group of neurons increases the “pressure” of the system, and the balance quickly switches from arousal to sleep or vice-versa. In addition, the orexin neurons of the lateral hypothalamus exert a constant pressure which stabilizes the system and prevents too many switches, thereby reinforces the circadian and homeostatic modulation exerted on the two sides of the balance [21]. Similar mechanisms have been proposed to explain the rapid switching from SWS to REM sleep [22].



**Figure 2:** The 'flip-flop' sleep-wake switch mechanism. Neurons of The Ventrolateral Preoptic Nucleus (VLPO) are activated under the pressure of both homeostatic and circadian signals.

The VLPO neurons inhibit the one of the tubero-mamillary nucleus, the Locus Coeruleus (LC) and the raphe which is part of the arousal system. The balance switches on the side of awake systems when the circadian “alerting” signal is reinforced. The change occurs quickly because of the inhibitory action on the VLPO neurons. The lateral hypothalamic orexin neurons likely play a stabilizing role for the switch [21].

## Physiological Characteristics of Wakefulness and Sleep

Sleep is characterized by an active physiological process that is tightly linked to daytime function. Electroencephalography (EEG) technology has provided researchers with a method to measure the electrical activity of the brain during both wakefulness and sleep [23,24]. In general, there are four physiological EEG rhythms (alpha, beta, theta, and delta), defined by their frequency (in cycles per second, Hz), amplitude (microvolts) and morphological shape that are used to distinguish between wakefulness and sleep.

Wakefulness is characterized by rapid, beta (13-30 Hz) and alpha (8-13 Hz) EEG activity associated with the persistence of postural tone and responses to external stimuli. Compared to wakefulness, there is a progressive slowing of the EEG activity during the four distinct stages of sleep; three stages of Non-Rapid Eye Movement (NREM) sleep and one stage of Rapid Eye Movement (REM) sleep [24]. NREM Stage 1 (~5% of total sleep time, TST) consists predominately of theta waves (3-8 Hz) and a reduction in muscle activity. NREM Stage 2 (~50% of TST) is characterized by the presence of the K-complex, sleeps spindles, or both, and includes background theta activity. NREM Stage 3 (~20% of TST), is considered “deep sleep” and is characterized by slow waves or delta activity (0.5-2 Hz), very low muscle tone and the absence of eye movements. In NREM stage 3, the threshold for arousal by auditory stimuli is lowest, whereas in other stages of NREM sleep. Finally, REM sleep (~20% of TST) is characterized by low voltage mixed frequency EEG patterns, rapid eye movements and complete muscle atonia. The combination of a period of NREM sleep followed by a period of REM sleep is defined as a sleep cycle. In adults, each night of sleep consists of 4 to 6 sleep cycles of about 90 minutes each [25].

Sleep is required to maintain health and achieve optimal psychophysiological performance epidemiological and experimental research suggests that between 7-8 hours of sleep on average is required for optimal health and performance in adults [26-28]. Though, the length and the number of sleep cycles are genetically determined and therefore explain why some people are “long sleepers”, who need to sleep 9 hours or more, and others are “short sleepers” who need to sleep less than 7 hours or less per 24 h period. In addition, the sleep

need of athletes remains poorly understood, though it is a general consensus that athletes require the same or more sleep than sedentary counterparts [29-31].

## Ramadan as Circadian Modulator

During the month of Ramadan, Muslims abstain from eating and drinking from dawn to sunset. For approximately one month, eating behaviors change from three balanced, daily meals to two nocturnal meals. This eating pattern plus more activity at night modifies the metabolic profile of fasting subjects, and as a consequence, impacts on core body temperature and sleep. In addition, when Ramadan occurs in the summer months, the fasting period is much longer (than winter) and therefore more lifestyle disturbances are presented. Indeed, summer daylight fasting could vary from 15 h a day in Middle East to 18-20 h for Northern European countries. Thus, the physiological and metabolic disturbances related to Ramadan are greater in countries with higher latitude.

## Circadian Rhythm and Daytime Disturbances during Ramadan

Several studies have shown that chronobiology is affected by Ramadan intermittent fasting [32,33]. The amplitude of body temperature and cortisol secretion is decreased and a phase delay of 2 hours of their acrophase has been observed during Ramadan [34,35]. Rocky et al., [36] also showed that the amplitude of the melatonin circadian rhythm is decreased during Ramadan. Notably, melatonin is a primary neurohormone involved in the regulation of the sleep-wake cycle mostly indirectly via changes in core body temperature [37]. During Ramadan, researchers have demonstrated an increase in body temperature during the night which was attributed to sleep disturbances [38,39]. Interestingly, increased locomotors activity during fasting can modulate the circadian release of orexin and therefore may change the flip-flop mechanism of sleep, eliciting sleepiness [40], which can have serious health and safety consequences during the daytime.

Research shows that mental alertness declines during Ramadan. In healthy subjects, Roky et al., [32] demonstrated that subjective alertness decreased at 9:00 and 16:00 h (fasting state) and increased at 23:00 h (feeding state). In another study, daytime alertness progressively decreased during the four weeks of Ramadan [41]. Notably, most Muslim countries reduce the administrative working hours and keep professional duties to a minimum; however this still forces fasting workers to be awake and alert during part of the daytime. This requirement for alertness during the daytime combined with reduced time for sleep at night (discussed in more detail below), must therefore be taken into consideration of both daytime performance and general health and safety concerns during Ramadan.

Indeed, daytime sleepiness increases during Ramadan among those who fast. Using the iterative EEG-based Multiple Sleep Latency Test (MSLT), daytime sleepiness increased between 14:00 and 16:00 h during Ramadan in fasting subjects [42]. Daytime sleepiness has substantial impact on sleep behaviour during the daytime. For example, the prevalence of napping was nearly 3 times greater in healthy subjects during Ramadan, though normalized to normal behaviour 15 days after Ramadan [43].

Daytime sleepiness, or better yet drowsiness, can have serious health consequences during Ramadan. Drowsiness is a significant risk factor for traffic accidents. A study conducted in the United Arab Emirates showed that emergency admissions due to accidents increased during Ramadan [44]. Similar results were obtained in Saudi Arabia [45] and even in London, UK [46]. Nevertheless, contradictory results from Jordan and Morocco demonstrate a reduced rate of driving accidents [47,48]. Given the differences in populations and geographic regions studied, it is likely that cultural difference (i.e., whether or not both sexes drive, whether the accident rate varied according to ethnicity) can account for some of the variance between results. Moreover, assessing the status of vigilance/drowsiness from hospital emergency admissions or road accidents statistics provides some trends but is not

ideal. Prospective studies about vigilance and cognitive function should be conducted in fasters to provide more accurate results.

## Sleep Disturbances during Ramadan

It is clear that Ramadan greatly influences the sleep-wake pattern. Research shows that Ramadan leads to reduced sleep quality and recurrent sleep loss, but not total sleep deprivation *per se* [33]. In addition, the negative impact of recurrent sleep deprivation is larger as the number of restricted-sleep nights' increase.

Early studies on sleep during Ramadan were based on the analysis of sleep diaries and have demonstrated major changes in sleep quantity and quality. For example, a general delay in sleep time and a substantial reduction in sleep duration have been reported [50,51]. Indeed, it is a usual fact that fasting Muslims delay their bed time to stay awake and have more opportunities for eating, drinking, and socializing during dark hours. Moreover, night time is usually accompanied with religious prayers and events which sometimes drastically delay bed time.

More objective data further demonstrates substantial sleep disturbances among fasting subjects during Ramadan. Rocky et al., [32] monitored the sleep of eight healthy Moroccan volunteers in a laboratory using the gold-standard procedure of polysomnography and demonstrated that Ramadan affects the distribution of sleep stages, the magnitude of daytime sleepiness, and core body temperature. In particular, sleep latency increased from 19.2 minutes before Ramadan to 58.1 min on average during Ramadan. Total sleep time decreased from 422 min to 383 min, before and during Ramadan respectively [36]. The quality of sleep was also decreased as evidence by changes in sleep architecture. The proportion of NREM stage 2 sleep was increased (50.2% vs. 55% before and during Ramadan, respectively) while REM sleep slightly decreased (22.7% vs. 19.4% before and during Ramadan, respectively). In addition, participants self-reported a general 1 h delay in bed time. These changes in sleep pattern were associated with an increased nocturnal body temperature, in part due to the later meal times as fasters keep on eating and snacking all along the dark hours [36].

A subsequent study involved Saudi students who were monitored using ambulatory sleep recordings. The results showed in fasting subjects that, on the one hand there was a shift from morning chronotype to evening chronotype, on the other hand, there was a significant reduction in sleep latency and REM sleep during the third week of Ramadan. No significant differences in sleep architecture were reported. Recently, [41] investigated the sleep of 20 healthy subjects using sleep diaries for 6 weeks before, during, and after Ramadan. The results showed that sleep latency increased, the total sleep time during the night was reduced, and the number and duration of intra-sleep awakenings were increased. Moreover, the diurnal sleep time was significantly increased. In other words, the fasting subjects adopted a polyphasic sleep profile and distributed their sleep over the nyctemeron, or 24 h period, which included long periods of sleep during the day and at night. There was also a clear "weekend" effect during Ramadan with a significant increase of sleep time during these days by comparison with the other days of the week. Interestingly, the sleep patterns of non-fasting adults living in Muslim majority countries are similarly disturbed during Ramadan, which suggest that other factors than just fasting play an important role in modifying sleep behavior during Ramadan [52]. These factors are likely related to the social and spiritual events and activities held at night time, as well as the change in work and retail hours.

Finally, in contrast to these findings, researchers also reported that total nocturnal sleep time did not change during Ramadan, and that even the 24 h total sleep opportunity (sleep + nap time) was longer during Ramadan compared to pre-Ramadan baseline measures [53]. Thus, it is apparent that differences in cultures, geographic locations (e.g. sun rise

and sunset times), and employment status, likely play a role in moderating the influence of Ramadan on sleep.

### Sleep in athletes during Ramadan

Given the high physical and mental demands placed on athletes, researchers have studied the association between sleep loss and aspects of sports performance [54]. As reported in the general population, sleep loss in athletes during Ramadan more closely resembles recurrent sleep loss in the form of partial sleep deprivation and not total sleep loss *per se*.

Sleep in athletes during Ramadan has been investigated using subjective questionnaires and not objective measurement. The majority of reported findings demonstrated a reduced quantity of sleep (Table 1) [29] and a delay in bedtime. For example, sleep duration decreased during Ramadan by ~60 min in football players undertaking their usual training and match schedule [55], by ~88 min in middle-distance athletes [56], and by ~30 min in another group of football players [57]. In accordance with the latter, Moroccan football players' sleep duration decreased by half an hour with sleep time being delayed by ~3 h, inducing a significant decrease of subjective sleep quality [29,58]. In addition, Herrera [59] showed in another group of football players from Qatar that the average total pre-Ramadan sleep time was quite low (6.5 hours) and that it was further and significantly reduced at the end of Ramadan (5.5 hours). These findings suggest there may be cultural differences in the amount of habitual sleep, or in this case a large sleep debt, and therefore potential for sleep improvement to optimize recovery and performance.

Study	Sample	Total sleep time before Ramadan	Total sleep time during Ramadan	Average change in total sleep time & quality
Zerguini et al., 2008 [57]	55 football players	8.4 h	8.2 h	-30 min; reduced sleep quality
Leiper et al., 2008 [55]	54 football players	(not available)	(not available)	-60 min; no change in sleep quality
Meckel et al., 2008 [60]	19 football players	8.6 h	8.6 h	No change; no change in sleep quality
Chennaoui et al., 2009 [56]	8 runners	7.3 h	5.8	-88 min; no change in sleep quality
Karli et al., 2007 [61]	10 power athletes	8.3 h	9.2h	No significant changes
Herrera 2012 [59]	9 football players	6.5 h	5.5 h	-60 min; no change in sleep quality

**Table 1:** Influence of Ramadan on subjective sleep quantity and quality in athletes [29].

Nevertheless, other studies reported no significant change in sleep duration among adolescent football players [60] or power athletes [61]. Such discrepancy in the literature is likely due to differences in study populations (adult vs. youth athletes), different study questionnaires, or to potentially unidentified cultural differences; for example, some but not all people in a Muslim country will completely invert the day and night.

The relationship between the timing of training and competition sessions with performance during Ramadan has also been investigated. Both Roky et al., [29] and Chamari et al., [62], reported that football players did not go to bed before 3:00 AM due to late evening training sessions and sohoor consumption. Chamari et al., [62] further demonstrated an increased rate of musculo-tendinous injuries in the players. Interestingly, the increased rate of injuries was observed in both fasting and non-fasting players, although there were significantly more injuries in the fasting players. A separate study found no change in injury rates among Muslim football players during Ramadan; however non-Muslims in fact had an increased rate of injuries during Ramadan [63]. Taken together, we can speculate that the changes in sleep pattern were therefore likely due to the accompanying “style” or cultural observance of Ramadan which are known to be somewhat variable between Muslim countries.

Finally, research suggests that the changes in core body temperature directly influence the changes in sleep during Ramadan. Given that sleep onset is triggered by a rapid decrease in core temperature, with the maximum rate of its' decline being observed 60 min before

sleep onset [64], it has been suggested that the delayed bed time and related decreased total sleep time observed during Ramadan could be due to the delay in the decline in core body temperature [42]. During Ramadan, meals are only consumed at night and most training and competition sessions occur later in the night compared to before Ramadan. This delay of activity likely delays the thermogenic effect of physical activity on body temperature and therefore interrupts sleep [42].

## **General effects of sleep loss on physical performance**

In the general society, individuals are increasingly experiencing partial sleep deprivation due to self-imposed late bedtimes (e.g. due to social interactions or sports competition), early morning awakenings, or due to frequent travel (e.g. jet-lag). Total sleep deprivation on the other hand, is not a common societal issue besides certain population segments (i.e., military, shift-workers, ultra endurance sport events). Nonetheless, research into the effects of both partial and total sleep deprivation has provided key insights regarding that role that sleep has in health and performance.

In an early study by Reilly and Piercy [65], researchers investigated the effects of restricting sleep to only 3 hours per night over 3 consecutive days. This resulted in a decrease in maximal bench press, leg press, and dead lifts, whereas bicep curls did not show any alteration compared to a normal sleep condition. More recently, researchers have studied the effects of end-of-night partial sleep deprivation (i.e. waking up at 3:00 instead of 6:00 AM) on physical performance in the afternoon. Among the 21 judokas, acute, partial sleep deprivation negatively affected peak and mean power output measured during the 30 sec all-out cycle Wingate test, whereas hand grip strength remained unaltered compared to normal sleeping conditions [66]. In the same study, ratings of perceived exertion at the end of the Wingate test were marginally increased after the end of night partial sleep deprived night. The authors therefore suggested that the reduction in muscle power measured during the Wingate tests after sleep deprivation could be due to psychological factors such as motivation. Indeed, since the Wingate test requires a strong level of motivation [67], a potentially lower level of motivation could in part be the cause of the lower Wingate performance after partial sleep deprivation. The authors also speculated that the subjects could have adopted a working pacing strategy in order to distribute effort throughout the 30 sec time span, evidencing a relative “mental fatigue” that could have led to lower muscular power performance. Indeed, Jarraya et al., [68] demonstrated that partial sleep deprivation impairs reaction time and attention in handball goalkeepers.

In another study by the same group [69] measured physical and mental performance of 12 judokas (average, 19 years) after partial sleep deprivation in a more complex protocol. This study involved two conditions of partial sleep deprivation: beginning of the night and end of the night sleep deprivation were compared to a control, normal sleep condition. The results showed that 4 h of sleep deprivation, either at the beginning or at the end of the night, blunted the afternoon (16:00 h) increase of muscular power compared to morning session (9:00 h) that was observed after the normal sleep condition. Notably, the end-of-night sleep loss resulted in a more detrimental reduction in afternoon performance than the beginning of night sleep deprivation. Post-competition RPE was also significantly higher in the afternoon (16:00 h) after the end-of-night sleep deprivation, confirming that early rising is detrimental to the perceived effort, probably contributing to the decreased muscular power measured during the Wingate test [70].

Another more recent study [71] showed that 4 h of sleep deprivation either at the beginning or at the end of the night did not alter the intermittent endurance performance of Taekwondo athletes. Athletes were tested in randomized order after a normal sleep condition (sleeping between 22:30 and 23:30 until 6:00 AM), a beginning of night sleep deprivation condition (e.g. 4 h later bedtime but same wake time 6:00 AM), and an end of night sleep deprivation condition (same bedtime but 3:00 AM wake time). Performance on the  $Y_0Y_0$  intermittent

recovery test level 1, performed between 7:00 and 8:00 AM was not altered; neither were HR, post exercise Lactate and RPE, by either condition. The authors highlighted that the  $Y_oY_o$  test is composed of repeated short 40 m shuttles (2x20 m) with 10 sec of recovery in-between, thus solicits the anaerobic energy pathway in a relatively high proportion, and therefore they concluded that anaerobic effort performed in the morning is not altered by the previous night partial sleep deprivation as shown by Souissi et al., [69].

Several methodological factors could explain some discrepancies between studies. Not only can the level of expertise and sport speciality of athletes impact on performance tests [54], but also an individual's chronotype type can affect performance [72]. Usually chronobiological studies assess the morningness – eveningness type of the subjects and exclude the ones who are not comfortable with the study design (i.e., excluding evening type subjects for early morning testing sessions). Anecdotally, it is known that evening type subjects are reluctant to perform in the morning, and vice versa for morning type athletes. This has to be considered when interpreting chronobiological studies that test athletes' performance. Moreover, differences in study results could be due to the fact that some but not all subjects are routinely practicing morning and/or evening training sessions, which may reduce the time-of-day impact on muscle strength and power. This “morning trainability” may positively impact on the early day testing sessions allowing them to achieve “normal” performance measures compared to reference normal-sleep night conditions [73,74]. Finally, fitness level might influence the results since the performance of untrained subjects is more affected by time-of-day factors than for fit athletes [75].

In contrast to partial sleep loss, the negative impact of total sleep deprivation is quite marked after 24 hours of continued wakefulness. For example, Bulbulian et al., [76] reported that periods exceeding 24 h of continuous awakening impacted negatively on peak torques of the knee extensors and flexors in trained men assessed at 30 h of sleep deprivation. This study also showed that a longer period of continuous awakening, i.e., 64 h, had a significant negative impact on vertical jump height and isokinetic knee extension strength, but measures such as isometric strength and 40 m sprint time were unaltered, as was shown earlier [77]. Conversely, other researchers did not find an effect of sleep deprivation on short-term power (e.g. anaerobic) exercises. Indeed, Blumert et al., [78] demonstrated that college student athletes' weight lifting performance subsequent to 24 hours of sleep deprivation was not different to a “normal sleep” condition. Thus, the effects of sleep deprivation on muscle function are modest until at least 24 hours of wakefulness.

In relation to endurance type performance (e.g. aerobic), sleep deprivation significantly and negatively impacted running distance over half an hour [79]. Skein et al., [80] also showed that 30 h of sleep deprivation reduced endurance and intermittent sprint performances. In this study, each session included a 30 min graded exercise run and a protocol comprising 50 min intermittent-sprint exercise (15 m maximal sprint every minute). The authors concluded that sleep loss and the associated reductions in muscle glycogen and perceptual stress, reduced sprint performance and slowed pacing strategies during intermittent-sprint exercise for the studied male team-sport athletes.

## Conclusion

Chronobiology refers to the study of biological functions which vary according to the cycle of day and night. Core body temperature and the sleep-wake cycle are closely linked to daytime mental and physical performance. Ramadan intermittent fasting and increased nocturnal activity induces several chronobiological changes which disturbs sleep and affects daytime performance. In particular, sleep loss during Ramadan negatively impacts on health, safety and also post-exercise physical recovery, which then can reduce physical and mental performance. Given that sleep loss is often self-imposed, and therefore a modifiable factor, monitoring for sleep disturbances and provision of sleep health education can positively influence daily life and optimize daytime performance.



## References

1. Touitou Y, E Haus (1992) Biological rhythms in clinical laboratory and medicine. New York: Springer Verlag.
2. Aschoff J (1979) Circadian rhythms: influences of internal and external factors on the period measured in constant conditions. *Z Tierpsychol* 49: 225-249.
3. Moore RY (1983) Organization and function of a central nervous system circadian oscillator: the suprachiasmatic hypothalamic nucleus. *Fed Proc* 42: 2783-2789.
4. Weaver DR (1998) The suprachiasmatic nucleus: a 25-year retrospective. *J Biol Rhythms* 13: 100-112.
5. King DP, Takahashi JS (2000) Molecular genetics of circadian rhythms in mammals. *Annu Rev Neurosci* 23: 713-742.
6. Atkinson G, Reilly T (1996) Circadian variation in sports performance. *Sports Med* 21: 292-312.
7. Brandenberger G, Weibel L (2004) The 24-h growth hormone rhythm in men: sleep and circadian influences questioned. *J Sleep Res* 13: 251-255.
8. Wisser H, Breuer H (1981) Circadian changes of clinical chemical and endocrinological parameters. *J Clin Chem Clin Biochem* 19: 323-337.
9. Moore-Ede MC (1986) Physiology of the circadian timing system: predictive versus reactive homeostasis. *Am J Physiol* 250: 737-752.
10. Horne JA, Ostberg O (1977) Individual differences in human circadian rhythms. *Biol Psychol* 5: 179-190.
11. Benoit O, Foret J (1988) Circadian regulation of the sleep-wake cycle. *Neurophysiol Clin* 18: 403-431.
12. Billiard M, Carlander B, Besset A (1996) Circadian rhythm in normal and pathological sleep. *Pathol Biol (Paris)* 44: 509-517.
13. Borbély AA (1982) A two process model of sleep regulation. *Hum Neurobiol* 1: 195-204.
14. Porkka-Heiskanen T, Strecker RE, Thakkar M, Bjorkum AA, Greene RW, et al. (1997) Adenosine: a mediator of the sleep-inducing effects of prolonged wakefulness. *Science* 276: 1265-1268.
15. McCarley RW (2007) Neurobiology of REM and NREM sleep. *Sleep Med.* 8:302-330.
16. Krueger JM (2008) The role of cytokines in sleep regulation. *Curr Pharm Des* 14: 3408-3416.
17. Clinton JM, Davis CJ, Zielinski MR, Jewett KA, Krueger JM (2011) Biochemical regulation of sleep and sleep biomarkers. *J Clin Sleep Med* 7: 38-42.
18. Jewett KA, Krueger JM (2012) Humoral sleep regulation; interleukin-1 and tumor necrosis factor. *Vitam Horm* 89: 241-257.
19. Krueger JM, Fang J, Hansen MK, Zhang J, Obál F Jr (1998) Humoral Regulation of Sleep. *News Physiol Sci* 13: 189-194.
20. Daan S, Beersma DG, Borbély AA (1984) Timing of human sleep: recovery process gated by a circadian pacemaker. *Am J Physiol* 246: 161-183.
21. Saper CB, Chou TC, Scammell TE (2001) The sleep switch: hypothalamic control of sleep and wakefulness. *Trends Neurosci* 24: 726-731.
22. Saper CB, Fuller PM, Pedersen NP, Lu J, Scammell TE (2010) Sleep state switching. *Neuron* 68: 1023-1042.
23. Dement W, Kleitman N (1957) Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. *Electroencephalogr Clin Neurophysiol* 9: 673-690.
24. Iber C, Ancoli-Israel S, Chesson A, Quaf SF. (2007). The AASM manual for the scoring of sleep and associated events: rules, terminology, and technical specification, (1<sup>st</sup> edition). American Academy of Sleep Medicine, Westchester, Illinois, USA
25. Roth T (2004) Characteristics and determinants of normal sleep. *J Clin Psychiatry* 65: 8-11.
26. McEwen BS (2006) Sleep deprivation as a neurobiologic and physiologic stressor: Allostasis and allostatic load. *Metabolism* 55: 20-23.



27. Irwin M (2002) Effects of sleep and sleep loss on immunity and cytokines. *Brain Behav Immun* 16: 503-512.
28. Knutson KL, Van Cauter E (2008) Associations between sleep loss and increased risk of obesity and diabetes. *Ann N Y Acad Sci* 1129: 287-304.
29. Roky R, Herrera CP, Ahmed Q (2012) Sleep in athletes and the effects of Ramadan. *J Sports Sci* 30: 75-84.
30. Samuels C (2008) Sleep, recovery, and performance: the new frontier in high-performance athletics. *Neurol Clin* 26: 169-180.
31. Davenne, D. (2009) Sleep of athletes-problems and possible solutions. *Biol Rhythm Res* 1: 45-52.
32. Roky R, Iraki L, HajKhlifa R, Lakhdar Ghazal N, Hakkou F (2000) Daytime alertness, mood, psychomotor performances, and oral temperature during Ramadan intermittent fasting. *Ann Nutr Metab* 44: 101-107.
33. Reilly T, Waterhouse J (2007) Altered sleep-wake cycles and food intake: the Ramadan model. *Physiol Behav* 90: 219-228.
34. Roky R, Houti I, Moussamih S, Qotbi S, Aadil N (2004) Physiological and chronobiological changes during Ramadan intermittent fasting. *Ann Nutr Metab* 48: 296-303.
35. Ben Salem L, Bchir S, Bouguerra R, Ben Slama C (2003) Cortisol rhythm during the month of Ramadan. *East Mediterr Health J* 9: 1093-1098.
36. Roky R, Chapotot F, Hakkou F, Benchekroun MT, Buguet A (2001) Sleep during Ramadan intermittent fasting. *J Sleep Res* 10: 319-327.
37. Dawson D, Encel N (1993) Melatonin and sleep in humans. *J Pineal Res* 15: 1-12.
38. Kadri N, Tilane A, El Batal M, Taltit Y, Tahiri SM, et al. (2000) Irritability during the month of Ramadan. *Psychosom Med* 62: 280-285.
39. Bogdan A, Bouchareb B, Touitou Y (2001) Ramadan fasting alters endocrine and neuroendocrine circadian patterns. Meal-time as a synchronizer in humans? *Life Sci* 68: 1607-1615.
40. Wu MF, John J, Maidment N, Lam HA, Siegel JM. (2002) Hypocretin release in normal and narcoleptic dogs after food and sleep deprivation, eating, and movement. *Am J Physiol Regul Integr Comp Physiol*, 283: 1079-1086.
41. Berrichi H, Davenne D (2013) rythme veille-sommeil au cours du Ramadan. *MédecineSommeil* 82-83.
42. Roky R, Chapotot F, Benchekroun MT, Benaji B, Hakkou F, et al. (2003) Daytime sleepiness during Ramadan intermittent fasting: polysomnographic and quantitative waking EEG study. *J Sleep Res* 12: 95-101.
43. Margolis SA, Reed RL (2004) Effect of religious practices of Ramadan on sleep and perceived sleepiness of medical students. *Teach Learn Med* 16: 145-149.
44. Bener A, Absood GH, Achan NV, Sankaran-Kutty M (1992) Road traffic injuries in Al-Ain City, United Arab Emirates. *J R Soc Health* 112: 273-276.
45. Shanks NJ, Ansari M, al-Kalai D (1994) Road traffic accidents in Saudi Arabia. *Public Health* 108: 27-34.
46. Langford EJ, Ishaque MA, Fothergill J, Touquet R (1994) The effect of the fast of Ramadan on accident and emergency attendances. *J R Soc Med* 87: 517-518.
47. Khammash MR, Al-Shouha TF (2006) Do road traffic accidents increase during the fasting month of Ramadan. *Neurosciences (Riyadh)* 11: 21-23.
48. Herrag M, Lahmiti S, Yazidi AA (2010) Ramadan: a different side of the emergencies? *Afr Health Sci* 10: 215-216.
49. Reilly T, Piercy M (1994) The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics* 37: 107-115.
50. Laraqui CH., et al. (2001). "The effects of fasting and of the quality of sleep on work during the month of Ramadan." *Archives des Maladies Professionnelles de Medecine du Travail* 62: 115-120.
51. Taoudi Benchekroun M, Roky R, Toufiq J, Benaji B, Hakkou F (1999) Epidemiological study: chronotype and daytime sleepiness before and during Ramadan. *Therapie* 54: 567-572.
52. BaHamam A (2005) Assessment of sleep patterns, daytime sleepiness, and chronotype during Ramadan in fasting and nonfasting individuals. *Saudi Med J* 26: 616-622.

53. BaHammam A, Alrajeh M, Albabtain M, Bahammam S, Sharif M (2010) Circadian pattern of sleep, energy expenditure, and body temperature of young healthy men during the intermittent fasting of Ramadan. *Appetite* 54: 426-429.
54. Reilly T, Edwards B (2007) Altered sleep-wake cycles and physical performance in athletes. *Physiol Behav* 90: 274-284.
55. Leiper JB, Junge A, Maughan RJ, Zerguini Y, Dvorak J (2008) Alteration of subjective feelings in football players undertaking their usual training and match schedule during the Ramadan fast. *J Sports Sci* 26 Suppl 3: 55-69.
56. Chennaoui M, Desgorces F, Drogou C, Boudjema B, Tomaszewski, A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Appl Physiol Nutr Metab* 34: 587-594.
57. Zerguini Y, Dvorak J, Maughan RJ, Leiper JB, Bartagi Z, et al. (2008) Influence of Ramadan fasting on physiological and performance variables in football players: summary of the F-MARC 2006 Ramadan fasting study. *J Sports Sci* 26: 3-6.
58. Herrera CP, C Lippert, B Sas (2011) Influence of Ramadan on Subjective Sleep Quality and Daytime Sleepiness. *Sleep* 34: 260-261.
59. Herrera CP (2012) Total sleep time in Muslim football players is reduced during Ramadan: a pilot study on the standardized assessment of subjective sleep-wake patterns in athletes. *J Sports Sci* 30: 85-91.
60. Meckel Y, Ismaeel A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *Eur J Appl Physiol* 102: 651-657.
61. Karli U, Guvenc A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *Journal of Sports Science and Medicine*, 6: 490-497.
62. Chamari K, Haddad M, Wong del P, Dellal A, Chaouachi A (2012) Injury rates in professional soccer players during Ramadan. *J Sports Sci* 30: 93-102.
63. Eirale C, Tol JL, Smiley F, Farooq A and Chalabi H. (2013) Does Ramadan affect the risk of injury in professional football? *Clin J Sports medicine* 23: 261-266.
64. Murphy PJ, Campbell SS (1997) Nighttime drop in body temperature: a physiological trigger for sleep onset? *Sleep* 20: 505-511.
65. Reilly T, Piercy M (1994) The effect of partial sleep deprivation on weight-lifting performance. *Ergonomics* 37: 107-115.
66. HajSalem M, Chtourou H, Aloui A, Hammouda O, Souissi N (2013) Effects of partial sleep deprivation at the end of the night on anaerobic performances in judokas. *Biological Rhythm Research*, in press.
67. Chtourou H, Chaouachi A, Hammouda O, Chamari K, Souissi N (2012) Listening to music affects diurnal variation in muscle power output. *Int J Sports Med* 33: 43-47.
68. Jarraya M, Jarraya S, Chtourou H, Souissi N, Chamari K (2013) The effect of partial sleep deprivation on the reaction time and the attentional capacities of the handball goalkeeper. *Biological Rhythm Research* 44: 503-510.
69. Souissi N, Chtourou H, Aloui A, Hammouda O, Dogui M, et al. (2013) Effects of time-of-day and partial sleep deprivation on short-term maximal performances of judo competitors. *J Strength Cond Res* 27: 2473-2480.
70. Reilly T, Deykin T (1983) Effects of partial sleep loss on subjective states, psychomotor and physical performance tests. *J Hum Mov Stud* 9: 157-170.
71. Mejri MA, Hammouda O, Zouaoui K, Chaouachi A, Chamari K et al. (2013) Effect of two types of partial sleep deprivation on Taekwondo players' performance during intermittent exercise. *Biological Rhythm Research*, in press
72. Souissi N, Souissi M, Souissi H, Chamari K, Tabka Z, et al. (2008) Effect of time of day and partial sleep deprivation on short-term, high-power output. *Chronobiol Int* 25: 1062-1076.
73. Chtourou H, Chaouachi A, Driss T, Dogui M, Behm DG, et al. (2012) The effect of training at the same time of day and tapering period on the diurnal variation of short exercise performances. *J Strength Cond Res* 26: 697-708.

74. Souissi H, Chtourou H, Chaouachi A, Dogui M, Chamari K, et al. (2012) The effect of training at a specific time-of-day on the diurnal variations of short-term exercise performances in 10- to 11-year-old boys. *Pediatr Exerc Sci* 24: 84-99.
75. Atkinson G, Coldwells A, Reilly T, Waterhouse J (1993) A comparison of circadian rhythms in work performance between physically active and inactive subjects. *Ergonomics* 36: 273-281.
76. Bulbulian R, Heaney JH, Leake CN, Sucec AA, Sjöholm NT (1996) The effect of sleep deprivation and exercise load on isokinetic leg strength and endurance. *Eur J Appl Physiol Occup Physiol* 73: 273-277.
77. Takeuchi L, Davis GM, Plyley M, Goode R, Shephard RJ (1985) Sleep deprivation, chronic exercise and muscular performance. *Ergonomics* 28: 591-601.
78. Blumert PA, Crum AJ, Ernsting M, Volek JS, Hollander DB, et al. (2007) The acute effects of twenty-four hours of sleep loss on the performance of national-caliber male collegiate weightlifters. *J Strength Cond Res* 21: 1146-1154.
79. Oliver SJ, Costa RJ, Laing SJ, Bilzon JL, Walsh NP (2009) One night of sleep deprivation decreases treadmill endurance performance. *Eur J Appl Physiol* 107: 155-161.
80. Skein M, Duffield R, Edge J, Short MJ, Mündel T (2011) Intermittent-sprint performance and muscle glycogen after 30 h of sleep deprivation. *Med Sci Sports Exerc* 43: 1301-1311.

## Chapter 18

# Ramadan Fasting and Sport Performance

**Asma Aloui<sup>1,2\*</sup>, Hamdi Chtourou<sup>1,3</sup>, Nizar Souissi<sup>1,4</sup> and Karim Chamari<sup>1,5</sup>**

<sup>1</sup>Research Laboratory “Sport Performance Optimization” National Center of Medicine and Sciences in Sport (CNMSS), Tunis, Tunisia

<sup>2</sup>High Institute of Sport and Physical Education of Gafsa, University of Gafsa, Gafsa, Tunisia

<sup>3</sup>High Institute of Sport and Physical Education of Sfax, University of Sfax, Sfax, Tunisia

<sup>4</sup>High Institute of Sport and Physical Education of Ksar-Said, University of Manouba, Manouba, Tunisia

<sup>5</sup>Athlete Health and Performance Research Center, ASPETAR, Qatar Orthopedic and Sports Medicine Hospital, Qatar

**\*Corresponding author:** Asma Aloui, Research Laboratory “Sport Performance Optimization”, National Center of Medicine and Sciences in Sport (CNMSS), Bp 263, Ave Med Ali Akid, 1004 El Menzah, Tunisia, Tel: + 216 27 87 75 08; E-mail: [aloui.asma@gmail.com](mailto:aloui.asma@gmail.com)

## Abstract

Ramadan fasting is annually observed by Muslims all over the world. This religious tenet involves a full abstinence from both food and fluid ingestion from dawn to sunset. This limitation of energy intake to the hours of darkness usually disrupts the normal sleeping and activity pattern of fasters, which could negatively affect sport performance. Scientific literature presents conflicting results concerning the effect of Ramadan observance on sport performance. In this context, performance during brief (e.g., squat jump, countermovement jump, maximal voluntary contraction) or very short-duration (e.g., 5-m sprint, 10-m sprint, 20-m sprint) maximal exercises is generally maintained during Ramadan. However, single or repetitive short-term maximal efforts (e.g., Wingate test) and long-duration exercises are generally affected by Ramadan even though some studies did not show any significant change. Furthermore, Muslim athletes continue to train and compete during daylight hours while observing the Ramadan fast, which may present a challenge for them. Indeed, they are not able to consume nutrients and fluids to recover during daylight competitions or training sessions. Even though in the majority of Muslim-countries some competitions and sport events take place after sunset during Ramadan, this solution is not applicable in non-Muslim countries or in international events where timetables are sometimes dictated by television schedules, and where the majority of athletes are non-Muslims.

This chapter will focus on the impact of Ramadan observance on sport performance and the possible underlying mechanisms of the performance decrement observed in this month in some studies. In addition, some strategies to cope with the daytime fast and sport participation will be presented.

**Keywords:** Athletes; Fasting; Muslims; Performance; Ramadan; Sport

## Introduction

Ramadan is a holy month during which devoted Muslims refrain from eating, drinking, smoking, and having sexual relations from dawn to sunset. Fasting during Ramadan is the fourth pillar of Islam. It concerns every healthy Muslim since he experiences puberty. Muslim adults who are ill, travelling (distance dictated by Islamic rules), pregnant, diabetic (according to doctor's advice) or going through menstrual bleeding are not allowed to fast.

Ramadan lasts from 29 to 30 days based on the detection of the crescent moon. Also, this month advances by ~11 days each year with respect to the Gregorian calendar and can therefore occur during any season. Consequently, the effects of daytime fasting are strongly influenced by climatic conditions as Ramadan occurring in summer at high altitudes presents very different features compared with Ramadan in winter at lower altitudes. The fast duration doesn't only depend on the geographical location, but also on the season of the year. In other words, it can be as long as 18-h a day in the summer of temperate regions. In some other countries located more to the poles, the fast duration could be longer, representing a real challenge for fasters.

Each day before dawn, Muslims observe a pre-fast meal called *sahour* and fast until sunset. The fast-breaking meal is known as *iftar*. Then, unlimited food intake and hydration are allowed till dawn. The obligation to eat only within a short overnight span leads to several behavioral changes in sleep, eating schedule, and meal times [1]. Indeed, sleep time is delayed and sleep duration is shortened because Muslims continue to consume foods till late hours at night. Most studies showed that changes in sleep habits and food and fluid intakes caused at least some aspects of sport performance to deteriorate in Ramadan [2]. In this context, several studies have assessed the impact of Ramadan fasting upon sport performance and presented conflicting results. While some studies reported slight decrement or non-significant effect [3,4], others showed significant impairment in performance during Ramadan [5-7]. For instance, sprint time [8], vertical jump height [6,9], muscle power [5,7,10], and performance during endurance exercises [5,8,9,11] were lower during Ramadan compared with the out-of-Ramadan control period.

The exact underlying mechanisms responsible for these discrepancies are not well established. However, they could be attributed to different lengths of periods of food and water deprivation, different performance test protocols, failing to purge masking and exacerbating factors [12], the timing of experimental sessions, environmental conditions, training status, and age of the subjects [13].

One of the challenging aspects of Ramadan scientific studies also lies in the "control situation". Ideally, the control situation should be the near out-of-Ramadan period (pre- and post-Ramadan), and a non-fasting paired control group. Obtaining such a group is somewhat sensitive, as it is not possible for researchers to ask Muslims "not to fast" just for the need of any scientific study. Therefore, most studies just compare the Ramadan variables to near out-of-Ramadan control ones. This, of course, pauses a methodological problem as the same subjects serve as their own controls, but they have been assessed at different moments with pre- and post- Ramadan assessments being usually interspersed by two months. Moreover, finding a naturally non-fasting sample in Muslim-majority countries or, inversely, finding a fasting sample in non-Muslim-majority countries is also a challenging for researchers. Therefore, among the other variables that could influence the Ramadan-studies' outcomes, as the timing and location of Ramadan, the local life-style and eating habits among others. Also, the absence of control group has to be considered when interpreting the presented results.

As sport competitions and training are held during Ramadan, e.g., the last London 2012 Olympics and the upcoming FIFA 2014 world cup, the number of studies that examine the effect of Ramadan upon athletic performance is increasing. The various investigations

aimed to identify factors responsible for possible performance decrement during Ramadan and to present strategies to maintain fitness and performance during Ramadan.

In view of the previous considerations, this chapter aims to review the current state of knowledge about the effect of Ramadan fasting on sport performance and the underlying mechanisms responsible for the performance decrement that are reported by some studies. In addition, some strategies to cope with challenges imposed by daytime fasting will be presented.

## Effect of Ramadan Observance on Sport Performance

Ramadan fasting displacement in energy intake and hydration to the hours of darkness partly reverses the normal circadian pattern of eating and drinking [2]. Furthermore, if the period of daytime fasting is fractured by some naps, the normal sleep-wakefulness cycle associated with the solar day will be drastically disrupted [14]. Also, the large meal in the evening is likely to hinder sleep onset [2]. Accumulated sleep-loss has negative impacts on cognitive function, mood, daytime sleepiness, and performance [15].

Generally, the behavioral changes that characterize Ramadan are associated with some alterations in the metabolic, physiological, and psychological variables of an individual, and could potentially decrease sport performance [2].

Studies that have examined the effect of Ramadan observance on sport performance presented conflicting results (Table 1). In fact, performance during brief or very short-duration exercises is generally maintained, while single or repetitive short-term maximal or long-duration efforts are reported to be impaired during Ramadan in comparison with before Ramadan mainly when test sessions are conducted in the late afternoon just before *Iftar* (fast break). However, the point at which the components of performance are affected is not well established.

Authors	Subjects	Measured parameters	Timing of measurement	Ramadan effect (compared with control period)
Bouhlef et al., [7]	10 male physical education students Age: 21.8 ± 1.9 years	Handgrip force	Between 15:00 h and 17:00 h	NC
		CMJ height		NC
		Arms' maximal power (force-velocity test)		↓ in the first week (-0.28%) and the fourth week (-0.12%) of Ramadan
		Legs' maximal power (force-velocity test)		↓ in the first week (-0.13%) and the fourth week (-0.06%) of Ramadan
		Resting hemoglobin		NC
		Resting hematocrit		↑ in the first week (+0.02%) and NC in the fourth week of Ramadan
		Resting plasma volume		↓ in the first week and NC in the fourth week of Ramadan
Girard & Farooq [13]	18 young non-athlete boys Age: 12.6 ± 1.5 years	Best time in a single trial during a repeated sprint test (6 × 15-m interspersed with 15-s of passive recovery)	Between 13:00 h and 14:00 h	NC
		Cumulated sprint time		NC during the first week and ↑ during the fourth week (+2.47%) of Ramadan
		Sprint decrement score		NC

Racinais et al., [16]	11 Muslim males Age: 31 ± 3 years	Activity pattern (72-h tri-axial accelerometer)	Between 10:00 h and 13:00 h	Higher level of activity from 02:00 h to 05:00 h
		Knee extensors' maximal isometric torque		NC
		Knee flexors' maximal isometric torque		NC
		Electromyography activity of the vastus lateralis		NC
Asl et al., [17]	15 male athletes Age: 22.5 ± 1.14 years	Mean HR during 45-min running at 55% VO <sub>2</sub> max followed by another 45-min running at 90% VO <sub>2</sub> max	Between 10:00 h and 12:30 h	NC
		Blood lactate after 45-min running at 55% VO <sub>2</sub> max followed by another 45-min running at 90% VO <sub>2</sub> max		↑ in the middle of Ramadan (+15.07%)
Aziz et al., [18]	18 outfield soccer players (fasting group = 10, non-fasting group = 8) Age: 17.95 ± 0.7 years	RPE 20-min after training session	Between 17:30 h and 18:00 h	No significant difference was observed between the fasting and the non-fasting group
Brisswalter et al., [19]	18 well trained runners (fasting group = 9, non-fasting group = 9) Age: 23.6 ± 2.9 years	VO <sub>2</sub> max (estimated by an Incremental Running Test; Hausswirth et al. [20])	-	NC
		Speed at VO <sub>2</sub> max (Incremental Running Test)		↓ during the last week of Ramadan in the fasting group (-11.87%)
		Speed at VT1 % VO <sub>2</sub> max (Incremental Running Test)		NC
		VEmax (Incremental Running Test)		NC
		HRmax (Incremental Running Test)		NC
		Running efficiency (Incremental Running Test)		NC
		MVC		↓ during the last week of Ramadan in the fasting group (-3.75%)

Chtourou et al., [5]	20 soccer players Age: 17.6 ± 0.6 years	RPE after a Yo-Yo test level 1	17:00 h	↑ in the second week (+10.96%) and the fourth week (+12.59%) of Ramadan
		RPE after a RSA test (5 × 6-s maximal sprints every 30-s)		↑ in the second week (+11.52%) and the fourth week (+12.51%) of Ramadan
		RPE after a 30-s Wingate test		↑ in the second week (+9.47%) and the fourth week (+12.63%) of Ramadan
		POMS questionnaire		↑ fatigue in the second week (+11.96%) and the fourth week (+22.8%) of Ramadan
		Peak power during the Wingate test		↓ in the second week (-1.64%) and the fourth week (-1.82%) of Ramadan
		Mean power during the Wingate test		↓ in the second week (-2.43%) and the fourth week (-2.89%) of Ramadan
		Fatigue index during the Wingate test		↑ in the second week (+6.81%) and the fourth week (+11.43%) of Ramadan
		Total distance covered in the Yo-Yo test		NC in the second week and ↓ in the fourth week (-11.93%) of Ramadan
		MAV in the Yo-Yo test		NC in the second week and ↓ in the fourth week (-3.68%) of Ramadan
		Total work in the RSA test		NC in the second week and ↓ in the fourth week (-3.78%) of Ramadan
		Peak power in the RSA test		NC in the second week and ↓ in the fourth week of Ramadan for all sprints
		Percentage of peak power decrement in the RSA test		NC in the second week and ↓ in the fourth week (-51.63%) of Ramadan



Güvenç [21]	16 soccer players Age: 17.4 ± 1.2 years	Performance parameters were assessed during a modified 20-m shuttle run test		
		Peak running distance	Between 16:00 h and 18:00 h	NC
		Peak running time		NC
		Peak running velocity		NC
		Running velocity at lactate concentration of 4 mmol.L <sup>-1</sup>		NC
		Lactate concentration at 8 km.h <sup>-1</sup>		NC
		Lactate concentration at 10 km.h <sup>-1</sup>		NC
		Lactate concentration at 11 km.h <sup>-1</sup>		NC
		Lactate concentration at 12 km.h <sup>-1</sup>		NC
		Peak lactate concentration		NC
		HR at 8 km.h <sup>-1</sup>		NC
		HR at 10 km.h <sup>-1</sup>		NC
		HR at 11 km.h <sup>-1</sup>		NC
		HR at 12 km.h <sup>-1</sup>		NC
		Peak HR		NC
		RPE at 8 km.h <sup>-1</sup>		NC
		RPE at 10 km.h <sup>-1</sup>		↑ in the beginning (+9.45%) and at the end (+11.97%) of Ramadan
		RPE at 11 km.h <sup>-1</sup>		↑ in the beginning (+9%) and at the end (+6.99%) of Ramadan
		RPE at 12 km.h <sup>-1</sup>		↑ in the beginning (+8.47%) and at the end (+6.37%) of Ramadan
		Peak RPE		NC

Memari et al., [22]	12 female taekwondo players Age: 15-27 years	Agility time	Between 16:00 h and 18:00 h	↑ during the second week (+7.29%) and the fourth week (+5.10%) of Ramadan
		Vertical jumping height		NC
		Balance time		NC
Aziz et al., [23]	10 moderately trained runners Age: 27.3 ± 7.2 years	Distance covered during a 30-min time trial run	Between 16:00 h and 18:00 h	↓ during Ramadan (-3.55%)
		Mean speed during a 30-min time trial run		↓ during Ramadan at the 15th and 25th min marks
		HR during a 60-min endurance treadmill running		NC
		RPE at the end of the 60-min run		NC
		Blood lactate concentration after the 60-min run		NC
		Subjective readiness to train (VAS; Wewers & Lowe [24])		NC
		Subjective level of tiredness (VAS; Wewers & Lowe [24])		NC
		Subjective level of alertness (VAS; Wewers & Lowe [24])		↓ during Ramadan (-17.30%)
Subjective level of concentration (VAS; Wewers & Lowe [24])	↓ during Ramadan (-15.66%)			
Lotfi et al., [25]	9 resistance athletes Age: 23 ± 3 years	HR 15-min after a 1000-m run	12.00 h - 13.00 h	NC
		Systolic blood pressure 15-min after a 1000-m run		NC
		Diastolic blood pressure 15-min after a 1000-m run		NC
		Motor time 15-min after a 1000-m run		NC
		Recognition time 15-min after a 1000-m run		NC
		Total reaction time 15-min after a 1000-m run		NC
		Resting critical flicker fusion		NC
		Critical flicker fusion 15-min after a 1000-m run		↑ in the first week (+3.71%) and NC in the fourth week of Ramadan

Chaouachi et al., [4]	15 elite judokas Age: 18 ± 1 years	SJ height	Between 14:00 h and 16:00 h	NC
		SJ force		NC
		SJ peak power		NC
		CMJ height		NC
		CMJ peak power		NC
		Ratio SJ height/CMJ height		NC
		30-s repeated jumping test average height		NC
		30-s repeated jumping test average power		NC in the middle and ↓ at the end (-4.27%) of Ramadan
		Lactate concentration measured 3-min after the 30-s repeated jumping test		NC
		5-m sprint time		NC
		10-m sprint time		NC
		30-m sprint time		NC
		VO <sub>2</sub> max (estimated by a Multistage Fitness Test; Léger & Gadoury [26])		NC
		vVO <sub>2</sub> max		NC
HRmax during the Multistage Fitness Test	NC			
Lactate concentration measured 3-min after the Multistage Fitness Test	NC			
Total fatigue score (Chatard et al., [27])	↑ in the middle (+58.33%) and at the end (+33.33%) of Ramadan			
Chennaoui et al., [11]	8 middle distance runners Age: 25 ± 1.3 years	MAV	10:00 h	↓ at day 7 (- 2.89%) and day 21 (- 3.86%) of Ramadan
		POMS questionnaire		↑ fatigue score at the end of Ramadan (+31.5%)
Meckel et al., [9]	19 adolescent soccer players Age: 14-16 years	Agility (4 × 10-m shuttle run time)	-	NC
		CMJ height		↓ in the last 2 days of Ramadan (-1.79%)
		Speed endurance (6 × 40-m sprints with 30-s rest between the runs)		↑ in run time (+0.81%) and performance decrement (+5.26%) in the last 2 days of Ramadan
		2 × 20-m sprint time		NC
		3000-m run time		↑ in the last 2 days of Ramadan (+0.87%)

Karli et al., [28]	10 male elite power athletes Age: 20-24 years	Absolute peak power during a 30-s Wingate test	Between 15:00 h and 17:30 h	↑ in the last 3 days of Ramadan (+0.05%) and the last 3 days of the fourth week after the end of Ramadan (+0.08%)
		Relative peak power during a 30-s Wingate test		↑ in the last 3 days of Ramadan (+0.04%) and the last 3 days of the fourth week after the end of Ramadan (+0.07%)
		Absolute mean power during a 30-s Wingate test		NC
		Relative mean power during a 30-s Wingate test		NC
		Fatigue index during a 30-s Wingate test		NC
		Peak blood lactate concentration		NC
		Peak HR		NC
Zerguini et al., [8]	48 professional soccer players Age: 17-34 years	Vertical jump height	14:00 h	NC
		Dribbling time (Rosch et al., [29])		↑ during the last week of Ramadan (+9.36%)
		Agility time (Rosch et al. [27])		↑ during the last week of Ramadan (+6.80%)
		5-m speed time		NC
		10-m speed time		NC
		20-m speed time		NC
		12-min run distance		↓ during the last week of Ramadan (-15.92%)
		HR after 12-min run		↓ during the last week of Ramadan (-22.69%)
HR 5-min after 12-min run	NC			
Bigard et al., [30]	11 senior fighter pilots Age: 27-49 years	MVC of right elbow flexors	-	↓ during the first week (-9.30%) and the fourth week (-9.55%) of Ramadan
		MVC of left elbow flexors		↓ during the first week (-12.05%) and NC during the fourth week of Ramadan
		MVC of knee extensors		NC during the first week and ↓ during the fourth week of Ramadan (-14.76%)
		Muscle endurance at 35% MVC		NC during the first week and ↓ during the fourth week of Ramadan (-28.36%)
		Muscle endurance at 70% MVC		NC during the first week and ↓ during the fourth week of Ramadan (-22.20%)
Sweileh et al., [31]	Sedentary subjects	VO <sub>2</sub> max	-	↓ in the first week of Ramadan with a return to pre-Ramadan levels in the last week of Ramadan

Authors	Subjects	Measured parameters	Timing of measurement	Ramadan effect (compared with control period)
Bouhlel et al., [7]	10 male physical education students Age: 21.8 ± 1.9 years	Handgrip force	Between 15:00 h and 17:00 h	NC
		CMJ height		NC
		Arms' maximal power (force-velocity test)		↓ in the first week (-0.28%) and the fourth week (-0.12%) of Ramadan
		Legs' maximal power (force-velocity test)		↓ in the first week (-0.13%) and the fourth week (-0.06%) of Ramadan
		Resting hemoglobin		NC
		Resting hematocrit		↑ in the first week (+0.02%) and NC in the fourth week of Ramadan
		Resting plasma volume		↓ in the first week and NC in the fourth week of Ramadan
Girard & Farooq [13]	18 young non-athlete boys Age: 12.6 ± 1.5 years	Best time in a single trial during a repeated sprint test (6 × 15-m interspersed with 15-s of passive recovery)	Between 13:00 h and 14:00 h	NC
		Cumulated sprint time		NC during the first week and ↑ during the fourth week (+2.47%) of Ramadan
		Sprint decrement score		NC
Racinais et al., [16]	11 Muslim males Age: 31 ± 3 years	Activity pattern (72-h tri-axial accelerometer)	Between 10:00 h and 13:00 h	Higher level of activity from 02:00 h to 05:00 h
		Knee extensors' maximal isometric torque		NC
		Knee flexors' maximal isometric torque		NC
		Electromyography activity of the vastus lateralis		NC
Asl et al., [17]	15 male athletes Age: 22.5 ± 1.14 years	Mean HR during 45-min running at 55% VO <sub>2</sub> max followed by another 45-min running at 90% VO <sub>2</sub> max	Between 10:00 h and 12:30 h	NC
		Blood lactate after 45-min running at 55% VO <sub>2</sub> max followed by another 45-min running at 90% VO <sub>2</sub> max		↑ in the middle of Ramadan (+15.07%)
Aziz et al., [18]	18 outfield soccer players (fasting group = 10, non-fasting group = 8) Age: 17.95 ± 0.7 years	RPE 20-min after training session	Between 17:30 h and 18:00 h	No significant difference was observed between the fasting and the non-fasting group
Brisswalter et al., [19]	18 well trained runners (fasting group = 9, non-fasting group = 9) Age: 23.6 ± 2.9 years	VO <sub>2</sub> max (estimated by an Incremental Running Test; Hausswirth et al., [20])	-	NC
		Speed at VO <sub>2</sub> max (Incremental Running Test)		↓ during the last week of Ramadan in the fasting group (-11.87%)
		Speed at VT1 % VO <sub>2</sub> max (Incremental Running Test)		NC

		VEmax (Incremental Running Test)		NC
		HRmax (Incremental Running Test)		NC
		Running efficiency (Incremental Running Test)		NC
		MVC		↓ during the last week of Ramadan in the fasting group (-3.75%)
Chtourou et al., [5]	20 soccer players Age: 17.6 ± 0.6 years	RPE after a Yo-Yo test level 1	17:00 h	↑ in the second week (+10.96%) and the fourth week (+12.59%) of Ramadan
		RPE after a RSA test (5 × 6-s maximal sprints every 30-s)		↑ in the second week (+11.52%) and the fourth week (+12.51%) of Ramadan
		RPE after a 30-s Wingate test		↑ in the second week (+9.47%) and the fourth week (+12.63%) of Ramadan
		POMS questionnaire		↑ fatigue in the second week (+11.96%) and the fourth week (+22.8%) of Ramadan
		Peak power during the Wingate test		↓ in the second week (-1.64%) and the fourth week (-1.82%) of Ramadan
		Mean power during the Wingate test		↓ in the second week (-2.43%) and the fourth week (-2.89%) of Ramadan
		Fatigue index during the Wingate test		↑ in the second week (+6.81%) and the fourth week (+11.43%) of Ramadan
		Total distance covered in the Yo-Yo test		NC in the second week and ↓ in the fourth week (-11.93%) of Ramadan
		MAV in the Yo-Yo test		NC in the second week and ↓ in the fourth week (-3.68%) of Ramadan
		Total work in the RSA test		NC in the second week and ↓ in the fourth week (-3.78%) of Ramadan
		Peak power in the RSA test		NC in the second week and ↓ in the fourth week of Ramadan for all sprints
		Percentage of peak power decrement in the RSA test		NC in the second week and ↓ in the fourth week (-51.63%) of Ramadan

Güvenç [21]	16 soccer players Age: 17.4 ± 1.2 years	Performance parameters were assessed during a modified 20-m shuttle run test		
		Peak running distance	Between 16:00 h and 18:00 h	NC
		Peak running time		NC
		Peak running velocity		NC
		Running velocity at lactate concentration of 4 mmol.L <sup>-1</sup>		NC
		Lactate concentration at 8 km.h <sup>-1</sup>		NC
		Lactate concentration at 10 km.h <sup>-1</sup>		NC
		Lactate concentration at 11 km.h <sup>-1</sup>		NC
		Lactate concentration at 12 km.h <sup>-1</sup>		NC
		Peak lactate concentration		NC
		HR at 8 km.h <sup>-1</sup>		NC
		HR at 10 km.h <sup>-1</sup>		NC
		HR at 11 km.h <sup>-1</sup>		NC
		HR at 12 km.h <sup>-1</sup>		NC
		Peak HR		NC
		RPE at 8 km.h <sup>-1</sup>		NC
		RPE at 10 km.h <sup>-1</sup>		↑ in the beginning (+9.45%) and at the end (+11.97%) of Ramadan
		RPE at 11 km.h <sup>-1</sup>		↑ in the beginning (+9%) and at the end (+6.99%) of Ramadan
		RPE at 12 km.h <sup>-1</sup>		↑ in the beginning (+8.47%) and at the end (+6.37%) of Ramadan
		Peak RPE		NC

Memari et al., [22]	12 female taekwondo players Age: 15-27 years	Agility time	Between 16:00 h and 18:00 h	↑ during the second week (+7.29%) and the fourth week (+5.10%) of Ramadan
		Vertical jumping height		NC
		Balance time		NC
Aziz et al., [23]	10 moderately trained runners Age: 27.3 ± 7.2 years	Distance covered during a 30-min time trial run	Between 16:00 h and 18:00 h	↓ during Ramadan (-3.55%)
		Mean speed during a 30-min time trial run		↓ during Ramadan at the 15th and 25th min marks
		HR during a 60-min endurance treadmill running		NC
		RPE at the end of the 60-min run		NC
		Blood lactate concentration after the 60-min run		NC
		Subjective readiness to train (VAS; Wewers & Lowe [24])		NC
		Subjective level of tiredness (VAS; Wewers & Lowe [24])		NC
		Subjective level of alertness (VAS; Wewers & Lowe [24])		↓ during Ramadan (-17.30%)
Subjective level of concentration (VAS; Wewers & Lowe [24])	↓ during Ramadan (-15.66%)			
Lotfi et al., [25]	9 resistance athletes Age: 23 ± 3 years	HR 15-min after a 1000-m run	12.00 h - 13.00 h	NC
		Systolic blood pressure 15-min after a 1000-m run		NC
		Diastolic blood pressure 15-min after a 1000-m run		NC
		Motor time 15-min after a 1000-m run		NC
		Recognition time 15-min after a 1000-m run		NC
		Total reaction time 15-min after a 1000-m run		NC
		Resting critical flicker fusion		NC
		Critical flicker fusion 15-min after a 1000-m run		↑ in the first week (+3.71%) and NC in the fourth week of Ramadan



Chaouachi et al., [4]	15 elite judokas Age: 18 ± 1 years	SJ height	Between 14:00 h and 16:00 h	NC
		SJ force		NC
		SJ peak power		NC
		CMJ height		NC
		CMJ peak power		NC
		Ratio SJ height/CMJ height		NC
		30-s repeated jumping test average height		NC
		30-s repeated jumping test average power		NC in the middle and ↓ at the end (-4.27%) of Ramadan
		Lactate concentration measured 3-min after the 30-s repeated jumping test		NC
		5-m sprint time		NC
		10-m sprint time		NC
		30-m sprint time		NC
		VO <sub>2</sub> max (estimated by a Multistage Fitness Test; Léger & Gadoury [26])		NC
		vVO <sub>2</sub> max		NC
HRmax during the Multistage Fitness Test	NC			
Lactate concentration measured 3-min after the Multistage Fitness Test	NC			
Total fatigue score (Chatard et al., [27])	↑ in the middle (+58.33%) and at the end (+33.33%) of Ramadan			
Chennaoui et al., [11]	8 middle distance runners Age: 25 ± 1.3 years	MAV	10:00 h	↓ at day 7 (- 2.89%) and day 21 (- 3.86%) of Ramadan
		POMS questionnaire		↑ fatigue score at the end of Ramadan (+31.5%)
Meckel et al., [9]	19 adolescent soccer players Age: 14-16 years	Agility (4 × 10-m shuttle run time)	-	NC
		CMJ height		↓ in the last 2 days of Ramadan (-1.79%)
		Speed endurance (6 × 40-m sprints with 30-s rest between the runs)		↑ in run time (+0.81%) and performance decrement (+5.26%) in the last 2 days of Ramadan
		2 × 20-m sprint time		NC
		3000-m run time		↑ in the last 2 days of Ramadan (+0.87%)

Karli et al., [28]	10 male elite power athletes Age: 20-24 years	Absolute peak power during a 30-s Wingate test	Between 15:00 h and 17:30 h	↑ in the last 3 days of Ramadan (+0.05%) and the last 3 days of the fourth week after the end of Ramadan (+0.08%)
		Relative peak power during a 30-s Wingate test		↑ in the last 3 days of Ramadan (+0.04%) and the last 3 days of the fourth week after the end of Ramadan (+0.07%)
		Absolute mean power during a 30-s Wingate test		NC
		Relative mean power during a 30-s Wingate test		NC
		Fatigue index during a 30-s Wingate test		NC
		Peak blood lactate concentration		NC
		Peak HR		NC
Zerguini et al., [8]	48 professional soccer players Age: 17-34 years	Vertical jump height	14:00 h	NC
		Dribbling time (Rosch et al., [29])		↑ during the last week of Ramadan (+9.36%)
		Agility time (Rosch et al. [27])		↑ during the last week of Ramadan (+6.80%)
		5-m speed time		NC
		10-m speed time		NC
		20-m speed time		NC
		12-min run distance		↓ during the last week of Ramadan (-15.92%)
		HR after 12-min run		↓ during the last week of Ramadan (-22.69%)
HR 5-min after 12-min run	NC			

Bigard et al., [30]	11 senior fighter pilots Age: 27-49 years	MVC of right elbow flexors	-	↓ during the first week (-9.30%) and the fourth week (-9.55%) of Ramadan
		MVC of left elbow flexors		↓ during the first week (-12.05%) and NC during the fourth week of Ramadan
		MVC of knee extensors		NC during the first week and ↓ during the fourth week of Ramadan (-14.76%)
		Muscle endurance at 35% MVC		NC during the first week and ↓ during the fourth week of Ramadan (-28.36%)
		Muscle endurance at 70% MVC		NC during the first week and ↓ during the fourth week of Ramadan (-22.20%)
Sweileh et al., [31]	Sedentary subjects	VO <sub>2</sub> max	-	↓ in the first week of Ramadan with a return to pre-Ramadan levels in the last week of Ramadan

**Table 1:** Effect of Ramadan observance on sport performance

NC: No significant change during Ramadan; VO<sub>2</sub>max: maximal oxygen uptake; MAV: Maximal Aerobic Velocity; POMS: Profile of Mood States; CMJ: Counter-movement Jump; HR: Heart Rate; SJ: Squat Jump; vVO<sub>2</sub>max: velocity associated with VO<sub>2</sub>max; HRmax: maximal Heart Rate; RPE: Rating of Perceived Exertion; MVC: Maximal Voluntary isometric Contraction; VAS: Visual Analogue Scale; VE: Ventilation; VT: Ventilatory Threshold; RSA: Repeated Sprint Ability.

## Mechanisms Responsible for Performance Decrement during Ramadan

Authors considered that many factors are involved in performance decrement during Ramadan. Most known factors are circadian rhythms' alteration, hypo-hydration (i.e., reduced total body water), disturbance of the sleep-wake cycle, modified training load, changed body composition, and fatigue.

Current evidence suggests that athletes who maintain their total energy intake, training load, and body mass are able to sustain their physical performance during Ramadan fasting. For instance, previous studies showed that fitness was not reduced [4] or even increased [3] when the training load was maintained during Ramadan. In this context, Chaouachi et al., [4] reported that single vertical jump performance, force, and peak power appeared to be unaffected during Ramadan fasting in elite judokas. Nevertheless, Ramadan fasting affected mean power output during a continuous 30-s vertical jump test [4]. Moreover, in Tunisian soccer players, Kirkendall et al., [3] observed that when training load was maintained, sprint performance was better during Ramadan in comparison with before Ramadan. It seems that when special attention is given to the maintenance of training load, one could avoid big decrements in fitness, and mostly maintain physical performance, with some studies even showing some improvements in some physical performance measures [3,28].

Likewise, previous studies also showed that athletes were able to sustain their sport performance when energy intake was maintained during Ramadan [4,21]. In this context, Güvenç [21] reported that peak running distance, time, and velocity in the 20-m shuttle run test and running velocity at the onset of blood lactate accumulation in the 20-m shuttle run test were maintained during Ramadan when total energy intake was the same for Ramadan compared to before Ramadan. Furthermore, previous studies showed that sport performance was maintained during Ramadan when body mass was unchanged [21,32]. In this context,

Zarrouk et al., [32] observed that karate athletes were able to maintain their body mass, maximal voluntary isometric contraction, and sub-maximal knee extension isometric contraction time (at 75% of the maximal voluntary contraction until exhaustion) during Ramadan. Therefore, when body mass, energy intake, and training load are maintained, the decrements in fitness during Ramadan are usually not observed or small.

Regarding the hydration status, Bigard et al., [30], Bouhlel et al., [7,33], Bouhlel et al., [7] and Aloui et al., [34] showed increased hematocrit and hemoglobin values and a reduction in plasma volume during Ramadan. Moreover, a reduction in urine volume, sodium, potassium, and total solute excretion and an increase in urinary osmolality [35,36] were reported during Ramadan. These measurements confirm that subjects were hypo-hydrated in the fasting state. Besides, some studies showed that body mass was significantly reduced during Ramadan [31,34]. This body mass loss can be attributed to acute body water loss and/or decreased fat free mass.

Severe hypo-hydration (i.e., reduced total body water) can lead to impairments in exercise performance [14]. In this context, abundant research documents the detrimental effects of hypo-hydration on endurance exercise performance [37]. Similarly, other studies demonstrated that hypo-hydration decreases muscular performance [38-40]. Altered hydration can influence athletes cognitively in addition to physically; this can even occur before the level of dehydration reaches a point where the exerciser's physical performance would normally be affected [41]. Mild dehydration has been attributed to decrease in perceived alertness and attentional resources and an increase in self-reported tiredness and headache [41].

Likewise, fatigue caused by daytime fasting may explain performance decrement during Ramadan. In this context, higher ratings of perceived exertion were observed during Ramadan compared with control periods mainly in the afternoon [5,34]. Also, Chaouachi et al., [4] reported an increase in total fatigue scores during Ramadan in elite judo athletes maintaining their usual training loads and most physical performances levels. Fatigue can also result from disturbances in sleep-wake cycle during Ramadan. Indeed, sleep duration is reduced because of the large amount of food eaten at night and social/religious events that occur during the nighttime. Research has shown that sleep-loss has negative effects on physical performance mainly when tests are conducted in the afternoon [42,43]. In this context, HajSalem et al., [44] recently showed that partial sleep deprivation may adversely affect muscle power output during a 30-s Wingate test. However, they also observed that muscle strength during a hand-grip test (which is a very short-term performance measure) was not significantly affected by sleep-loss. More recently, Souissi et al., [45] demonstrated that performance during maximal voluntary contraction, hand grip, and 30-s Wingate tests was significantly affected by partial sleep-loss when assessed in the afternoon hours, but not in the morning of the following day.

## Strategies to Cope with Daytime Fasting

Recent review papers have detailed practices that athletes should use to minimize the negative impact of Ramadan fasting/observance on sport performance [46-49]. Indeed, Ramadan has not to be considered only as a food and fluid intake alteration (fasting), but as a whole of life style changes including sleep and other variables (observance) that will likely to affect physical performance.

Training loads should not be reduced during Ramadan as compared to before Ramadan to avoid any detraining effect. Also, heavy training sessions should be scheduled either in the early evening or, when impossible to do so, in the late afternoon, so that players can replenish their glycogen stores and rehydrate immediately after training [46].

Chaouachi et al., [46] have suggested that athletes who maintain their energy and macronutrient intake, training load, body composition, and sleep are unlikely to suffer any

substantial decrements in performance during the whole month of Ramadan. Moreover, during Ramadan, Muslim athletes should consume foods and drinks in the hours of darkness to supply the nutrients needed to promote performance, adaptation, and recovery in their sports [47]. Careful choice of fluid and food intake during or after exercise undertaken in the evening is also important to support needs for performance and recovery [47]. Also, special sports foods should be used to reduce gastrointestinal discomfort [47]. Furthermore, as sleep-loss and disruption in the normal circadian cycles can adversely affect physical performance, athletes should progressively establish a new sleep-wake cycle before Ramadan, with regular sleeping and eating schedules that match the ones followed during Ramadan [46]. Sleep-loss should be minimized and regular daytime naps may be required to sustain hard physical activity [2,46,48].

Likewise, Islam advises Muslims through “Hadith” (Practice of the Prophet Mohammad “may the blessing of Allah and peace be upon him”) to fast two days a week (Mondays and Thursdays). This practice is widely spread among some Muslims. Also, some others fast three days in the middle of the pre-Ramadan month (Chaabene) and six days during the post-Ramadan month (Chawal). This practice could help the human body to be progressively prepared for the next coming period, possibly dampening the deep changes that occur during Ramadan and the first week after it. This should be experimented with respect to its possible effect on sport performance.

## Conclusion

The effect of Ramadan observance on sport performance is a controversial issue. Till now, the exact underlying mechanisms of performance decrement observed during Ramadan are not well identified. Although speculative, disturbance in sleep-wake cycle and circadian rhythms, hypo-hydration, possible alterations in body composition, environmental conditions, training load/regimen changes, and fatigue could explain the negative effect of Ramadan observance on sport performance.

Coping strategies adopted while fasting and training during Ramadan are greatly varied among athletes. However, if some could manage Ramadan fasting and sport quite easily, some other athletes may not be able to maintain the required exercise performance during Ramadan. Therefore, the technical and medical staffs should emphasize on individualization in that regard.

## References

1. Iraki L, Bogdan A, Hakkou F, Amrani N, Abkari A, et al. (1997) Ramadan diet restrictions modify the circadian time structure in humans. A study on plasma gastrin, insulin, glucose, and calcium and on gastric pH. *J Clin Endocrinol Metab* 82: 1261-1273.
2. Waterhouse J (2010) Effects of Ramadan on physical performance: chronobiological considerations. *Br J Sports Med* 44: 509-515.
3. Kirkendall DT, Leiper JB, Bartagi Z, Dvorak J, Zerguini Y (2008) The influence of Ramadan on physical performance measures in young Muslim footballers. *J Sports Sci* 26: 15-27.
4. Chaouachi A, Coutts AJ, Chamari K, Wong del P, Chaouachi M, et al. (2009) Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. *J Strength Cond Res* 23: 2702-2709.
5. Chtourou H, Hammouda O, Souissi H, Chamari K, Chaouachi A, et al. (2011) The effect of ramadan fasting on physical performances, mood state and perceived exertion in young footballers. *Asian J Sports Med* 2: 177-185.
6. Aloui A, Chtourou H, Masmoudi L, Chaouachi A, Chamari K and Souissi N (2012) Effects of Ramadan fasting on male judokas' performances in specific and non-specific judo tasks. *Biol Rhythm Research* 44: 645-654.
7. Bouhlel H, Shephard RJ, Gmada N, Aouichaoui C, Peres G, et al. (2013) Effect of Ramadan observance on maximal muscular performance of trained men. *Clin J Sport Med* 23: 222-227.

8. Zerguini Y, Kirkendall D, Junge A, Dvorak J (2007) Impact of Ramadan on physical performance in professional soccer players. *Br J Sports Med* 41: 398-400.
9. Meckel Y, Ismaeel A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *Eur J Appl Physiol* 102: 651-657.
10. Souissi N, Souissi H, Sahli S, Tabka Z, Dogui M, et al. (2007) Effect of Ramadan on the diurnal variation in short-term high power output. *Chronobiol Int* 24: 991-1007.
11. Chennaoui M, Desgorces F, Drogou C, Boudjemaa B, Tomaszewski A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Appl Physiol Nutr Metab* 34: 587-594.
12. Javad Fallah S (2010) Ramadan fasting and exercise performance. *Asian J Sports Med* 1: 130.
13. Girard O, Farooq A (2012) Effects of Ramadan fasting on repeated sprint ability in young children. *Science & Sports* 27: 237-240.
14. Reilly T, Waterhouse J (2007) Altered sleep-wake cycles and food intake: the Ramadan model. *Physiol Behav* 90: 219-228.
15. Roky R, Herrera CP, Ahmed Q (2012) Sleep in athletes and the effects of Ramadan. *J Sports Sci* 30: 75-84.
16. Racinais S, Périard JD, Li CK, Grantham J (2012) Activity patterns, body composition and muscle function during Ramadan in a Middle-East Muslim country. *Int J Sports Med* 33: 641-646.
17. Asl NS (2011) The effects of Ramadan fasting on endurance running performance in male athletes. *International. J. Sport Std* 1: 18-22.
18. Aziz AR, Chia M, Singh R and Wahid MF (2011) Effects of Ramadan fasting on perceived exercise intensity during high-intensity interval training in elite youth soccer players. *Int J Sports Sci Coach* 6: 87-98.
19. Brisswalter J, Bouhlel E, Falola JM, Abbiss CR, Vallier JM, et al. (2011) Effects of Ramadan intermittent fasting on middle-distance running performance in well-trained runners. *Clin J Sport Med* 21: 422-427.
20. Hausswirth C, Le Meur Y, Bieuzen F, Brisswalter J, Bernard T (2010) Pacing strategy during the initial phase of the run in triathlon: influence on overall performance. *Eur J Appl Physiol* 108: 1115-1123.
21. Güvenç A (2011) Effects of ramadan fasting on body composition, aerobic performance and lactate, heart rate and perceptual responses in young soccer players. *J Hum Kinet* 29: 79-91.
22. Memari AH, Kordi R, Panahi N, Nikookar LR, Abdollahi M, et al. (2011) Effect of ramadan fasting on body composition and physical performance in female athletes. *Asian J Sports Med* 2: 161-166.
23. Aziz AR, Wahid MF, Png W, Jesuvadian CV (2010) Effects of Ramadan fasting on 60 min of endurance running performance in moderately trained men. *Br J Sports Med* 44: 516-521.
24. Wewers ME, Lowe NK (1990) A critical review of visual analogue scales in the measurement of clinical phenomena. *Res Nurs Health* 13: 227-236.
25. Lotfi S, Madani M, Abassi A, Tazi A, Boumahaza M, et al. (2010) CNS Activation, Reaction Time, Blood Pressure and Heart Rate Variation During Ramadan Intermittent Fasting and Exercise. *World J. Sport Sci* 3: 37-43.
26. Léger L, Gadoury C (1989) Validity of the 20 m shuttle run test with 1 min stages to predict  $\text{VO}_2\text{max}$  in adults. *Canadian Journal of Sport Sciences* 14: 21-26.
27. Chatard JC, Atlaoui A, Pichot V, Gourné C, Duclos M, Guézennec YC (2003) Training follow up by questionnaire fatigue, hormones and heart rate variability measurements. *Science & Sports* 18: 302-304.
28. Karli U, Guvenç A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *J Sports Sci Med* 6: 490-497.
29. Rösch D, Hodgson R, Peterson TL, Graf-Baumann T, Junge A, et al. (2000) Assessment and evaluation of football performance. *Am J Sports Med* 28: 29-39.
30. Bigard AX, Boussif M, Chalabi H, Guezennec CY (1998) Alterations in muscular performance and orthostatic tolerance during Ramadan. *Aviat Space Environ Med* 69: 341-346.
31. Sweileh N, Schnitzler A, Hunter GR, Davis B (1992) Body composition and energy metabolism in resting and exercising muslims during Ramadan fast. *J Sports Med Phys Fitness* 32: 156-163.

32. Zarrouk N, Hug F, Hammouda O, Rebai H, Tabka Z, et al. (2013) Effect of Ramadan intermittent fasting on body composition and neuromuscular performance in young athletes: a pilot study. *Biol Rhythm Research* 44: 697-709.
33. Bouhlel E, Salhi Z, Bouhlel H, Mdella S, Amamou A, et al. (2006) Effect of Ramadan fasting on fuel oxidation during exercise in trained male rugby players. *Diabetes Metab* 32: 617-624.
34. Aloui A, Chaouachi A, Chtourou H, Wong del P, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated-sprint performances. *Int J Sports Physiol Perform* 8: 254-263.
35. Cheah SH, Ch'ng SL, Husain R, Duncan MT (1990) Effects of fasting during Ramadan on urinary excretion in Malaysian Muslims. *Br J Nutr* 63: 329-337.
36. Leiper JB, Molla AM, Molla AM (2003) Effects on health of fluid restriction during fasting in Ramadan. *Eur J Clin Nutr* 57 Suppl 2: 30-S38.
37. Chevront SN, Carter R 3rd, Haymes EM, Sawka MN (2006) No effect of moderate hypohydration or hyperthermia on anaerobic exercise performance. *Med Sci Sports Exerc* 38: 1093-1097.
38. Schoffstall JE, Branch JD, Leutholtz BC, Swain DE (2001) Effects of dehydration and rehydration on the one-repetition maximum bench press of weight-trained males. *J Strength Cond Res* 15: 102-108.
39. Smith A, Maben A, Brockman P (1994) Effects of evening meals and caffeine on cognitive performance, mood and cardiovascular functioning. *Appetite* 22: 57-65.
40. Yoshida T, Takanishi T, Nakai S, Yorimoto A, Morimoto T (2002) The critical level of water deficit causing a decrease in human exercise performance: a practical field study. *Eur J Appl Physiol* 87: 529-534.
41. Maughan RJ (2003) Impact of mild dehydration on wellness and on exercise performance. *Eur J Clin Nutr* 57: 19-S23.
42. Souissi N, Souissi M, Souissi H, Chamari K, Tabka Z, et al. (2008) Effect of time of day and partial sleep deprivation on short-term, high-power output. *Chronobiol Int* 25: 1062-1076.
43. Abedelmalek S, Chtourou H, Aloui A, Aouichaoui C, Souissi N, et al. (2013) Effect of time of day and partial sleep deprivation on plasma concentrations of IL-6 during a short-term maximal performance. *Eur J Appl Physiol* 113: 241-248.
44. HajSalem M, Chtourou H, Aloui A, Hammouda O and Souissi N (2013) Effects of partial sleep deprivation at the end of the night on anaerobic performances in judokas. *Biol Rhythm Res* 44: 815-821.
45. Souissi N, Chtourou H, Aloui A, Hammouda O, Dogui M, et al. (2013) Effects of time-of-day and partial sleep deprivation on short-term maximal performances of judo competitors. *J Strength Cond Res* 27: 2473-2480.
46. Chaouachi A, Leiper JB, Chtourou H, Aziz AR, Chamari K (2012) The effects of Ramadan intermittent fasting on athletic performance: recommendations for the maintenance of physical fitness. *J Sports Sci* 30: 53-73.
47. Burke LM, King C (2012) Ramadan fasting and the goals of sports nutrition around exercise. *J Sports Sci* 30: 21-31.
48. Roy J, Hwal OC, Singh R, Aziz AR and Jin CW (2011) Self-generated coping strategies among Muslim athletes during Ramadan fasting. *Journal of Sports Science and Medicine* 10: 137-144.
49. Kirkendall DT, Chaouachi A, Aziz AR, Chamari K (2012) Strategies for maintaining fitness and performance during Ramadan. *J Sports Sci* 30: 103-108.

## Chapter 19

# Ramadan Fasting and Diurnal Variation in Sport Performance

**Hamdi Chtourou<sup>1,2\*</sup>, Asma Aloui<sup>1</sup>, Omar Hammouda<sup>1,3</sup>, Monoem Haddad<sup>1</sup>, Nizar Souissi<sup>1,3</sup>, and Karim Chamari<sup>4</sup>**

<sup>1</sup>Research Laboratory "Sport Performance Optimization" National Center of Medicine and Sciences in Sport (CNMSS), Tunis, Tunisia

<sup>2</sup>High Institute of Sport and Physical Education, Sfax University, Sfax, Tunisia

<sup>3</sup>High Institute of Sport and Physical Education, Ksar-Saïd, Manouba University, Manouba, Tunisia

<sup>4</sup>Research and Education Center, Aspetar, Qatar Orthopedic and Sports Medicine Hospital, Aspire Zone, Doha

**\*Corresponding author:** Hamdi Chtourou, Research Laboratory "Sport Performance Optimization", National Centre of Medicine and Sciences in Sport (CNMSS), Bp 263, Ave Med Ali Akid, 1004 El Menzah, Tunis, Tunisia, Tel: + 216 22 87 20 95; E-mail: [h\\_chtourou@yahoo.fr](mailto:h_chtourou@yahoo.fr)

## Abstract

Muslim athletes, whether living in a Muslim majority country or a non-Muslim country, should fast from dawn to sunset daily during Ramadan. Most athletes will continue to train and compete during this month. Ramadan is associated with behavioral changes that affect the metabolic, physiological, and psychological responses of athletes to a training session or a competition. This updated review aimed to present the current state of knowledge concerning the effects of Ramadan on athletic performance and its diurnal variations. To date, there are conflicting findings on the effects of Ramadan on athletic performance. However, in general, Ramadan fasting has minor effects upon athletic performance. Indeed, the available data indicate that high-level athletes who maintain their training load and control their sleep, food, and fluid intake and therefore do not undergo body composition changes, could sustain their performance during Ramadan. Performance changes were generally observed when test sessions were conducted in the afternoon just before sunset. However, no negative effect was observed when tests were conducted in the morning. Moreover, the amplitude of the diurnal rhythm of performance was reduced during Ramadan. Therefore, coaches should take into account the needs of Muslim athletes who observe Ramadan when scheduling training sessions or the participation to sport events, especially when competitions are programmed at different times-of-day.

**Keywords:** Athletes; Chronobiology; Diurnal Rhythm; Health; Ramadan; Sport

## Introduction

Fasting during Ramadan, the ninth month of the Islamic lunar calendar, is a religious obligation for every physically and mentally able Muslim adult [1,2]. This act of devotion to God is one of the five pillars of Islam that requires abstaining from eating, drinking, smoking, chewing, and having sexual relations from dawn till sunset [3]. It seeks to replace aggressive



thoughts and behaviors with ideal principles of reflection, piety, charity, patience, righteousness, and restraint [4]. Because the lunar calendar is shorter than the Gregorian calendar, Ramadan shifts by ~10-11 days each year and occurs at different seasons with a 33-year cycle.

During Ramadan, typically two meals are eaten each day: *Sahour* (i.e., just before dawn) and *Iftar* (i.e., after sunset). Although there might be regional and cultural differences in dietary practices, this concentration of food and fluid intake into the hours of darkness may accumulate an energy deficit and a progressive dehydration occurring during daylight hours [5]. Some people are unable to achieve energy balance due to the shift of eating and sleeping times, and some people increase fat consumption and/or consume excessive amount of food due to the large variety of foods available during this month compared with the rest of the year [6]. Also, previous studies reported that Ramadan fasting reduced the total sleep duration [7], increased sleep latency [8], and delayed the nocturnal sleep phase of approximately 2-3 hours [9]. In this context, recent studies reported that athletic performance was significantly reduced after one night of partial sleep deprivation [10,11].

Sport events and competitions could be scheduled during Ramadan such as the Olympics 2012 and the FIFA World Cup 2014. Thus, an understanding of the effects of Ramadan on athletic performance, particularly on fasting Muslim athletes, is essential for coaches and sport scientists in order to be able to better cope with this annual constraint [12].

The changes associated with the acute diurnal dehydration that characterize Ramadan fasting may produce many effects upon athletes' physiology and psychology possibly having detrimental effects on sport performance. However, modifications of athletic performances during Ramadan are a matter of debate. In this context, Aloui et al., [13] showed that short- and long-duration exercise performance was adversely affected during Ramadan in judo athletes. Likewise, Chtourou et al., [14] reported that performance during a  $Y_o$ - $Y_o$  intermittent recovery test, a repeated sprint test (5×6 s sprints with 24 s of recovery in-between), and a 30 s Wingate test was significantly reduced during Ramadan compared to before Ramadan in young soccer players. However, Zarrouk et al., [15] showed that Maximal Voluntary Contraction (MVC) of the knee extensor muscles and muscle endurance at 75% of the MVC were not significantly affected by Ramadan fasting in karate players.

The discrepancies between studies could be, in part, linked to the time-of-day of testing. Indeed, recent studies reported that athletic performance was significantly reduced during Ramadan when athletes were tested in the afternoon hours (i.e., just before sunset) [16-19]. However, when tests were performed in the morning, Ramadan fasting did not affect athletic performance [16-19]. These results could be explained by the fact that fluid and food intake before sunrise could lead to a "normal" morning status (i.e., very short fasting duration) and, thus, athletes maintain the same performance during Ramadan as compared to before the fasting month for the early morning hours.

In addition to the effect of Ramadan fasting on morning and evening performances, the second aim of recording athletic performance at different times-of-day during this month is to investigate the disruption of the diurnal rhythm of short- and long-duration performances. Indeed, food intake and sleep pattern changes during Ramadan may affect the sleep-wake cycle. For example, Ramadan could delay nocturnal sleep by ~2-3 hours [9]. These modifications could affect the *zeitgebers* of the rhythm and, therefore, affect the typical diurnal variations of athletic performance.

In another context, it is well established that short-term maximal performance is time-of-day dependent with evening acrophases, morning nadirs, and amplitudes ranging 3-22% [20-25]. However, these morning-evening differences were reduced during Ramadan due to a significant decrease in late afternoon and/or evening performance [16-19].

In view of the above considerations, the aims of this chapter were:

- (i) To update the effect of time-of-day on athletic performance,

- (ii) To present the effect of Ramadan fasting on athletic performance, and
- (iii) To review the effect of Ramadan fasting on the diurnal variation of athletic performance.

### **Effect of time-of-day on athletic performance**

Various psychological and physiological functions have been shown to undergo circadian (i.e., ~24 h) or diurnal rhythmicity [26-31]. To date, it is well established that short-term maximal performance fluctuates according to a circadian [32,33] or a diurnal rhythm [34-38] with evening maximum values (i.e., acrophases), morning minimum values (i.e., nadirs), and amplitudes of 3-22% [26]. However, the literature presents conflicting results concerning the circadian or diurnal rhythmicity of long-duration exercise performance [26,39,40].

**Short-term maximal performance:** Previous studies reported circadian [32,33] and diurnal [19-25] variations in peak and mean power output measured during the 30 s Wingate test. Also, Atkinson et al., [32] showed that back and leg strength, grip strength, and vertical jump heights attained their maximal values at ~18:00 h (performance was recorded at ~02:00 h, 06:00 h, 10:00 h, 14:00 h, 18:00 h, and 22:00 h) with an amplitude of ~2-10%. Moreover, Souissi et al., [33] observed that Wingate test peak and mean power varied in a circadian manner (performance was recorded at ~02:00 h, 06:00 h, 10:00 h, 14:00 h, 18:00 h, and 22:00 h) with acrophases observed at  $17:24 \pm 00:36$  h and  $18:00 \pm 01:01$  h respectively, and amplitudes of  $7.6 \pm 0.8\%$  and  $11.3 \pm 1.1\%$ , respectively. Likewise, when studying the diurnal rhythm of short-term maximal performance, previous studies reported that Wingate test peak and mean power were higher at 17:00 h than 07:00 h in physical education students (amplitudes: 2.6% and 2.0% respectively, [23]) and young soccer players (amplitudes: 3.1% and 2.6% respectively, [25]). Moreover, in judo athletes, Chtourou et al., [20] showed that hand-grip strength and Wingate test peak and mean power were higher at 09:00 h compared to 12:30 h and 16:00 h with amplitudes of 3.3%, 2.3%, and 3.5% respectively.

Although diurnal and circadian variations in short-term maximal performance are well established [41-43], the literature regarding the effect of time-of-day on muscle fatigue or performance decrement after high-intensity short-duration exercise yields inconclusive results [44]. In this context, in healthy male road competitive cyclists, Lericollais et al., [45] did not observe any significant morning-evening difference in power decrement during a 60 s Wingate test, indicating that fatigue is not affected by time-of-day. However, Lericollais et al., [46] showed that power decrement during a 60 s Wingate test defined two phases:

- (i) During the first 20 s, fatigue (power decrement) was higher at 18:00 h compared with 06:00 h, and
- (ii) during the last 40 s, values were not different between 18:00 h and 06:00 h.

Likewise, Chtourou et al., [23] and Souissi et al., [47] reported higher fatigue index and power decrement during a 30 s Wingate performed in the evening compared to the morning. During a 10×6 s repeated sprint exercise (with a 30 s recovery in-between), Racinais et al., [48] showed that power output decrement throughout the sprints was higher in the evening compared with the morning. However, this time-of-day effect on muscle fatigue was not present when participants produced the same initial power output in the evening and in the morning. These results demonstrate that the greater initial power output developed in the afternoon/evening could be responsible for the higher power decrement observed at this time-of-day. Therefore, when it comes to interpreting the fatigue index values of repeated short-term performance or RSA (Repeated Sprint Ability), checking any difference in the initial power developed during the first sprint is of paramount importance to allow fair comparison between efforts.

**Long-duration exercise performance:** The available scientific data appear to be equivocal. In this context, previous studies failed to show circadian or diurnal rhythmicity in time to exhaustion during cycling exercise [49], total work and average power output during a 15 min time trial cycling exercise [50], and work rate during submaximal cycling exercise [51].

However, Hammouda et al., [18] reported that the distance covered during a Yo-Yo intermittent recovery test was higher in the evening compared with the morning. In this regard, a limitation of this field test is that the exercise is that effort is intermittent nature and subject to voluntary exhaustion; therefore, the participant should be highly motivated to achieve the end-point on each occasion the test is conducted [26]. Likewise, Bessot et al., [52] showed that time to exhaustion at 95% of maximal power during a cycling exercise was higher in the evening compared with the morning. These divergent results could be due to the reluctance of some subjects to exercise to voluntary exhaustion during troughs in arousal as it is the case in the morning for some subjects, especially the evening-type individuals [26].

To explain the diurnal or circadian rhythm of athletic performance, previous studies reported that many of these rhythms are parallel to the daily variation in body temperature [53-55]. Indeed, some studies have suggested that the simultaneous increases in core temperature and athletic performance are causally related and that the increase in core temperature in the evening could exert a passive warm-up effect enhancing metabolic reactions, increasing the extensibility of connective tissue, reducing muscle viscosity, and increasing the conduction velocity of action potentials [26].

### **Effect of Ramadan fasting on athletic performance**

Actually, studies that have examined the effect of Ramadan fasting on athletic performance suggested that there is modest or no effect [15,56,57], although others showed significant impairment in performance during Ramadan [13,14,16-18,58].

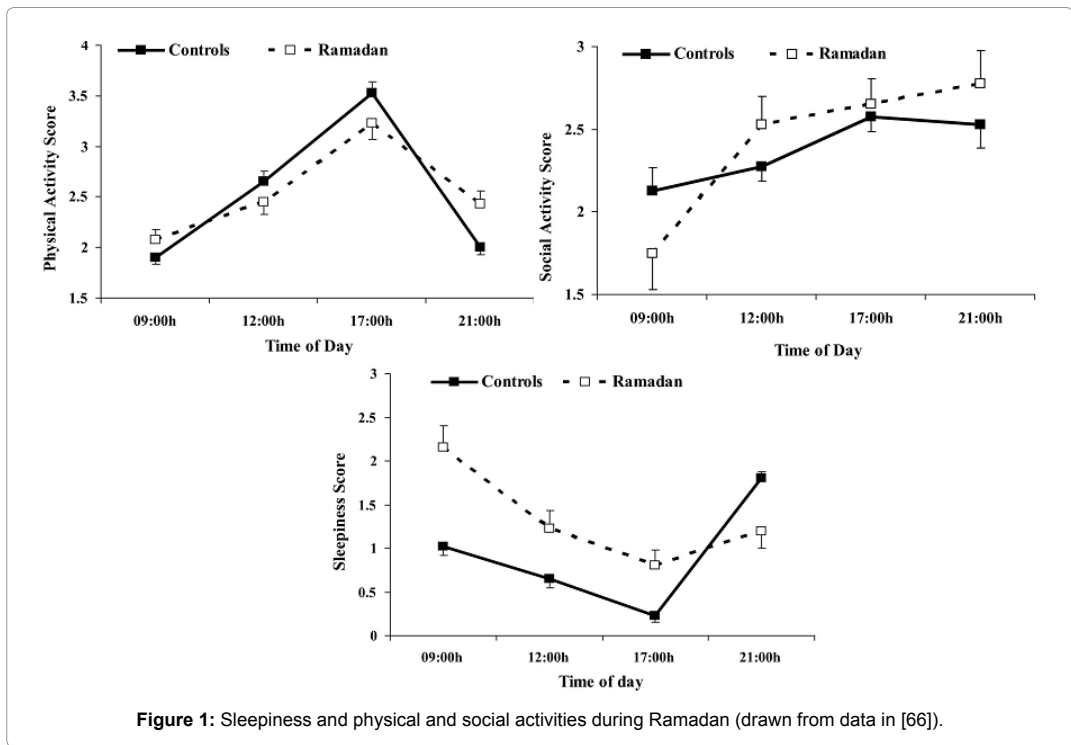
In young soccer players, Chtourou et al., [14] examined the effect of Ramadan fasting on short- and long-duration exercise performance (a 30 s Wingate test, a 5×6 s repeated sprint test (with 24 s of recovery in-between), and a  $Y_0$ - $Y_0$  intermittent recovery test) as well as ratings of perceived exertion and the profile of mood state. The authors observed that peak and mean power during the Wingate test decreased significantly during Ramadan in comparison with before Ramadan by ~1.6-1.9% and 2.4-2.9% during the second and the fourth weeks of Ramadan respectively. Moreover, peak power and total work developed during the repeated sprint test were impaired during Ramadan (3.8% decrease for the total work). Likewise, estimated maximal aerobic velocity and the total distance covered during the  $Y_0$ - $Y_0$  intermittent recovery test were lower during Ramadan in comparison with before Ramadan by 3.7% and 11.9% respectively. Moreover, the authors reported higher rating of perceived exertion scores (11 and 12.6% in rating of perceived exertion during the second and the fourth weeks of Ramadan respectively) and fatigue estimated by the profile of mood state (12 and 22.8% during the second and the fourth weeks of Ramadan respectively) during Ramadan in comparison with before Ramadan. The decrement in performance observed during Ramadan could be explained by the fact that the study was carried out during the offseason period. Indeed, Chaouachi et al., [59,60] indicated that athletes could maintain their performance during Ramadan when they sustain the same training load during this fasting month. The drawback of the study of Chtourou et al., is that body composition and energy intake were not monitored through the study impeding any interpretation of the decreased physical performance with respect to the body composition status. Another possible explanation of the decrease in performance could come from the fasting history. Indeed, the study subjects [14] trained while fasting for only 1 to 3 years. In the study of Chaouachi et al., [56] showing no impact of Ramadan fasting on performance, participants used to train and fast for a mean of 7 years. This might be a variable impacting the effects of Ramadan on athletes' performance.

In youth soccer players, Güvenç et al., [61] showed that peak running distance, time, and velocity in the 20 m shuttle run test were not adversely affected during Ramadan. Likewise, the authors reported that blood lactate, heart rate, and ratings of perceived exertion were similar before and during Ramadan. In elite judo athletes, Chaouachi et al., [56] showed that Ramadan fasting did not affect performance measured during the squat jump, counter-

movement jump, 30 m sprint, and the multistage fitness tests. In karate players, Zarrouk et al., [15] reported that maximal voluntary contraction of the knee extensors and time to exhaustion at 75% of the maximal voluntary contraction were not adversely affected during Ramadan. Recently, Bouhlel et al., [62] investigated the effect of Ramadan fasting on short-term maximal performance during vertical jump and force-velocity tests in physical education students. The authors showed that the largest changes in fitness parameters occur during the first part of Ramadan with muscle power generally returning to pre-Ramadan levels by the end of the fasting month.

Conversely, in soccer players, Kirkendall et al., [57] showed that athletic performance was greater during Ramadan in comparison with before Ramadan. Indeed, significant improvements in 7×30 m repeated sprint time, 10 m sprint time, counter-movement jump height, agility time during the 4-line agility test, and the running distance during a 20 m multistage shuttle run test were reported. However, the authors didn't observe significant differences between the fasting and the non-fasting subjects and concluded that Ramadan had little effect on youth soccer players observing Ramadan fasting. In the same way, in trained subjects (2 wrestlers, 7 sprinters, and 1 thrower), Karli et al., [63] showed that peak and mean power during a 30 s Wingate test were not modified during Ramadan compared with before Ramadan, with an unchanged body mass throughout the study.

The discrepancies between studies could be attributed to the different ways in which Ramadan is observed and the consequent lifestyle changes that occur [39]. Concerning lifestyle changes, it has been shown that during Ramadan, nocturnal sleep is short and daytime sleepiness is longer, with increased number and duration of daylight naps [64]. Therefore, during daylight hours, mood and the ability to optimally perform physical and mental activities decrease (Figure 1 [65]). In this context, the changes in individuals' feeding habits as well as their sleep-wake patterns have been described as to affect their physiology and metabolism [65].



On the other hand, as Islamic calendar is lunar, Ramadan timing advances ~10-11 day/year during a 33 years cycle. Therefore, Ramadan could fall in every season at any latitude resulting in widely divergent durations of fast and climatic conditions [64]. Indeed, fasting demands in the summer heat of equatorial regions are very different from those during winter at high latitudes: the times of sunrise and sunset vary little across the seasons near the equator, but are very different between summer and winter near the earth's poles [63]. As an example, for the start of Ramadan 2013 (9<sup>th</sup> of July), a daylight of 15 h 13 min in Doha (Qatar) is much shorter than the 18 h 07 min of daylight in an European Capital as Brussels (Belgium). Of course, if it comes to comparing two other cities with wider differences in location: closer to the Equator than Doha and closer to the North Pole than Brussels, even wider differences will represent a real challenge for enduring the long daylight of northern cities in the summer times. This illustrates the inter-locations differences that are encountered by fasting Muslims and might differently impact athletic performance.

Moreover, one strategy adopted by coaches in an attempt to help athletes cope with training and Ramadan is to reduce the volume and intensity of training [67]. Inadvertently, this attempt may lead to an extended period of relative detraining that could negatively impact athletic performance during Ramadan. In this context, two studies showed that while the Ramadan performance was accompanied by decreased performance, it was also related to decreased training intensity [68,69]. This shows the importance of monitoring training load for any study related to Ramadan fasting in athletes, allowing appropriate interpretation of any eventual observed change in performance.

Lastly, one of the factors that might impact the effect of Ramadan on athletic performance is the time of day of performance measurement. This variable will be treated in the next section.

### Effect of Ramadan fasting on the diurnal variation in athletic performance

Studies that have examined the effect of Ramadan fasting on athletic performance present inconclusive results. As mentioned here above, these discrepancies could be explained by several factors such as lifestyle modifications (sleep, nutrition, etc.), training load variations, and time-of-day of testing. In this context, recent studies [16-19] showed that athletic performance was adversely affected during Ramadan in the afternoon, just before sunset (Table 1). However, athletic performance was maintained during Ramadan when physical tests were scheduled in the morning, some hours after sunrise [16-19] (Table 1). The testing sessions of Ramadan studies have been conducted on wide span of hours broadly ranging from 07:00 h to 18:00 h. Therefore, the interpretation of the results should take into consideration the timing of *Iftar* (fast break) with respect to the timing of testing. For example, a testing session conducted between 16:00 h and 17:00 h represents an end-of fasting day when the *Iftar* is scheduled for 18:00 h, while it will shift to middle of afternoon for longer daylight with *Iftar* occurring after 21:00 h for instance.

Authors	Subjects	Age	Measured parameters	Time points	Period of measurement during Ramadan	Ramadan effect on morning performance	Ramadan effect on evening performance	Acrophase		Amplitude			
								Before Ramadan	During Ramadan	Before Ramadan	During Ramadan		
Roky et al., [71]	Healthy young subjects	20-28	Oral temperature	09:00 h	BR 6 <sup>th</sup> day of Ramadan 15 <sup>th</sup> day of Ramadan 28 <sup>th</sup> day of Ramadan	↓ from 09:00 h to 16:00 h	↑ at 20:00 and 23:00 h	16:00 h	23:00 h	NR	NR		
			Reaction time	11:00 h									
			Critical flicker fusion	13:00 h 16:00 h 20:00 h 23:00 h									
						NS	NS	NS	NS	-	-		

Souissi et al., [19]	Physical education students	22.6 ± 1.3	Oral temperature	07:00 h 17:00 h 21:00 h	BR SWR ER two weeks AR	NS	↓ ER at 17:00 h and 21:00 h	21:00 h	21:00 h	0.9 °C	0.6 °C
			P <sub>max</sub>			NS	↓ SWR at 17:00 h ↓ ER at 17:00 h and 21:00 h	17:00 h	17:00 h during SWR NS during ER	NR	NR
			F <sub>0</sub>			NS	↓ SWR and ER at 17:00 h	17:00 h	21:00 h during SWR	NR	NR
			V <sub>0</sub>			NS	NS	NS	NS	-	-
			PP			NS	↓ SWR at 17:00 h and 21:00 h ↓ ER at 17:00 h and 21:00 h ↓ AR at 17:00 h and 21:00 h	17:00 h	17:00 h during SWR	NR	NR
			MP			NS	↓ ER at 17:00 h and 21:00 h	21:00 h	21:00 h SWR	NR	NR
			FI			NS	NS	NS	NS	-	-
Waterhouse et al., [66]	Trained subjects	18	Hand grip	12:00 h 17:00 h	BR FWR ER one week AR.	NS	NS	17:00 h	17:00 h	NR	NR
			Cadence during a 15-min cycling exercise against constant load of 120 watts			↓	↑	17:00 h	17:00 h	NR	NR
Hammouda et al., [18]	Soccer players	17.3 ± 0.48	Oral temperature	07:00 h 17:00 h	BR SWR ER	NS	NS	17:00 h	17:00 h	0.7 °C	0.4 °C
			PP during a RSA test			NS	↓ at ER	17:00 h	NS	NR	NR
			Wt during a RSA test			NS	↓ at ER	17:00 h	NS	NR	NR
			P <sub>dec</sub> during a RSA test			NS	NS	NS	NS	-	-
			RPE after a RSA test			NS	↑ at ER	NS	NS	-	-
			TD covered during a Y <sub>0</sub> -Y <sub>0</sub> test			NS	↓ at SWR and ER	17:00 h	NS	NR	-
			HR <sub>max</sub> during a Y <sub>0</sub> -Y <sub>0</sub> test			NS	↓ at SWR and ER	NS	NS	-	-
RPE after a Y <sub>0</sub> -Y <sub>0</sub> test	NS	↓ at SWR and ER	17:00 h	NS	NR	NR					
Chtourou et al., [17]	Soccer players	17.0 ± 0.5	PP during a 30-s Wingate test	07:00 h 17:00 h	BR SWR ER	NS	↓ at SWR and ER	17:00 h	NS	3.1 %	0.6-0.9 %
			MP during a 30-s Wingate test			NS	↓ at SWR and ER	17:00 h	NS	2.9 %	0.2-1 %
			FI during a 30-s Wingate test			NS	↑ at SWR and ER	17:00 h	17:00 h	10.6 %	16-20 %
			RPE after a 30-s Wingate test			NS	↑ at SWR and ER	NS	17:00 h	-	NR

Aziz et al., [72]	Trained subjects (martial art sports)	18.9 ± 1.1	Wt during 6 bouts of a 30-s Wingate test with 4-min in-between	08:00 h 18:00 h 21:00 h	BR ER	↓	↓ at 18:00 h and 21:00 h	NS	NS	-	-
			T <sub>exh</sub> cycle at 4% of the individuals' body mass			↓	↓ at 18:00 h	NS	NS	-	-
Aloui et al., [16]	Soccer players	20.1 ± 1.6	Oral temperature	07:00 h 17:00 h	BR SWR ER Two weeks AR	NS	↓ during ER	17:00 h	17:00h	NR	NR
			MVC			NS	↓ during SWR and ER	17:00 h	NS	NR	NR
			MVC after 5 × 6-s RSA with 24-s in-between			NS	NS	NS	NS	-	-
			MVC 5-min after 5 × 6-s RSA with 24-s in-between			NS	NS	NS	NS	-	-
			PP during 5 × 6-s RSA with 24-s in-between			NS	↓ during SWR and ER	17:00 h	NS	NR	-
			Wt during 5 × 6-s RSA with 24-s in-between			NS	NS	NS	NS	-	-
			P <sub>dec</sub> during 5 × 6-s RSA with 24-s in-between			NS	↓ during SWR and ER	17:00 h	NS	NR	-
			Percentage of MVC decrement between before and after 5 × 6-s RSA with 24-s in-between			NS	↓ during SWR and ER	17:00 h	NS	NR	-
RPE after 5 × 6-s RSA with 24-s in-between	NS	↑ during SWR and ER	NS	17:00 h	-	NR					

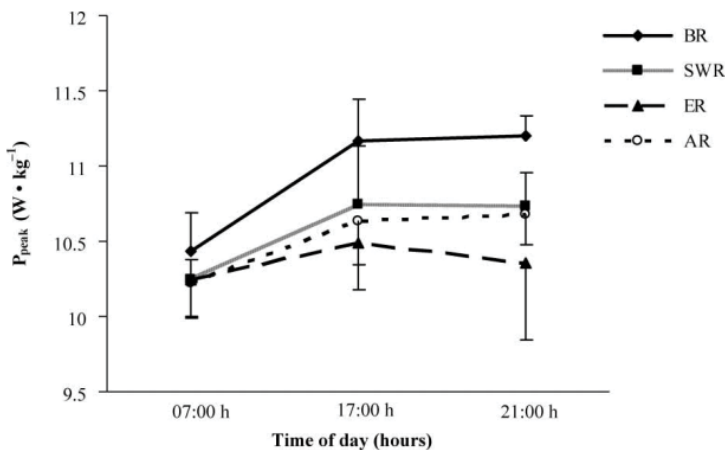
**Table 1:** Effect of Ramadan fasting on the diurnal variations in athletic performance, oral temperature, and ratings of perceived exertion.

P<sub>max</sub>: Maximal Power during the Force-Velocity Test; F<sub>0</sub>: The Braking Force corresponding to Zero Velocity; V<sub>0</sub>: Maximal Velocity at Zero Braking Force; PP: Peak Power during the 30 second Wingate Test; MP: Mean Power during the 30 second Wingate Test; FI: Fatigue Index during the 30 second Wingate Test; Wt: Total Work; P<sub>dec</sub>: Power Decrement; TD: Total Distance; HR<sub>max</sub>: Maximal Heart Rate; RPE: Ratings of Perceived Exertion; T<sub>exh</sub>: Time to Exhaustion; MVC: Maximal Voluntary Contraction; RSA: Repeated Sprint Ability; BR: Before Ramadan; FWR: First Week of Ramadan; SWR: Second Week of Ramadan; ER: End Ramadan; AR: After Ramadan; NS: No-Significant; NR: Not-Reported. ↓: Decrement; ↑: Increase

Souissi et al., [19] investigated the effect of Ramadan fasting on the diurnal variation in short-term maximal performance. The authors recorded oral temperature, maximal power

during a force-velocity test, and peak and mean powers during a 30 s Wingate test at 07:00 h, 17:00 h, and 21:00 h before Ramadan, during the second week of Ramadan, during the fourth week of Ramadan, and two weeks after Ramadan. During this study, the length of each fasting day was ~12-13 hours and Ramadan started on October 4<sup>th</sup> and ended on November 3<sup>rd</sup>, 2004, corresponding to *Iftar* times ranging 17:24 h to 17:44 h for the daylight timings of first and last days of Ramadan, respectively.

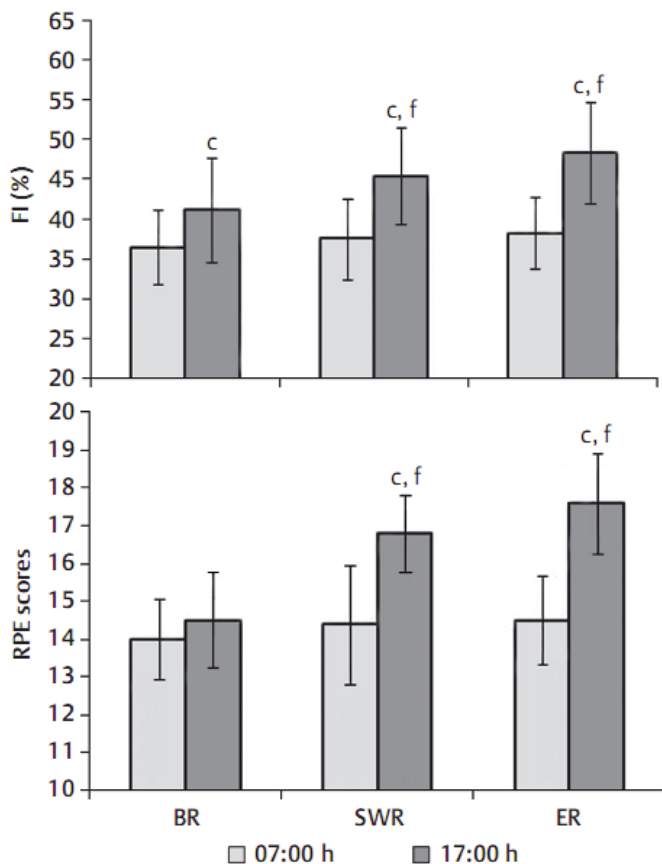
The authors reported significant time-of-day effect on oral temperature, maximal power, peak power, and mean power before Ramadan. These diurnal variations were maintained during Ramadan for oral temperature with a reduction in the amplitude of the rhythm (0.9°C vs. 0.6°C before and during Ramadan, respectively). Moreover, this study showed that Ramadan fasting negatively affected the afternoon performance (i.e., at 17:00 h). However, no significant changes were observed in morning performance (Figure 2). This reduction in the evening performance affected the typical diurnal variation in short-term maximal performance observed before Ramadan. The performance decrement reported in the afternoon could be, in part, explained by the duration of fast. Indeed, during this investigation, subjects fasted from 01:30 h (end of *Sohour* time) resulting, therefore, in ~5-6 hours of fast before the morning tests and ~15-16 hours of fast before the evening tests.



**Figure 2:** Peak power ( $P_{peak}$ ) during a 30 s Wingate test recorded at ~07:00 h, 17:00 h, and 21:00 h Before Ramadan (BR), during the Second Week of Ramadan (SWR), at the End of Ramadan (ER), and two weeks After Ramadan (AR) (drawn from data in Souissi et al., [19]).

In the same context, Chtourou et al., [17] investigated the effect of Ramadan fasting on the diurnal variations in muscle power and fatigue in soccer players. The authors recorded peak and mean power as well as the fatigue index during a 30 s Wingate test at 07:00 h and 17:00 h before Ramadan and during the second and the fourth weeks of Ramadan. Moreover, ratings of perceived exertion were obtained immediately after the Wingate test. The study was carried out from August 11<sup>th</sup> to September 10<sup>th</sup>, 2010 with a fasting duration of ~15-16 hours per day. The authors reported higher muscle power and fatigue during the Wingate test before Ramadan at 17:00 h. However, these diurnal variations were maintained for the fatigue index (Figure 3) and disappeared during Ramadan by a decrease in the evening performance (i.e., there was no change in the morning performance). Furthermore, the authors showed an increase in ratings of perceived exertion during Ramadan in comparison with before Ramadan (Figure 3). Thus, the impairment in the evening performance during Ramadan could be, in part, explained by a higher muscle fatigue at this time-of-day in fasting conditions.





**Figure 3:** Fatigue Index (FI) and Rating of Perceived Exertion (RPE) scores recorded during a 30 second Wingate test at 07:00 h and 17:00 h Before Ramadan (BR), during the Second Week of Ramadan (SWR) and at the End of Ramadan (ER) (drawn from data in Chtourou et al., [17]). c: significant time-of-day effect; f: significant Ramadan effect.

Recently, Aloui et al., [16] investigated the effect of Ramadan fasting on the diurnal variation in performance during a Repeated Sprint Exercise (RSE: 5×6 s maximal cycle sprints interspersed with a 24 s passive recovery) as well as muscle fatigue induced by this exercise (i.e., power decrement and difference between Maximal Voluntary Contractions (MVC) recorded before, immediately and 5 min after the RSE). The authors measured oral temperature, MVC, and peak power and total work during the RSE, and recorded Ratings of Perceived Exertion (RPE) after exercise. Moreover, they calculated the percentage of power decrement during the RSE and the percentage of decrement in MVC from before to after the RSE. The tests were performed at ~07:00 h and 17:00 h before Ramadan, during the second week of Ramadan, at the end of Ramadan, and two weeks after Ramadan. The study was carried out when Ramadan began on August 11<sup>th</sup> and ended on September 10<sup>th</sup>, 2010 and the fasting duration was ~14-15 hours, with *Iftar* occurring at ~19:06 h and ~18:40 h for the first and last days of Ramadan, respectively. During this study, subjects took their last meal at ~01:00-h AM Before Ramadan, Aloui et al., [16] showed that oral temperature, the first sprint's peak power, resting maximal voluntary contraction, power decrement during RSE, and the difference between MVC measured before and after the RSE were time-of-day dependent with higher values observed at 17:00 h compared to 07:00 h. RPE scores obtained after the RSE were not significantly different between the two times-of-testing before Ramadan. During Ramadan, the diurnal variations in physical performances

disappeared by decreased muscle strength and power in the evening hours, while morning performance and fatigue were not adversely affected by Ramadan fasting. Moreover, this study showed a significant increase in RPE scores during Ramadan in the evening with values being significantly higher at 17:00 h compared to 07:00 h [16]. The authors concluded that Ramadan circadian rhythm alterations in core temperature, hypohydration, disturbances of the sleep-wake cycle, and fatigue may explain performance impairments reported in the afternoon during this month. The reduced body mass observed in the afternoon compared to the morning could be related to the hypohydration and could have contributed to the evening performance decrements.

In conclusion, the diurnal rhythmicity of athletic performance typically observed before Ramadan tended to disappear during the fasting month by a decreased performance in the afternoon but not in the morning hours. However, the observed impairment in the afternoon performance is relatively small and could be explained by several factors such as the selection of the subjects (e.g., physical education students in the study of Souissi et al., [19] and soccer players in the studies of Hamouda et al., [18], Chtourou et al., [17], and Aloui et al., [16] and the timing of testing (exact time of day, and timing of testing during Ramadan with respect to the whole year' training schedule). Indeed, during the studies of Hamouda et al., [18], Chtourou et al., [17], and Aloui et al., [16], test sessions were performed in the off-season period and the impairment of the afternoon performance could be explained by the reduced training load and/or detraining observed at this period. For any further studies on the circadian rhythm of performance measures during Ramadan, the present chapter's authors advice to take into account:

1. The body mass variations over the month and over the time-of-day, with special reference to fat free mass.
2. The food and fluid intake, with related status of hydration (urine osmolarity measures, urine specific gravity measures and urine color monitoring).
3. General physical activity and training load underwent by the subjects/athletes and their training status (amateurs, professionals, sub-elite, elite etc ...).
4. The period of the year with respect to their training schedule.
5. Body temperature variations over the day.
6. Precise testing timing with respect to specific Ramadan moments referring to *Sohour* and *Iftar* times (and corresponding daylight at the place of the study).
7. Measure general fatigue/recovery index as contained in some validated tests (e.g., Hooper index [70]) assessing perceived: 1- quality and quantity of sleep 2- stress, 3- DOMS (delayed onset muscle Soreness), and 4 – general fatigue.
8. Assess training load and the rating of perceived exertion of the standardized testing sessions.

## Conclusion

To date, the effect of Ramadan fasting on athletic performance is a subject of debate. Indeed, while some studies reported a significant negative effect of Ramadan on athletic performance, it is generally accepted that these changes are minor and typically observed when tests are conducted in the afternoon just before sunset. However, athletic performance has not been shown to be adversely affected when tests were scheduled in the morning hours. The main observed effects were that the morning-evening differences in athletic performance measured before Ramadan were reduced and/or suppressed during Ramadan.

The effects of Ramadan fasting on athletic performance depend on several factors including training status, competition demands, environmental conditions, and fasting duration.

In view of the above considerations, coaches and if possible, sport event organizers should be aware of the effect of Ramadan fasting on Muslim athletes, although the scheduling of major competitions is determined by several factors (e.g. Medias, etc). Moreover, the selection of the competition period during the daytime requires consideration especially in events when competitions are held on successive days or when multiple competitions are held on a single day. Fasting athletes who are training or competing should minimize disruptions of their lifestyle during Ramadan by following some of the recommendations published elsewhere [64,73].

## References

1. Souissi N, Zouita A, Chtourou H, Ferchichi H, Dziri C, et al. (2013) The effect of Ramadan intermittent fasting on dynamic postural control in judo athletes. *Biological Rhythm Research*. DOI: 10.1080/09291016.2013.787759
2. Souissi N, Chtourou H, Zouita A, Dziri C, Souissi N (2013) Effects of Ramadan intermittent fasting on postural control in judo athletes. *Biological Rhythm Research* 44: 237-244.
3. Aloui A, Chtourou H, Hammouda O, Chaouachi A, Chamari K, et al. (2013) The challenge of rapid weight loss prior to competition for Muslim combat sport athletes during Ramadan. *Biological Rhythm Research*. DOI: 10.1080/09291016.2013.780698
4. El-Khatib AH, Tolbert TA and McIlvain GE (2012) Participation of Muslim Athletes During the Month of Ramadan. *International Journal of Athletic Therapy & Training* 17: 41-45.
5. Wilson D, Drust B, and Reilly TR (2009) Is diurnal lifestyle altered during Ramadan in professional Muslim athletes? *Biological Rhythm Reserach* 40: 385-397.
6. Maughan RJ (2010) Fasting and sport: an introduction. *Br J Sports Med* 44: 473-475.
7. Laraqui CH, Tripodi D, Laraqui O, Rahhali A, Caubet A, et al. (2001) The effects of fasting and of the quality of sleep on work during the month of Ramadan. *Archives des Maladies Professionnelles de Médecine du Travail* 62: 115-120.
8. Roky R, Chapotot F, Hakkou F, Benchekroun MT, Buguet A (2001) Sleep during Ramadan intermittent fasting. *J Sleep Res* 10: 319-327.
9. Bahammam A (2006) Does Ramadan fasting affect sleep? *Int J Clin Pract* 60: 1631-1637.
10. Abdelmalek S, Souissi N, Chtourou H, Denguezli M, Aouichaoui C, et al. (2013) Effects of partial sleep deprivation on proinflammatory cytokines, growth hormone, and steroid hormone concentrations during repeated brief sprint interval exercise. *Chronobiol Int* 30: 502-509.
11. HajSalem M, Chtourou H, Aloui A, Hammouda O, Souissi N (2013) Effects of partial sleep deprivation at the end of the night on anaerobic performances in judokas. *Biological Rhythm Research*. DOI: 10.1080/09291016.2012.756282
12. Rebai H, Chtourou H, Zarrouk N, Harzallah A, Kanoun I, et al. (2013) Reducing resistance training volume during Ramadan improves muscle strength and power in football players. *International Journal of Sports Medicine*.
13. Aloui A, Chtourou H, Masmoudi L, Chaouachi A, Chamari K, et al. (2012) Effects of Ramadan fasting on male judokas' performances in specific and non-specific judo tasks. *Biological Rhythm Research* 44: 645-654.
14. Chtourou H, Hammouda O, Souissi H, Chamari K, Chaouachi A, et al. (2011) The effect of ramadan fasting on physical performances, mood state and perceived exertion in young footballers. *Asian J Sports Med* 2: 177-185.
15. Zarrouk N, Hug F, Hammouda O, Rebai H, Tabka Z, et al. (2013) Effect of Ramadan intermittent fasting on body composition and neuromuscular performance in young athletes: a pilot study. *Biological Rhythm Research*. DOI: 10.1080/09291016.2012.730891
16. Aloui A, Chaouachi A, Chtourou H, Wong del P, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated-sprint performances. *Int J Sports Physiol Perform* 8: 254-262.
17. Chtourou H, Hammouda O, Chaouachi A, Chamari K, Souissi N (2012) The effect of time-of-day and Ramadan fasting on anaerobic performances. *Int J Sports Med* 33: 142-147.

18. Hammouda O, Chtourou H, Farjallah MA, Davenne D, and Souissi N (2012) The effect of Ramadan fasting on the diurnal variations in aerobic and anaerobic performances in Tunisian youth soccer players. *Biological Rhythms Research* 43: 177-190.
19. Souissi N, Souissi H, Sahli S, Tabka Z, Dogui M, et al. (2007) Effect of Ramadan on the diurnal variation in short-term high power output. *Chronobiol Int* 24: 991-1007.
20. Chtourou H, Aloui A, Hammouda O, Chaouachi A, Chamari K et al. (2013) The effect of time-of-day and judo match on short-term maximal performances judokas. *Biological Rhythm Research*. DOI: 10.1080/09291016.2012.756269
21. Chtourou H, Chaouachi A, Driss T, Dogui M, Behm DG, et al. (2012) The effect of training at the same time of day and tapering period on the diurnal variation of short exercise performances. *J Strength Cond Res* 26: 697-708.
22. Chtourou H, Chaouachi A, Hammouda O, Chamari K, Souissi N (2012) Listening to music affects diurnal variation in muscle power output. *Int J Sports Med* 33: 43-47.
23. Chtourou H, Zarrouk N, Chaouachi A, Dogui M, Behm DG, et al. (2011) Diurnal variation in Wingate-test performance and associated electromyographic parameters. *Chronobiol Int* 28: 706-713.
24. Chtourou H, Driss T, Souissi S, Gam A, Chaouachi A, et al. (2012) The effect of strength training at the same time of the day on the diurnal fluctuations of muscular anaerobic performances. *J Strength Cond Res* 26: 217-225.
25. Chtourou H, Hammouda O, Souissi H, Chamari K, Chaouachi A, et al. (2012) Diurnal variations in physical performances related to football in young soccer players. *Asian J Sports Med* 3: 139-144.
26. Chtourou H, Souissi N (2012) The effect of training at a specific time of day: a review. *J Strength Cond Res* 26: 1984-2005.
27. Chtourou H, Hammouda O, Aloui A, Chaabouni K, Makni-Ayedi F, et al. (2013) The effect of time of day on hormonal responses to resistance exercise. *Biological Rhythm Research*. DOI: 10.1080/09291016.2013.805909
28. Hammouda O, Chtourou H, Chahed H, Ferchichi S, Kallel C, et al. (2011) Diurnal variations of plasma homocysteine, total antioxidant status, and biological markers of muscle injury during repeated sprint: effect on performance and muscle fatigue—a pilot study. *Chronobiol Int* 28: 958-967.
29. Jarraya M, Jarraya S, Chtourou H, Souissi N (2013) The effect of the partial sleep deprivation on the reaction time and the attentional capacities of the handball goalkeeper. *Biological Rhythm Research* 44: 503-510.
30. Jarraya S, Jarraya M, Chtourou H, Souissi N (2013) Diurnal variations on cognitive performances in handball goalkeepers. *Biological Rhythm Research*. DOI: 10.1080/09291016.2013.811032
31. Jarraya S, Jarraya M, Chtourou H, Souissi N (2013) Effect of time of day and partial sleep deprivation on the reaction time and the attentional capacities of the handball goalkeeper. *Biological Rhythm Research*. DOI: 10.1080/09291016.2013.787685
32. Atkinson G, Coldwells A, Reilly T, Waterhouse J (1993) A comparison of circadian rhythms in work performance between physically active and inactive subjects. *Ergonomics* 36: 273-281.
33. Souissi N, Gauthier A, Sesboüé B, Larue J, Davenne D (2004) Circadian rhythms in two types of anaerobic cycle leg exercise: force-velocity and 30-s Wingate tests. *Int J Sports Med* 25: 14-19.
34. Hammouda O, Chtourou H, Chahed H, Ferchichi S, Chaouachi A, et al. (2012) High intensity exercise affects diurnal variation of some biological markers in trained subjects. *Int J Sports Med* 33: 886-891.
35. Souissi M, Chtourou H, Hdidar R, Azaeiz R, Dogui M, et al. (2012) Effects of three types of chronobiotics on anaerobic performances and their diurnal variations. *Biological Rhythm Research* 44: 245-254.
36. Souissi M, Abedmalek S, Chtourou H, Atheymen R, Hakim A, et al. (2012) Effects of morning caffeine' ingestion on mood States, simple reaction time, and short-term maximal performance on elite judoists. *Asian J Sports Med* 3: 161-168.
37. Souissi N, Chtourou H, Aloui A, Hammouda O, Dogui M, et al. (2013) Effects of Time-of-Day and Partial Sleep Deprivation on Short-Term Maximal Performances of Judo Competitors. *J Strength Cond Res* 27: 2473-2480.
38. Souissi H, Chtourou H, Chaouachi A, Dogui M, Chamari K, et al. (2012) The effect of training at a specific

- time-of-day on the diurnal variations of short-term exercise performances in 10- to 11-year-old boys. *Pediatr Exerc Sci* 24: 84-99.
39. Hammouda O, Chtourou H, Chaouachi A, Chahed H, Bellimem H, et al. (2013) Time-of-day effects on biochemical responses to soccer-specific endurance in elite Tunisian football players. *J Sports Sci* 31: 963-971.
  40. Souissi M, Chtourou H, Zrane A, Ben Cheikh R, Dogui M, et al. (2012) Effect of time-of-day of aerobic maximal exercise on the sleep quality of trained subjects. *Biological Rhythm Research* 43: 323-330.
  41. Hammouda O, Chtourou H, Chahed H, Ferchichi S, Kallel C, et al. (2011) Diurnal variations of plasma homocysteine, total antioxidant status, and biological markers of muscle injury during repeated sprint: effect on performance and muscle fatigue—a pilot study. *Chronobiol Int* 28: 958-967.
  42. Zarrouk N, Chtourou H, Rebai H, Hammouda O, Souissi N, et al. (2012) Time of day effects on repeated sprint ability. *Int J Sports Med* 33: 975-980.
  43. Zarrouk N, Chtourou H, Zarrouk I, Rebai H, Tabka Z, et al. (2012) Variations diurnes des performances en natation : effet de la température de l'eau. *Science & Sports*. 27:101–106.
  44. Chtourou H, Hammouda O, Aloui A, Souissi N (2013) Effect of time-of-day on muscle fatigue: a review. *J Nov Physiother* 3: 160. doi:10.4172/2165-7025.1000160
  45. Lericollais R, Gauthier A, Bessot N, Sesboüé B, Davenne D (2009) Time-of-day effects on fatigue during a sustained anaerobic test in well-trained cyclists. *Chronobiol Int* 26: 1622-1635.
  46. Lericollais R, Gauthier A, Bessot N, Davenne D (2011) Diurnal evolution of cycling biomechanical parameters during a 60-s Wingate test. *Scand J Med Sci Sports* 21: 106-114.
  47. Souissi H, Chtourou H, Chaouachi A, Chamari K, Souissi N, et al. (2012) Time-of-day effects on EMG parameters during the Wingate test in boys. *Journal of Sports Science and Medicine* 11: 380-386.
  48. Racinais S, Perrey S, Denis R, Bishop D (2010) Maximal power, but not fatigability, is greater during repeated sprints performed in the afternoon. *Chronobiol Int* 27: 855-864.
  49. Deschenes MR, Sharma JV, Brittingham KT, Casa DJ, Armstrong LE, et al. (1998) Chronobiological effects on exercise performance and selected physiological responses. *Eur J Appl Physiol Occup Physiol* 77: 249-256.
  50. Dalton B, McNaughton L, Davoren B (1997) Circadian rhythms have no effect on cycling performance. *Int J Sports Med* 18: 538-542.
  51. Edwards BJ, Edwards W, Waterhouse J, Atkinson G, Reilly T (2005) Can cycling performance in an early morning, laboratory-based cycle time-trial be improved by morning exercise the day before? *Int J Sports Med* 26: 651-656.
  52. Bessot N, Moussay S, Gauthier A, Larue J, Sesboüé B, et al. (2006) Effect of pedal rate on diurnal variations in cardiorespiratory variables. *Chronobiol Int* 23: 877-887.
  53. Abdelmalek S, Chtourou H, Aloui A, Aouichaoui C, Souissi N, et al. (2013) Effect of time of day and partial sleep deprivation on plasma concentrations of IL-6 during a short-term maximal performance. *Eur J Appl Physiol* 113: 241-248.
  54. Abdelmalek S, Chtourou H, Souissi N, Tabka Z (2013) Effect of time-of-day and racial variation on short-term maximal performance. *Biological Rhythm Research*. DOI: 10.1080/09291016.2012.756261
  55. Chtourou H, Aloui A, Hammouda O, Chaouachi A, Chamari K, et al. (2013) Effect of static and dynamic stretching on the diurnal variations of jump performance in soccer players. *PLoS One* 8: 70534.
  56. Chaouachi A, Coutts AJ, Chamari K, Wong del P, Chaouachi M, et al. (2009) Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. *J Strength Cond Res* 23: 2702-2709.
  57. Kirkendall DT, Leiper JB, Bartagi Z, Dvorak J, Zerguini Y (2008) The influence of Ramadan on physical performance measures in young Muslim footballers. *J Sports Sci* 26: 15-27.
  58. Aloui A, Chtourou H, Hammouda O, Souissi H, Chaouachi A, et al. (2013) Effects of Ramadan on the diurnal variations of physical performance and perceived exertion in adolescent soccer players. *Biological Rhythm*

59. Chaouachi A, Leiper JB, Souissi N, Coutts AJ, Chamari K (2009) Effects of Ramadan intermittent fasting on sports performance and training: a review. *Int J Sports Physiol Perform* 4: 419-434.
60. Chaouachi A, Leiper JB, Chtourou H, Aziz AR, Chamari K (2012) The effects of Ramadan intermittent fasting on athletic performance: recommendations for the maintenance of physical fitness. *J Sports Sci* 30: 53-73.
61. Güvenç A (2011) Effects of ramadan fasting on body composition, aerobic performance and lactate, heart rate and perceptual responses in young soccer players. *J Hum Kinet* 29: 79-91.
62. Bouhlel H, Shephard RJ, Gmada N, Aouichaoui C, Peres G, et al. (2013) Effect of Ramadan observance on maximal muscular performance of trained men. *Clin J Sport Med* 23: 222-227.
63. Karli U, Guvenç A, Aslan A, Hazir T and Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *Journal of Sports Science and Medicine* 6: 490-497.
64. Maughan RJ, Zerguini Y, Chalabi H, Dvorak J (2012) Achieving optimum sports performance during Ramadan: some practical recommendations. *J Sports Sci* 30: 109-117.
65. Roky R, Chapotot F, Benchekroun MT, Benaji B, Hakkou F, et al. (2003) Daytime sleepiness during Ramadan intermittent fasting: polysomnographic and quantitative waking EEG study. *J Sleep Res* 12: 95-101.
66. Waterhouse J, Alabed H, Edwards B and Thomas R (2009) Changes in sleep, mood and subjective and objective responses to physical performance during the daytime in Ramadan. *Biological Rhythm Research* 40: 367-383.
67. Singh R, Hwa OC, Roy J, Jin CW, Ismail SM, et al. (2011) Subjective Perception of Sports Performance, Training, Sleep and Dietary Patterns of Malaysian Junior Muslim Athletes during Ramadan Intermittent Fasting. *Asian J Sports Med* 2: 167-176.
68. Meckel Y, Ismaeel A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *Eur J Appl Physiol* 102: 651-657.
69. Zerguini Y, Kirkendall D, Junge A, Dvorak J (2007) Impact of Ramadan on physical performance in professional soccer players. *Br J Sports Med* 41: 398-400.
70. Hooper SL, Mackinnon LT, Howard A, Gordon RD, Bachmann AW (1995) Markers for monitoring overtraining and recovery. *Med Sci Sports Exerc* 27: 106-112.
71. Roky R, Iraki L, HajKhlifa R, Lakhdar Ghazal N, Hakkou F (2000) Daytime alertness, mood, psychomotor performances, and oral temperature during Ramadan intermittent fasting. *Ann Nutr Metab* 44: 101-107.
72. Aziz AR, Chia MY, Low CY, Slater GJ, Png W, et al. (2012) Conducting an acute intense interval exercise session during the Ramadan fasting month: what is the optimal time of the day? *Chronobiol Int* 29: 1139-1150.
73. Kirkendall DT, Chaouachi A, Aziz AR, Chamari K (2012) Strategies for maintaining fitness and performance during Ramadan. *J Sports Sci* 30: 103-108.

## Chapter 20

# Injury Rate during Ramadan

**Karim Chamari<sup>\*1,2</sup>, Monoem Haddad<sup>2,3</sup>, Hamdi Chtourou<sup>2</sup>, Christopher Herrera<sup>1</sup> and Cristiano Eirale<sup>4</sup>**

<sup>1</sup>Research and Education Department, ASPETAR, Qatar Orthopaedic and Sport Medicine Hospital, Doha, Qatar

<sup>2</sup>Tunisian Research Laboratory "Sport Performance Optimization", National Center of Medicine and Science in Sports (CNMSS), Tunis, Tunisia

<sup>3</sup>University of Jandouba, ISSEP Kef, Tunisia

<sup>4</sup>Sport Medicine Department, ASPETAR, Qatar Orthopaedic and Sport Medicine Hospital, Doha, Qatar

**\*Corresponding author:** Professor Karim Chamari, Doctor in Exercise Physiology, Research Scientist, Research & Education Centre, ASPETAR, P.O. Box 29222, Doha, Qatar, Tel: (+974) 3318 6096; Fax: (+974) 441 32020; E-mail: [www.aspetar.com](http://www.aspetar.com)

## Introduction

Injury surveillance studies are an integral part in the effort to protect athletes' health in various sports activities. Furthermore, injury risk is a major concern for athletes and clubs in terms of health, safety, performance, and cost. Data in scientific literature must be made available through an effective injury surveillance system, and therefore better knowledge of the factors that affect injury will always be needed. There is also a need to identifying the injury risks and their respective dependent and independent variables, which are expected to differ in each specific population. Therefore epidemiological and etiological injury data for various sport activities need to be captured.

Investigations describing injury risk and patterns are usually conducted over seasons of European, Asian or American Leagues [1-3] obviously out of holy month of Ramadan or without taking into account the intermittent fasting occurring during Ramadan.

To our knowledge, only two studies [4,5] have focused on the injury-rates of Muslim athletes during the holy month of Ramadan. More specifically, these studies focused on soccer' injuries in order to improve the knowledge in that field in view of the preparation for the Olympics 2012 and the FIFA World Cup 2014 being organized during the Ramadan period. In this context, there is a debate on the possible effects of fasting and the other modifications of life pattern during Ramadan on injury risks. The present chapter is therefore focused on the effects of Ramadan on the injury rates in soccer, pending other studies to be conducted in other sport activities.

The main aim of the present book chapter is to present and discuss the athletes' injury rate during Ramadan and its related possible causes. It is hoped that by providing such analysis, coaches and scientists will better understand the impact of Ramadan fasting and choose an efficient planning and manipulation of the player's internal training load and life-style modifications during the Ramadan period to try to reduce the players' risks of injuries.

## Ramadan Characteristics

During Ramadan, fasting Muslims do not eat, drink, smoke, or have sexual activities daily from dawn (*Sahur*) to sunset (*Iftar*). Since the Islamic Calendar is based on the lunar cycle, which advances 11 days each year compared with the standard Gregorian calendar, Ramadan falls at different times of the seasonal year over a 33 year cycle [6]. This implies that Ramadan occurs at different environmental conditions between years in the same country [7,8]. Furthermore, depending on the seasonal and geographical conditions, fasting may vary from ~11 to ~18 hours per day.

It is supposed that most Muslim soccer players fast during Ramadan, even if some exceptions are observed. Ramadan fasting is intermittent in nature, and there is no restriction to the amount of food or fluid that can be consumed after dusk and before dawn. Therefore, since the international sporting calendar is not adapted for religious observances, and Muslim soccer players continue to compete and train during Ramadan, various studies have determined whether this religious fast has any effect on athletic performance [6] and cognitive functions [9,10]. These have suggested that only few aspects of physical fitness are negatively affected, and only modest decrements are observed when physical performance is considered on the basis of fitness testing [6]. The evidence to date indicates that high-level athletes can maintain most of the performance measures during Ramadan if physical training, diet, and sleep are well controlled. Nevertheless, despite this, fasting athletes have reported higher fatigue feelings at the end of Ramadan [6,11]. This could have a possible effect on injury rate during or at the end of the month of Ramadan.

The increased perception of fatigue reported at the end of Ramadan fasting and the combination of intense training with altered carbohydrate intake, hydration-status, and sleeping pattern may place fasting Muslim athletes at greater risk of overreaching or overtraining [12,13] which could result in physical injury specifically overuse injuries [14]. Most previous studies determined whether the holy month of Ramadan has any detrimental effect on performance and cognitive functions, but to our knowledge, only the studies of Chamari et al., [4] and Eirale et al., [5] have examined the impact of the month of Ramadan and its specific socio-cultural and religious environment on the injury rates of professional soccer players. The first was a pilot study while the second was a prospective cohort study. Both of them presented results on the injury rates between fasting and non-fasting players within teams before, during, and after the month of Ramadan in professional football teams during consecutive seasons.

## Studies Conditions

The study of Chamari et al., [4] was carried out during two consecutive seasons to investigate the injury rates senior professional soccer players in Tunisia. For this study, fasting status was determined only at the end of the Ramadan month using a personal interview with each player and discrete cross-checking with the player's team-mates and whenever possible with family members and/or friends. The players were retrospectively organized into fasting and non-fasting groups based on this information. The fasting group consisted of all players who fasted throughout the Ramadan month and the non-fasting group consisted of players who opted not to fast throughout the Ramadan month for both training and match days. All Muslim players who fasted in the study of Chamari et al., [4] had practiced the fast during Ramadan for at least the previous 7 years. Goalkeepers were included in the study. The studied team was competing at the highest level in the Tunisian first league and also participated in the African Cup of teams (CAF Cup) during the second season of the study. During this study, Ramadan occurred from 10<sup>th</sup> August to 11<sup>th</sup> of September 2010 and from 1<sup>st</sup> to 30<sup>th</sup> of August 2011, respectively, where the daily fast occurred from ~04 h to ~19.15 h, for a total fasting duration of ~15h 15min. All players were monitored for 4 weeks before Ramadan, for the month of Ramadan (4 weeks), and 4



weeks after Ramadan in each year. Training loads using the RPE-method [15], Hooper index [16] (i.e., Sum of individual's subjective well-being ratings relative to fatigue, stress, delayed onset muscle soreness (especially "heavy" legs), and sleep quality/disorders), and injuries were monitored in 42 professional soccer players (age,  $24 \pm 4$  years; height,  $185 \pm 8$  cm; body mass,  $78 \pm 4$  kg).

The prospective cohort study of Eirale et al., [5] was conducted during 3 consecutive seasons beginning in August 2008 and ending in April 2011 within male professional footballers from the Qatar Stars League (QSL) which is the senior professional first division football league in Qatar. According to the authors, the number of first division clubs increased from 10 to 12 after 2009. In Qatar, the soccer season lasts from July to April.

During both of the study of Chamari et al., [4] and Eirale et al., [5], injury data were considered when a player was unable to fully participate in any future soccer training sessions or matches owing to physical complaints [17]. Information about mechanism of injury (contact or noncontact), their etiology (acute trauma or overuse) and circumstances (training or match injury) were documented.

In this context, a traumatic injury refers to an injury resulting from a specific identifiable event, whereas an overuse injury was defined as an injury caused by repeated microtrauma without a single identifiable event responsible for the injury. Recurrent injuries were defined as an injury of the same diagnosis and at the same site, which occurred after a player's full return to participation from the same injury within a 2-month period. Injury severity was determined by the number of days of absence from games or training sessions due to injury and was further classified as mild (i.e., 1 to 3 days), minor (i.e., 4 to 7 days), moderate (i.e., 8 to 28), or severe injury (i.e., >28 days) [17].

During Ramadan, any game time between sunrise and sunset is generally avoided. Therefore, during the two studies [4,5], training sessions and matches were performed at least 2 to 3 hours after sunset (and thus *iftar*), allowing athletes to adequately replenish and rehydrate before starting sport activity. More specifically, during the study of Chamari et al., [4] training sessions and matches were performed after dusk (starting at 22 h) during Ramadan, while before and after Ramadan the sessions and matches were scheduled in the afternoon (starting at 15 or 16 h) and sometimes in the morning for training (for the days in which 2 training sessions were scheduled, starting at 09.30 h). It has to be noted that these double sessions' days remained exceptional. Also during the study of Eirale et al., [5], all clubs trained after sunset during Ramadan in all 3 seasons with absolutely no daytime football activity. Table 1 adapted from the prospective cohort study of Eirale et al., [5], shows the dates in which Ramadan occurred throughout the 3 seasons.

Season	2008 to 2009	2009 to 2010	2010 to 2011
Start Date	September 1, 2008	August 22, 2009	August 11, 2010
End Date	September 30, 2008	September 20, 2009	September 9, 2010

**Table 1:** Ramadan Time Frame for the three Seasons controlled according to Eirale et al., [5].

Chamari et al., [18] have more monitored ambient temperature, atmospheric pressure, and relative humidity which were measured for each training session (Table 2).

The duration of data collection over a 3 year period in the study of Eirale et al., [5] was limitation for this study. Ramadan falls on different months of the year over a 33 year cycle because it shifts 1 to 2 weeks earlier each year [19]. This seasonal shift impacts the environmental conditions, and the length of the daytime fasting period cannot be controlled. Injury data from Ramadan occurring in all year periods, would permit the elimination of potential bias arising from seasonal variation of injuries, as previously shown in soccer [20].

	Year	Ambient temperature (C°)	Atmospheric pressure (mmHg)	Relative humidity (%)
Before Ramadan	2010	28.83 (1.72)	1012.33 (2.25)	44.00 (5.02)
	2011	31.31 (5.38)	1011.38 (3.10)	39.15 (13.61)
Ramadan	2010	27.60 (4.04)	1014.20 (2.05)	55.80 (8.44)
	2011	24.50 (1.29)	1014.50 (2.65)	64.50 (6.56)
After Ramadan	2010	25.25 (2.06)	1014.00 (3.83)	61.50 (8.66)
	2011	28.50 (1.29)	1013.25 (3.10)	63.25 (8.54)

Values are mean (SD)

**Table 2:** Environmental conditions, table adapted from the study of Chamari et al., [4].

## Monitoring of Training Loads and Overtraining

During the prospective cohort study of Eirale et al., [5], only the training sessions' duration was recorded due to the study design. However, Eirale et al., [5] supposed that intensity may potentially be adjusted by coaches to avoid injuries, becoming a possible confounding factor. No prospective data collection of actual dietary, sleep habits, body composition, and training characteristics were present in this study. These factors might potentially have had their influences and authors recommended to examine them in future studies.

On other hand, in the study of Chamari et al., [4], daily individual training load was calculated using Foster's session-RPE procedure [21]. This method involves multiplying the training duration in minutes by the mean training intensity. As the players involved were all French speaking subjects, the session-RPE scale was based on the validated French translation of the Borg category ratio (CR-10) [18], which converts the player's perception of effort into a numerical score between 0 and 10. This method has been validated previously in soccer by Impellizzeri et al., [15]. Practically, the player is asked to respond to a simple question – How was your workout? – with the aim of obtaining an uncomplicated response that reflects the athlete's global impression of the workout. All players were familiarized with this scale for at least one month before the start of the study and followed standardized instructions for session-RPE assessments. Each player's session - RPE was collected approximately 20-30 min after each soccer training session and match to ensure that the perceived exertion referred to the whole training session and match rather than the most recent (end-of session) exercise intensity [15].

Overtraining syndrome was monitored by Hooper's Index [16]. This method is based on self-analysis questionnaires involving well-being ratings relative to fatigue, stress, delayed-onset muscle soreness (especially "heavy" legs), and sleep quality/disorders [16].

Before each training session and match, the players were asked to rate subjective quality of sleep, and quantity of stress, delayed-onset muscle soreness, and fatigue on a scale of 1-7 in accordance with Hooper and Mackinnon (1995) [16]. Hooper's Index is the sum of the four subjective ratings. Recently, Haddad et al., [22,23] have shown the absence of possible influence of the Hooper's Index and duration on RPE in professional soccer. Therefore, it is recommended that future studies use both the Hooper's index and session-RPE method as independent tools to closely monitor the players' training loads [4].

In that study [4], dietary composition was not assessed but body composition did not significantly change over the monitored months.

## Injury Rates

During both studies [4,5] injury rate was calculated as the ratio of the number of injuries per hour of exposure and expressed as the rate per 1000 hours.

The first study [4] has shown that rates of non-contact injuries and overuse injuries were significantly higher during training in fasting players during the two months of Ramadan

monitored with 84.21% out of total injuries observed, compared with before and after the holy month with only 22.22% of total muscle injuries in both cases.

For these two months of Ramadan [4], the overuse injuries were distributed as follows: muscle spasms (contractures) 43.75%, tendinopathy 43.75%, and muscle strains (one tear at the hamstrings and one strain at the thigh-adductors) 12.5%. The 7 contractures were located at the hamstrings (42.86%), calf muscles (28.57%), thigh-adductors (14.29%), and knee extensors (14.29%). The tendinopathy injuries were located at the thigh-adductors (42.86%) and foot quadriceps (14.29%), with the remaining tendinopathy injuries (42.86%) located at the abdomen and pelvis. The foremost result of the study of Chamari et al., [4] was the absence of significant difference between non-fasting and fasting players with regard to general injury rates, while the training overuse injury rates were significantly higher during Ramadan than before and after-Ramadan periods for the fasting players (Table 3). Overall, during the fasting months, only one goalkeeper got one injury in a traumatic training injury (ankle sprain) about three weeks before Ramadan.

	Before Ramadan *		Ramadan *		After Ramadan *	
	Fasting	Non-Fasting	Fasting	Non-Fasting	Fasting	Non-Fasting
Injury rate	3.3 (-0.3-6.8)	1.7 (-1.9-5.2)	8.1 (4.5-11.6)	3.9 (0.3-7.4)	4.5 (0.9-8.1)	1.6 (-2.0-5.1)
Rate of contact injury	2.7 (-0.9-6.3)	1.1 (-2.5-4.7)	1.3 (-2.3-4.9)	0.7 (-2.9-4.3)	3.4 (-0.2-7.0)	1.6 (-2.1-5.1)
Rate of non-contact injury	0.6 (-2.2-3.3)	0.6 (-2.2-3.3)	6.8 <sup>b</sup> (4.0-9.5)	3.2 (0.4-5.9)	1.1 (-1.7-3.9)	0 (-2.8-2.8)
Rate of contact injury during matches	1.6 (-0.8-4.1)	1.1 (-1.3-3.5)	0.7 (-1.7-3.2)	0.7 (-1.7-3.2)	2.1 (-0.3-4.5)	0 (-2.4-2.4)
Rate of overuse injury during matches	0 (-1.3-1.3)	0 (-1.3-1.3)	1.2 (-0.1-2.4)	0 (-1.3-1.3)	0.5 (-0.7-1.8)	0 (-1.3-1.3)
Rate of contact injury during training	1.1 (-0.9-3.1)	0 (-2.0-2.0)	0.6 (-1.4-2.6)	0 (-2.0-2.0)	1.3 (-0.7-3.3)	1.6 (-0.4-3.5)
Rate of overuse injury during training	0.6 (-1.1-2.2)	0.6 (-1.1-2.2)	5.6 <sup>b</sup> (4.0-7.2)	3.2 (1.5-4.8)	0.5 (-1.1-2.2)	0 (-1.6-1.6)

**Table 3:** Comparisons of injury rates in fasting and non-fasting players for the two monitored seasons [4].

\* each period consisted of 4 weeks respectively in each of the two studied seasons.

<sup>b</sup> significantly higher than before and after-Ramadan.

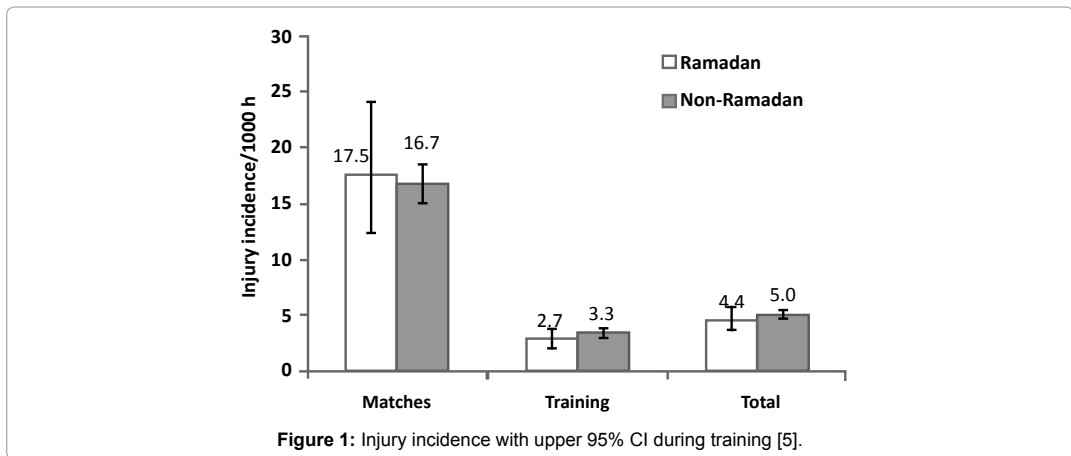
**Note:** values in bracket are 95% confidence intervals.

In the study of Eirale et al., [5], total exposure for the 3 consecutive seasons was 164 434 hours (included 145 734 hours for Muslims); match exposure was 22 206 hours (included 19 242 hours for Muslims); training exposure was 142 230 hours (included 126 492 hours for Muslims). Here it has to be noted that Eirale et al., [5] named “Muslims” the fasting players and that non-Muslims were non-fasting players.

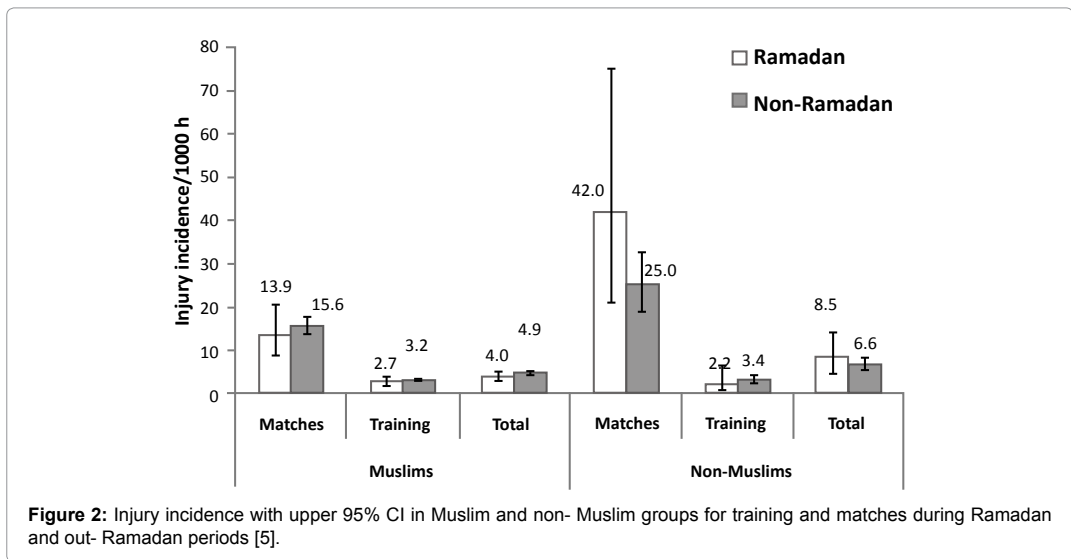
Total exposure during Ramadan was 17 009 hours, 15 237 hours for Muslim soccer players. Match exposure was 1695 hours (included 1442 hours for Muslims) and training exposure was 15 313 (included 13 795 hours for Muslims). Mean monthly exposure in the non-Ramadan period was 12 285 hours (included 10 875 hours for Muslims). From the 527 players assessed during the study of Eirale et al., [5], 403 reported at least 1 injury, with a total of 826 injuries (364 during matches and 462 during training sessions), leading to injury rate of 4.97/1000 hours (95% CI, 4.6-5.3). Match injury rate was higher than training [16.4/1000 hours (95% CI, 14.8-18.2) vs 3.1/1000 hours (95% CI, 2.9-3.5); P < 0.001, respectively]. A total of 77 injuries were observed during Ramadan, of which 36 (47%) occurred during match play and 41 (53%) during training sessions.

Figure 1 shows total, match, and training injury incidence during Ramadan and out-Ramadan periods according to Eirale et al., [5]. During this study, no significant difference was found between the 2 periods monitored (i.e., Ramadan and out of Ramadan). These results are consistent with those shown by Chamari et al., [4]. Obviously, injury rates

during matches was significantly higher than training rate during both Ramadan and out-Ramadan periods during the study of Eirale et al., [5].



Total, match, and training injury rate during the Ramadan and out-Ramadan months, considering Muslim and non-Muslim soccer players separately are shown in Figure 2 according to Eirale et al., [5]. Total, match, and training injury rates were not different for Ramadan compared to the rest of the season in both Muslim and non-Muslim players.



It is spectacular to know that a significantly total higher risk of injury was observed during the study of Eirale et al., [5] with Non-Muslim soccer players compared to Muslim soccer players throughout the season (i.e., both during Ramadan and out-Ramadan periods). This increase of injury rate was only demonstrated during matches, not during training settings. It may be speculated that these findings are related to age, an intrinsic risk factor, which is known to affect the risk of injury in footballers [24-26]. Indeed, the non-Muslims (29.2 ± 4.6 years) were on average older than Muslims (26.5 ± 4.6 years) in the study of Eirale et al., [5].

Eirale et al., [5] have shown that the probability of match injury among non-Muslims was the highest in Ramadan (3 times high risk of match injury) and the 2 consecutive months after.

According to Eirale et al., [5], Muslim players demonstrated a uniform rate throughout each month of the Islamic calendar. Adjusted odds ratio of injury among non-Muslims compared with Muslims was 3.7 (95% CI, 1.7-7.9, P = 0.001) during Ramadan (ninth) month, 2.4 (95% CI, 1.1-4.9, P = 0.021) during the 10<sup>th</sup> month and 2.7 (95% CI, 1.2-5.8, P = 0.013) during the 11<sup>th</sup> month as observed by Eirale et al., [5]. However, injury during training was not associated with Ramadan or religion/fasting status.

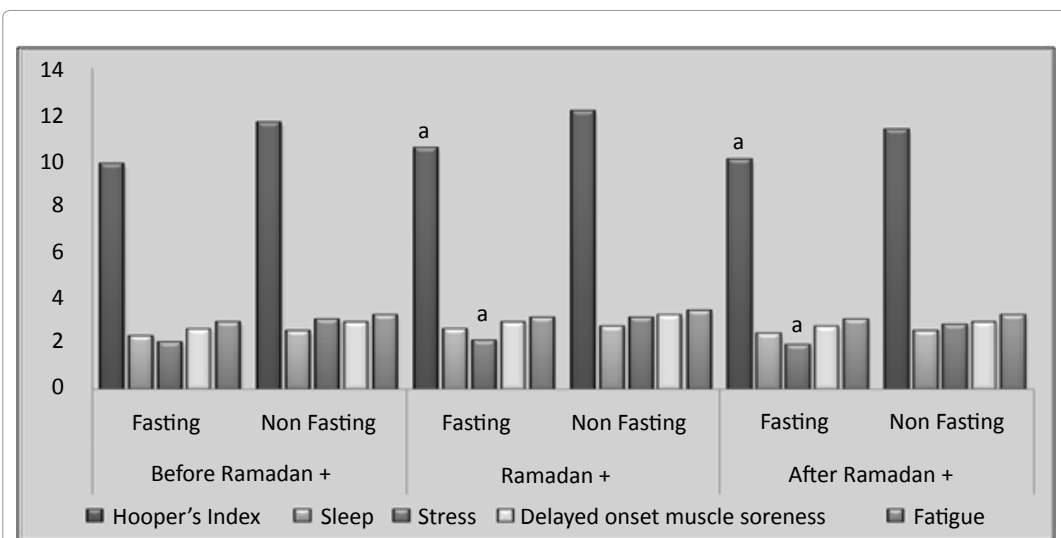
As suggested by Eirale et al., [5], these results above can be explained by the possible inability of non-Muslim players to cope with changes in the circadian rhythm imposed by the altered sleep/wake schedule during Ramadan. Because most of the non-Muslim soccer players were foreigners, another possible explanation could be the complexity they face with adapting to the hot and humid climate in Qatar, which may constitute as another risk factor for injury. Indeed, the hot climate in Qatar usually falls within the months of May and September, consequently, including the Ramadan months in the study of Eirale et al., [5]. However, these considerations remain a hypothesis because climate data were not collected and, therefore, cannot be excluded as a potential confounding factor. Non-Muslim soccer players may be more susceptible to injury, as they are unable to adjust to the general change of social life during the holy month of Ramadan in Qatar as suggested by Eirale et al., [5].

Moreover, these authors have shown that injuries defined as moderate were the most common for both Muslim and non-Muslim players during Ramadan and out-Ramadan periods. Nevertheless, no significant difference was observed in injury incidence between the 4 classifications (mild, minor, moderate, and severe injuries). Likewise, no significant difference in injury rate was found when comparing contact and non-contact injuries, overuse and traumatic injuries, and injuries and reinjuries during Ramadan and out-Ramadan periods.

Injury type and location were similar in Ramadan and non-Ramadan periods as observed by Eirale et al., [5]. The most common location of injury was thigh, followed by knee, and ankle in both periods. Also, the most common types of injury were muscle rupture and ankle sprain, followed by tendon injury, and contusion in both Ramadan and non-Ramadan periods. Eirale et al., [5] suggested that the similarity between injury characteristics and patterns may have important practical implications for the medical staff, as the same strategies for injury prevention may be applied during both Ramadan and out-Ramadan periods.

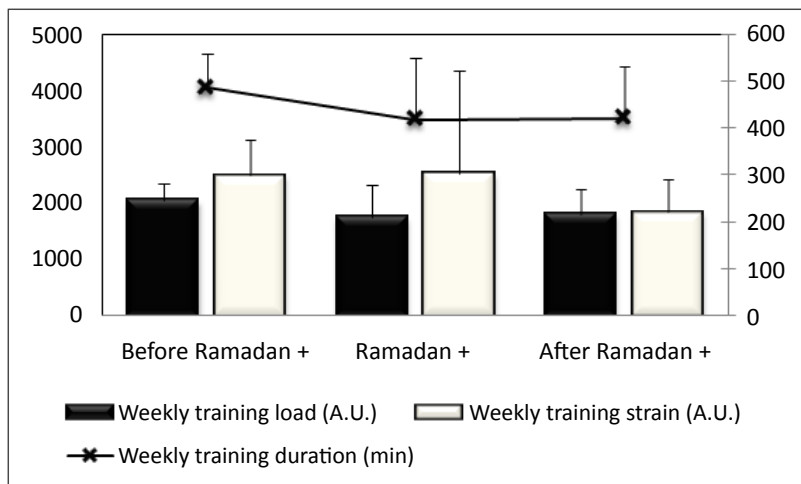
The injury rates reported during the month of Ramadan in both published studies [4,5], during training and matches, were consistent with data found in Union of European Football Associations {UEFA} [1], English Premier League [27], Swedish Premier League [28], Scottish league [2], and Norwegian league [3]. Nevertheless, the overuse injury rate of the study of Chamari et al., [4] outside the month of Ramadan is lower than what is typically reported in the literature. It has been stressed by the authors that this muscle injury rate concerns pre-season and the start of the season (because Ramadan was located quite soon during the season) and this might explain these lower rates. Indeed, pre-season is characterized by a high prevalence of endurance training and fitness training which were performed in a progressive manner by the staff of the studied team. The low frequency of matches at these stages might be the cause of the low overall injury rates of the studied periods [4]. Indeed, it has been well demonstrated that the match injury rates are always much higher than the training injury rates [1]. In this context, Koutedakis and Sharp [29] also showed that the preparation phase of the season is accompanied with fewer injuries than the competition phase. Despite a higher mean overall injury rate during the Ramadan months of the 2 studied seasons [4], i.e., 12.3 injuries/1000 h exposure vs 4.9 for the month's before-Ramadan and 6.7 for the month's after-Ramadan, the difference between non-fasting and fasting players was not significant. This result was later confirmed by Eirale et al., [5]. Nevertheless,

the rate of overuse injuries during training was significantly higher during Ramadan than before- and after-Ramadan in the fasting players (Table 3). However, these players showed lowered Hooper's index and perceived stress during and after the Ramadan than non-fasting players [30]. Moreover, no difference was observed between fasting and non-fasting players for the reported quality of sleep, and quantity of delayed onset muscle soreness and fatigue during, before, and after Ramadan (Figure 3).



**Figure 3:** Comparisons of Hooper Index, (sleep, stress, delayed onset muscle soreness, and fatigue) (means of the 2 studied seasons) [4].  
<sup>a</sup> each period consisted of 4 weeks in each year, respectively.  
<sup>a</sup> significant different from non-fasting players at p<0.05.

Despite the difference in Hooper Index and perceived stress observed, Chamari et al., [4] showed that training load, training strain, and training duration were maintained during the 3 periods (pre-, post- and during Ramadan) and between groups for the 2 monitored seasons (Figure 4). Of interest is to mention that the technical staffs of this study [4] had not decrease training load during Ramadan. This has been decided on basis of the key findings of Chaouachi et al., [6] who has suggested that elite athletes who were maintaining their usual training loads, could avoid steep decrements in their physical capacities while undergoing the Ramadan intermittent; However, although there is no study contrasting the suggestions of Chaouachi et al., [6], technical staffs should adapt the training load of their players based on daily observations and fasting conditions and environment. The suggestion of Chaouachi et al., [6] concerned elite Tunisian judo athletes with different characteristics of training compared to European top-level soccer teams for example. Indeed, in Tunisia, there is lower frequency of competitions/matches than in European top-class teams with games played each 3-4 days almost continuously for about 10 months (about 25 to 40 games vs 45-62 games, for elite Tunisian and European teams, respectively). Another concern with Ramadan fasting in Europe comes from the daylight duration. Indeed, in summer for example, fasting players in Europe abstain from food and fluids for 1 to 2 hours longer than northern African countries as Tunisia for example. In summer, with the relative heat, this could be a challenge for Muslim fasting players that are part of a European team. Indeed, in such cases, technical staffs of elite athletes have performance' objectives and hence, do not even think about managing the whole team training pattern/load for some exceptions as fasting players.



**Figure 4:** Comparisons of weekly training load, strain, and duration {mean of the 2 studied seasons} [4].

\* each period consisted of 4 weeks respectively in each season.

AU: Arbitrary Units

It is also important to note that the study of Chamari et al., [4] reported data of players that trained at night during Ramadan and that the technical staff avoided days including two training sessions but for very few exceptions. Consequently, their conclusions are not adaptable to Fasting players keeping training during the day. In this context, Elite Football teams often train in the morning (with the possibility of performing double sessions' days in some one-game per week microcycles), therefore fasting players would have to keep off their food and fluid intakes for the periods occurring just after the training sessions. This has to be considered with caution as the latter intakes are part of the pillars of recovery. More specifically, ending a high load training session at around 11:00 AM and having to keep on fasting for the remaining hours until the sunset (*Iftar*) presents a big challenge for fasting elite athletes, especially for the long daylight days (i.e., summer in the northern hemisphere). In this case, the eventual addition of a second training session in the afternoon is certainly not physiologically optimal and to the best knowledge of the present chapter' authors, no study has investigated such a training situation. In this context, some recommendations have been made by Kirkendall et al., [31] for advising the technical staffs and athletes to better deal with training during Ramadan. In this regard, further studies on injuries during Ramadan in different parts of the world, and through the year calendar are obviously needed. Other specific situations should also be investigated as some players chose to fast during the week but not the day of the games as many coaches wish to have non fasting players for games (data not published yet). This presents another pattern of specific fasting with related physiological adaptations and therefore performance and injury pattern.

## Possible Causes of Sport Injuries during Ramadan

### Consequences of sleep disturbance

Regarding the possible relationship between sleep loss and sport injuries, Luke et al., [32] demonstrated in adolescents that fatigue related injuries were associated with sleeping less than 6 h the night before the injury. One study has investigated sleep and injury rates in athletes during Ramadan. Chamari et al., [4] retrospectively analyzed the quality of sleep via the Hooper Index and recorded injury data for two years in Tunisian top-level football players (n = 42). Training load remained unchanged throughout the study period

but the timing of training was delayed from mid afternoon to 2200 h. Despite no change in perceived sleep quality, the timing of sleep was considerably delayed, with players not going to bed before 03:00 AM. Non-contact and training-overuse injuries were higher during the month of Ramadan among fasting players [4]. Nevertheless, even if the fasting players were generally satisfied with self-reported sleeping quality, it may be that the total sleep duration or time spent in the different sleep stages was modified. In this context, it has been well established that sleep architecture is characterized by a cyclic pattern of sleep stages throughout the night [33,34] and that disturbances during Ramadan can negatively affect alertness and psychomotor skills [35].

In that regard, disturbances to the circadian timing of the sleep-wake cycle – either due to delayed nutritional intake, exercise or both, may present physiological or psychological challenges occurring with circadian mis-alignments, that if not overcome will impact on athletic performance [36].

Therefore, changes in sleeping pattern (i.e., less sleep at night and more afternoon naps) and nutritional habits (i.e., eating only at night-time) during Ramadan may have altered the players' physiological status during Ramadan, probably leading to the observed higher over-use injury rate during the fasting month [37-39].

### **Physiological and hormonal disturbances**

Besides sleeping schedule disturbances, another probable cause of overuse injuries could be the end-of-Ramadan state of the fasting players. In this regard, Chaouachi et al., [13] have demonstrated that elite athletes continuing to undergo high training loads during Ramadan (at the same levels as before Ramadan) might display high levels of fatigue and are likely to experience a cascade of small “negative” biochemical adjustments: changes in hormonal, immunoglobulin, and antioxidant systems, along with an elevated inflammatory profile. These variations are similar to what is found in tissue traumatic processes as observed in athletes in state of over-reaching or even overtraining [13]. Although the reported variations are minimal and of small clinical relevance, they can still signal whole body' physiological stress [13]. In this context, the overtraining syndrome has been referred as “staleness or chronic fatigue and a mental lassitude along with possible associated injuries in parallel to a significant decline in physical performance” [40,41]. Overtraining has been shown to affect the musculoskeletal system with increased serum creatine kinase levels and enzymatic markers of muscle tissue injury that significantly elevated the day after high training loads' training sessions. For now, it is unclear whether the observed over-use injuries observed in the over-trained or over-reached athletes described in the literature could be resulting from excessively high training loads and/or the impaired ability of the athletes to recover from underwent training loads. As training load was similar in fasting and non fasting players in the study of Chamari et al., [4], it is therefore possible that the recovery processes could be altered by Ramadan intermittent fasting. Further studies are needed in this specific field.

### **Psychological alteration and general fatigue**

Contradictory with many studies (see for review [6] suggesting that the Ramadan month induces additional stress on the athlete, the perceived mental stress assessed by the Hooper scale during Ramadan in the non-fasting players of the study of Chamari et al., [4] was not different from stress measured before and after Ramadan. Rather, the fasting players reported decreased stress for Ramadan and for the month after-Ramadan compared to the pre-Ramadan month. The latter authors speculated that the religious beliefs and the well-being of living and practicing a holy month, could have led to a lower perception of stress in the fasting players. The possible habituation process in the fasting players has also to be considered. Indeed, the latter reported that they had fasted and trained at night simultaneously for a mean period of seven years. Therefore, the absence of total injury risk difference with respect to the non-fasting players relates to habituated fasting players



training at night in non-fasting state. Newly fasting players' data are not available from the study of Chamari et al., [4].

## Contextual conditions

The effect of Ramadan on the incidence of sporting injuries has to be considered with respect to the period of the year and changing climate. Indeed, the study of Chamari et al., [4] was conducted over the 2010 and 2011 years with the months of Ramadan occurring in August/September. For that study, the daily fasting lasted about 15 h 15 min in Tunisia and the temperature was relatively high (Table 2). Several fasting periods and environmental conditions should be experimented with respect to their effects on elite athletes' injury rates. It has also to be noted that in the study of Chamari et al., [4] the training sessions occurred during the evenings (22:00 h, i.e., about 3 hours after the "iftar" / breaking of the day's fast). In this context, the injury rates reported concern therefore "Fasting" players that were in a non-fasting state, as they did break the fast about three hours earlier and were thus allowed to drink ad-libitum before and during the training sessions and games. At present, no data is yet available for any injury rate occurring in fasting athletes during training or competition.

## Recommendations and Conclusion

The only two studies in scientific literature [4,5] on the muscle and general injury rate during the month of Ramadan were conducted in professional football players and show that the many changes in behavioral and social-routines occurring during the Ramadan fasting may potentially affect the injury risk of these athletes. In Muslim-majority countries, non-fasting players may also be affected by changes in eating and sleeping habits and in the scheduling of training and match play. Data of Chamari et al., [4] and Eirale et al., [5], however, show the absence of the effect of the holy month of Ramadan on the general injury rates of fasting and non-fasting elite soccer players where weekly training loads were maintained during Ramadan [4]. However, according to Chamari et al., [4] rates of non-contact injuries and rates of overuse injuries during training were higher during Ramadan than before or after Ramadan in fasting compared to the non-fasting players. On the other hand, Eirale et al., [5] have found a higher rate of match and total injuries in non-Muslim players during Ramadan and out-Ramadan periods. This difference was maintained for match injuries during the Holy month of Ramadan and the following 2 months after adjusting the data for age. These results could be explained by the possible inability of non-Muslim players to manage with changes in the circadian rhythm and sleep pattern imposed by the altered schedule during Ramadan in addition to the issue they face with adapting to the hot and humid climate in Qatar, which may constitute another risk factor for sport injury.

Therefore, it is recommended that coaches and medical staffs involved in the management of fasting players should monitor and adapt the training load according to the timing of Ramadan on the year's span (environmental conditions), and the cultural background and competing level of the players. Furthermore, special attention should be paid to the recovery interventions (rest, nutrition, hydration, etc), in an attempt to reduce the injury risks.

## References

1. Ekstrand J, Häggglund M, Waldén M (2011) Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med* 45: 553-558.
2. Dupont G, Nedelec M, McCall A, McCormack D, Berthoin S, et al. (2010) Effect of 2 soccer matches in a week on physical performance and injury rate. *Am J Sports Med* 38: 1752-1758.
3. Andersen TE, Tenga A, Engebretsen L, Bahr R (2004) Video analysis of injuries and incidents in Norwegian professional football. *Br J Sports Med* 38: 626-631.
4. Chamari K, Haddad M, Wong del P, Dellal A, Chaouachi A (2012) Injury rates in professional soccer players during Ramadan. *J Sports Sci* 30: 93-102.

5. Eirale C, Tol JL, Smiley F, Farooq A, Chalabi H (2013) Does ramadan affect the risk of injury in professional football?. *Clin J Sport Med* 23: 261-266.
6. Chaouachi A, Leiper JB, Souissi N, Coutts AJ, Chamari K (2009) Effects of Ramadan intermittent fasting on sports performance and training: a review. *Int J Sports Physiol Perform* 4: 419-434.
7. Leiper JB, Molla AM, Molla AM (2003) Effects on health of fluid restriction during fasting in Ramadan. *Eur J Clin Nutr* 57: 30-38.
8. Leiper JB, Maughan RJ, Kirkendall DT, Bartagi Z, Zerguini Y, et al. (2008) The F-MARC study on Ramadan and football: research design, population, and environmental conditions. *J Sports Sci* 26: 7-13.
9. Maughan RJ, Fallah J, Coyle EF (2010) The effects of fasting on metabolism and performance. *Br J Sports Med* 44: 490-494.
10. Waterhouse J (2010) Effects of Ramadan on physical performance: chronobiological considerations. *Br J Sports Med* 44: 509-515.
11. Güvenç A (2011) Effects of ramadan fasting on body composition, aerobic performance and lactate, heart rate and perceptual responses in young soccer players. *J Hum Kinet* 29: 79-91.
12. Chaouachi A, Coutts AJ, Chamari K, Wong del P, Chaouachi M, et al. (2009) Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. *J Strength Cond Res* 23: 2702-2709.
13. Chaouachi A, Coutts AJ, Wong del P, Roky R, Mbazaa A, et al. (2009) Haematological, inflammatory, and immunological responses in elite judo athletes maintaining high training loads during Ramadan. *Appl Physiol Nutr Metab* 34: 907-915.
14. Johnson MB, Thiese SM (1992) A review of overtraining syndrome-recognizing the signs and symptoms. *J Athl Train* 27: 352-354.
15. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM (2004) Use of RPE-based training load in soccer. *Med Sci Sports Exerc* 36: 1042-1047.
16. Hooper SL, Mackinnon LT (1995) Monitoring overtraining in athletes. Recommendations. *Sports Med* 20: 321-327.
17. Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, et al. (2006) Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med* 40(3): 193-201.
18. Haddad M, Chaouachi A, Castagna C, Hue O, Wong DP, et al. (2013) Validity and psychometric evaluation of the French version of RPE scale in young fit males when monitoring training loads. *Science & Sports* 28: 29-35.
19. Trepanowski JF, Bloomer RJ (2010) The impact of religious fasting on human health. *Nutr J* 9: 57.
20. Petersen J, Thorborg K, Nielsen MB, Hölmich P (2010) Acute hamstring injuries in Danish elite football: a 12-month prospective registration study among 374 players. *Scand J Med Sci Sports* 20: 588-592.
21. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, et al. (2001) A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109-115.
22. Haddad M, Chaouachi A, Wong del P, Castagna C, Hambli M, et al. (2013) Influence of fatigue, stress, muscle soreness and sleep on perceived exertion during submaximal effort. *Physiol Behav* 119: 185-189.
23. Haddad M, Chaouachi A, Wong DP, Castagna C, Hue O, et al. (2012) Influence of exercise intensity and duration on perceived exertion in adolescent Taekwondo athletes. *Eur J Sport Sci*.
24. Heir T, Eide G (1996) Age, body composition, aerobic fitness and health condition as risk factors for musculoskeletal injuries in conscripts. *Scand J Med Sci Sports* 6: 222-227.
25. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R (2010) Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *Am J Sports Med* 38: 2051-2057.
26. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R (2010) Intrinsic risk factors for hamstring injuries among male soccer players: a prospective cohort study. *Am J Sports Med* 38: 1147-1153.
27. Hawkins RD, Hulse MA, Wilkinson C, Hodson A, Gibson M (2001) The association football medical research programme: an audit of injuries in professional football. *Br J Sports Med* 35: 43-47.
28. Häggglund M, Waldén M, Ekstrand J (2006) Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med* 40: 767-772.
29. Koutedakis Y, Sharp NC (1998) Seasonal variations of injury and overtraining in elite athletes. *Clin J Sport Med* 8: 18-21.
30. Hooper SL, Mackinnon LT (1995) Monitoring overtraining in athletes. Recommendations. *Sports Med* 20: 321-327.
31. Kirkendall DT, Chaouachi A, Aziz AR, Chamari K (2012) Strategies for maintaining fitness and performance during Ramadan. *J Sports Sci* 30: 103-108.
32. Luke A, Lazaro RM, Bergeron MF, Keyser L, Benjamin H, et al. (2011) Sports-related injuries in youth athletes: is overscheduling a risk factor? *Clin J Sport Med* 21: 307-314.

33. Czeisler CA, Weitzman Ed, Moore-Ede MC, Zimmerman JC, Knauer RS (1980) Human sleep: its duration and organization depend on its circadian phase. *Science* 210: 1264-1267.
34. Duffy JF, Kronauer RE, Czeisler CA (1996) Phase-shifting human circadian rhythms: influence of sleep timing, social contact and light exposure. *J Physiol* 495 : 289-297.
35. Roky R, Houti I, Moussamih S, Qotbi S, Aadil N (2004) Physiological and chronobiological changes during Ramadan intermittent fasting. *Ann Nutr Metab* 48: 296-303.
36. Reilly T, Edwards B (2007) Altered sleep-wake cycles and physical performance in athletes. *Physiol Behav* 90: 274-284.
37. Bogdan A, Bouchareb B, Touitou Y (2001) Ramadan fasting alters endocrine and neuroendocrine circadian patterns. Meal-time as a synchronizer in humans? *Life Sci* 68: 1607-1615.
38. Montelpare WJ, Plyley MJ, Shephard RJ (1992) Evaluating the influence of sleep deprivation upon circadian rhythms of exercise metabolism. *Can J Sport Sci* 17: 94-97.
39. Reilly T, Waterhouse J (2007) Altered sleep-wake cycles and food intake: the Ramadan model. *Physiol Behav* 90: 219-228.
40. Kenttä G, Hassmén P (1998) Overtraining and recovery. A conceptual model. *Sports Med* 26: 1-16.
41. Halson SL, Jeukendrup AE (2004) Does overtraining exist? An analysis of overreaching and overtraining research. *Sports Med* 34: 967-981.

## Chapter 21

# Exercise Responses and Training during Daytime Fasting in the Month of Ramadan and its Impact on Training-Induced Adaptations

**Nurhayatul Filzah Damit<sup>1</sup>, Vivienna Tzia Woon Lim<sup>1</sup>, Ahmad Munir Che Muhamed<sup>2</sup>, Anis Chaouachi<sup>3</sup>, Karim Chamari<sup>4</sup>, Rabindarjeet Singh<sup>2</sup>, Michael Yong Hwa Chia<sup>5</sup> and Abdul Rashid Aziz<sup>5,6\*</sup>**

<sup>1</sup>Performance Optimisation Centre, Ministry of Defence, Brunei Darussalam

<sup>2</sup>Advanced Medical and Dental Institute, Universiti Sains Malaysia, Penang, Malaysia

<sup>3</sup>Tunisian Research Laboratory "Sport Performance Optimization", National Center of Medicine and Science in Sports, Tunis, Tunisia

<sup>4</sup>Research and Education Centre, Aspetar, Qatar Orthopedic and Sports Medicine Hospital, Doha, Qatar

<sup>5</sup>Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore

<sup>6</sup>Sports Science Centre, Singapore Sports Institute, Singapore Sports Council, Singapore

**\*Corresponding author:** Abdul Rashid Aziz, Sports Science Centre, Singapore Sports Institute, Singapore Sports Council, 230 Stadium Boulevard, Singapore 397 799, Tel no: +65-65005477; E-mail: [abdul\\_rashid\\_aziz@ssc.gov.sg](mailto:abdul_rashid_aziz@ssc.gov.sg)

## Abstract

During the month of Ramadan, restriction of food and fluid intake for many hours before and during exercise, together with other Ramadan-associated negative factors such as sleep and mood swings can be a real challenge for fasting Muslim athletes to perform at their optimum level. Numerous studies have looked at the effects of Ramadan fasting on exercise responses and performances but these studies were mostly focused on the effects of the religious fast on acute training sessions. This review aims to present studies that analyzed the effects of fasting during the daytime period on chronic training and on the magnitude of training-induced adaptations over the Ramadan month. These studies were selected based on a set of criteria laid out by the authors to ensure valid comparison. The results from the small number of validated studies chosen, in contrast to our initial hypothesis, have indicated equivalent improvements in the magnitude of training-induced adaptations by both fasted and non-fasted individuals during post-Ramadan testing. The data suggest that in order for optimal training-induced adaptations to take place in Muslim fasted athletes during Ramadan, a training programme imposing a sufficient training load or stimulus with the presence of optimal nutrition and rest-recovery are key factors.

**Key words:** Acute Exercise, Adaptations, Chronic Exercise, Intensity, Training Load

## Introduction

Exercise can be a real challenge for fasting Muslim athletes during the daytime in Ramadan. The inability to consume nutrients for many hours before and during exercise

means that the athletes face the possibility of reduced levels of endogenous fuel as well as dehydration towards the later part of the exercise or training session [1,2]. The situation is further exacerbated with other Ramadan-associated negative factors, such as daytime sleepiness and feelings of increased malaise and lethargy with undesirable mood swings [1,2]. These subjective feelings are due to chronic sleep debt and/or a drastic shift in the individual's daily circadian rhythm [1,2], which alone or when summed, can create a less than ideal "psycho-physiological" situation within the athlete during training.

### **Effect of Ramadan on Acute Exercise Training Session**

Although the physical conditions of the Ramadan fasted individuals is less than optimal, the effects of Ramadan fasting on exercise quality and quantity have been inconsistent [3]. The quantity of exercise has been shown to be compromised [4-6], while the quality of training, i.e., the fasted individual's responses to acute exercise physiological stress, has been less affected. For example, blood glucose concentration, which is an important source of fuel during exercise and is likely to be compromised only if the individual's blood glucose falls  $< 3.5 \text{ mmol}\cdot\text{L}^{-1}$ , i.e., to levels that could be deemed as hypoglycemic. Although some studies have shown a lower pre-exercise blood glucose concentration during Ramadan [7], particularly if measured in the late afternoon period, the glucose values were clearly within the normal range that would have minimal influence on the fasted individual's subsequent exercise capacity [4,8,9]. In these same studies, post-exercise blood glucose concentrations have been shown to be higher than pre-exercise levels. This indicates that the fasted individual is more than able to mobilize or breakdown their liver glycogen stores to produce the needed blood glucose for brain and muscle functions. Post-exercise blood lactate concentration has been used previously as an indirect indicator of muscle glycogen usage or breakdown during exercise [10]. Studies have also shown that post-exercise blood lactate concentration seem to increase to levels equivalent to that observed in the non-Ramadan fasted state [4,8,9]. These data indicates that Ramadan fasting did not have a negative effect on muscle glycogenolysis process during exercise and has little impact on exercise variables such as post-exercise blood glucose and blood lactate concentrations [3]. Therefore, Ramadan fasting has minimal impact on muscle metabolic functions during exercise. However this is a different case for exercise Heart Rate (HR) where several studies have shown a lower or no difference in HR during exercise of submaximal intensity in Ramadan vs. non-Ramadan periods [11-14]. In contrast, Leiper et al., [15] observed a higher HR (average of  $\sim 5 \text{ b}\cdot\text{min}^{-1}$ ) in Ramadan fasted vs. non-fasted players during a football training session. The authors argued that dehydration was one of the possible reasons for the observed differences.

While objective measures of acute exercise or training responses do not seem to be adversely affected, there is substantial evidence to indicate a negative impact of Ramadan fasting on subjective Ratings of Perceived Exertion (RPE) during acute exercise in fasted Muslims. Many studies indicate that RPE was always higher when exercising in the Ramadan fasted state when compared to the same exercise in the non-fasted state [16-19]. In retrospect, the adverse impact on perceived subjective effort of exercise is expected due to the individual's inability to ingest foods and fluids over a prolonged duration. As a result, fasted individuals usually present themselves in a hypohydrated state, with possibly low levels of endogenous fuels and higher levels of sleepiness and fatigue before the start of the exercise, particularly in the late afternoon period [16,19-21]. These less than ideal conditions could substantially limit the individuals' capacity or reduce their physiological ability to exercise at the same intensity, relative to what they are actually capable of performing when they are in the non-fasted state. In other words, whilst external training load imposed on the fasted athletes may be similar to that during the non-Ramadan period, in reality, the internal training load or stimulus experienced by these individuals are perceived or felt to be relatively greater during the Ramadan period. Thus, the same amount or rate of work seemed to be more "intense" or "difficult" in the Ramadan fasted state.

Whilst the impact of Ramadan fasting on training quality has been contentious, the available evidence on the effect of Ramadan fasting on training quantity is much more convincing. Studies have indicated that Muslim athletes were negatively affected by Ramadan fasting as, they tend to produce a lower level of exercise performance or complete a lower amount of work compared to what they are actually capable of performing in the non-Ramadan state [1,2]. In this regard, the study by Aziz et al., [4] is worth highlighting. Previous Ramadan-related exercise or training studies have usually employed an exercise protocol that resembles an exercise or a sport-specific performance measure. This is the only study, to our knowledge, that was specifically designed to examine the impact of Ramadan fasting on an acute exercise protocol that resembles a typical training-like session. The study's exercise protocols included six repeated 30 s Wingate anaerobic test all-out effort cycling bouts (with 4 min of recovery between each bout), followed by 6 min of recovery before cycling to exhaustion, which lasted between 8 and 20 min [4]. Exercise protocols were akin to the routine intense high-intensity interval workout session that taxed both the aerobic and anaerobic components of the individual's energy systems, which is typically undertaken by the well-trained athletes. The investigators showed that exercise in the daytime was adversely affected during Ramadan compared to the same exercise performed at the same time of the day in the non-Ramadan period [4]. Additionally, the use of pre-packaged meals helped to ensure that participants' maximal compliance to standardized micronutrients and energy intake over the 24 h period prior to the testing sessions further strengthened the validity of the results obtained in the study that was conducted in the Aziz et al., study [4].

The reasons for the decline in training quantity during acute exercise in the Ramadan fasted state are currently unknown, but there are several possibilities. Firstly, there may be a drastic shift in the energy metabolism during exercise as a result of the Ramadan fast. Indeed, Ramadan fasting can lead to a predominant use of lipids or fat rather than carbohydrate oxidation during exercise [6,22,23]. As a result, the Ramadan fasted working muscles are compelled to use lipids, which is clearly not suited for high-to-maximal intensity sustain work and thus leading to less than efficient muscular contractions, i.e., lower power output. Secondly, there is also a possibility of progressive muscle glycogen depletion in selective muscle fibres, such as on the fast twitch fibres rather than across the entire muscles, over the period of Ramadan. The glycolytic energy system can only utilize carbohydrates (i.e., glucose from blood glucose or from stored intramuscular glycogen), and since high-intensity exercise primarily recruits fast twitch fibres to a greater extent than slow fibres, it may be that high power-strength contractions may lead to a rapid depletion of the available endogenous substrate within these working fibres. This results in the early onset of fatigue, i.e., a lowering of power output in subsequent bouts of maximal exercise. A previous non-Ramadan study has also showed decreased levels of Phosphocreatine (PCr) concentration in muscles due to a slower rate rephosphorylation particularly of PCr, particularly within the fast-twitch fibres, during the recovery periods from prior bout of intense exercise [24]. This inability to replenish PCr concentration levels quickly or as effectively during the inactive recovery period will have an adverse impact in the subsequent bouts of maximal efforts during high-intensity intermittent exercise protocol. In addition, dehydration of as much as 1% of pre-exercise body mass may also lead to some internal disturbances within the muscular cells milieu which could interfere with the proper or optimal functioning of neuromuscular system and negatively influence exercise performance [25,26]. Alternatively, the onset of fatigue might originate from the brain or central nervous system leading to an attenuated recruitment of muscle fibres during sustained efforts. This centrally-mediated fatigue could be simply due to the individual's poor self-motivation as an outcome of drastic shifts in moods swings or due to placebo effects from observing the Ramadan fast. In summary, the literature is currently unclear as to the exact mechanism(s) for the adverse effects of Ramadan fasting on sustained high-intensity exercise performance; nonetheless it does appear that this early fatiguing of the fasted individual involves a combination of, or contribution from several factors, rather than a single factor.

The substantial reduction in overall training stimulus has also been touted as one of the major contributing factors for the decline in exercise performance towards the later period of the Ramadan month in fasted individuals [27]. For instance, there may be a direct decrease in the total external training load or stimulus during the early part of the Ramadan month, which is due to the fact that fasted athletes might consciously or unconsciously reduce their work capacity because of their own subjective feelings on the prevailing levels of fatigue or tiredness. Fasting is held only once a year, thus individuals possibly require some time to adapt or make adjustment to the drastic change in daily behavior patterns or circadian rhythm in Ramadan. In short, during the early part of Ramadan, the fasting Muslims may find themselves struggling to cope with the perturbations associated with the Ramadan fast [28]. As a result, many Muslim athletes experienced relatively higher levels of fatigue and perceived effort when completing the same amount of work or exercise during Ramadan as compared to the non-Ramadan period. Ramadan fasted individuals would possess minimal levels of tolerance to sustain moderate- to high-intensity of efforts for prolonged periods of time [5,8]. Alternatively, anecdotal evidence suggests that coaches deliberately reduce the team's or athlete's training load or intensity because of the heightened (*mis*) perception that Muslim athletes are not able to sustain high workload in the fasted state [29,30]. This means that the higher perceived effort during exercise experienced by Ramadan fasted individuals is simply due to the lowering of exercise stimulus over the early part of the Ramadan month and this may lead to a loss of some level of physical conditioning or detraining effects during the later part of the Ramadan month [27].

Another area that has an impact on exercise performance in the Ramadan fasted state but has received little research attention is the thermoregulation during exercise. The fasted individual commences exercise in the hypohydrated state due to the inability to consume fluid many hours before exercise. This hypohydrated situation is further exacerbated with the inability to ingest fluid during exercise which can further lead to excessive dehydration, particularly if the duration of exercise is prolonged and/or the exercise is performed in a hot environment. How such a situation affects the fasted individual's thermoregulatory processes is unknown, but will most likely have a negative impact on the fasting individual's exercise capacity and/or performance. To our knowledge, only two studies have investigated the impact of Ramadan fasting on exercise in a hot environment and interestingly, both showed that thermoregulation was not influenced by Ramadan fasting [31,32]. Gueye and colleagues [31] showed that there were no observed differences either in rectal or skin temperature at the end of the exercise between fasting and non-fasting conditions in the same Muslim individuals. However, the study's findings are limited because the cycle exercise was of relatively low intensity ( $<75\% \text{HR}_{\text{max}}$ ). Moreover, the prevailing environmental conditions where the cycle exercise was conducted were not reported in the study [31]. In the other study, professional Muslim football players training for eight weeks (4 weeks of Ramadan month and 4 weeks of non-Ramadan) showed similar peak body core temperature, and did not exhibit any heat-stress incidents during the Ramadan month [32]. This field study also has several shortcomings, for instance, training sessions during the Ramadan month were conducted in the evening period after the breaking of the days' fast in the non-fasted state and moreover, core temperature were assessed in only two players [32], there are methodological issues that limit the findings of both the cited Ramadan and thermoregulatory studies. Clearly additional research is required to closely examine the impact of Ramadan fasting on thermoregulation process in fasted individuals and the consequent physiological responses and performances, especially when exercising in the hot environment.

### **Effects of Ramadan on Chronic Exercise Training Sessions**

The packed international sporting calendar and the fact that the organizing sports bodies does not take into account of the Ramadan month in their competition scheduling implies that Muslims athletes must often train through the Ramadan month in preparation for competitions. Optimal training-induced adaptations often takes place as a result of systematic and progressive exercise that are of sufficient frequency, intensity, duration, in

the presence of optimal nutrition, appropriate rest-recovery duration and high quality of effort during the preceding sessions [33]. Henceforth, given the less than optimal conditions that the fasted individuals encountered or experienced, it is possible that the quality and/ or quantity of exercise performance of the athletes during an exercise or training session in the daytime during the month of Ramadan may be poor or even compromised [4]. Thus, if such ‘inferior’ training sessions persistent throughout the Ramadan month, it would then be expected that the magnitude or percentage of improvements, i.e., training-induced physiological adaptations derived from the Ramadan month exercise sessions, would be lower as compared to that in non-Ramadan month. Similarly, if the same training or exercise programme are being performed by two different groups of individuals, i.e., fasted and non- fasted individuals, it would also be expected that the non-fasted group will produce a relatively better quality or higher output of training, which would then lead to improvement of greater magnitude in physiological adaptations as compared to the fasted group.

Therefore the purpose of this short review is to examine the literature on the effects of fasting on chronic training during the daytime period in the month of Ramadan on the magnitude of training-induced adaptations. The studies in this review must fulfill several criteria to ensure fair and valid comparison. Firstly, studies should compare the individuals’ performances or sporting measures which were taken “before” and “after” the Ramadan month and where both of these pre- and post-Ramadan test sessions or performance measures are performed in the non-fasted state. The studies chosen should also involve two groups of subjects. One of the groups was Muslim individuals who are both training and observing the Ramadan fast (i.e., FAS group) and the other group should consist of either Muslim or non-Muslim individuals who are training but not performing the Ramadan fast (i.e., non-FAS group). In addition, both groups should be maintaining their normal or planned training program throughout the entire Ramadan month. Since training across the investigative period may differ or is periodized as would be the case in a coach-driven training programme, the non-FAS group would serve as a control to account for potential differences in training load/stimulus experienced by both groups across the study period. Another important methodological consideration is that training sessions during the Ramadan month must be performed during the daytime period (i.e., in the Ramadan fasted state for the FAS group), rather than in the evenings (i.e., after iftar). The studies selected should then be compared for improvements made from pre- to post-Ramadan test between the FAS and non-FAS groups as the criterion measure of the effectiveness (or non-effectiveness) of training-induced adaptations in the Ramadan fasted state.

Based on the four criteria set for this review, it was apparent that many of the Ramadan exercise and training studies previously published does not meet all the four criteria required for further analysis (Table 1). Only seven of them attained the necessary four criteria to be included but one of these studies [34] is omitted as blood markers were the only responses measured and no exercise performance measure was taken in the investigation and thus, this does not allow the evaluation of the effectiveness of the study’s training programme. The six remaining studies are listed in Table 2 with the details of each of the study prominently highlighted. It is interesting to note that five of the six studies in Table 2, except Kordi et al., [35], involved fasted individuals or players who were members of the same squad. This is advantageous because it further ensures that the overall or total training stimuli between the FAS and non-FAS groups during the Ramadan period of the study are more likely to be equivalent.

	<b>Criterion 1</b>	<b>Criterion 2</b>	<b>Criterion 3</b>	<b>Criterion 4</b>
<b>Study</b>	Were the exercise or test measures performed “before” and “after” the Ramadan month	Was a control group (i.e., training but non-FAS) included in the study?	Was the subjects’ training load or stimuli was maintained during Ramadan?	Was the subjects’ acute exercise responses to the training stimuli/ load described in the study?
Aloui et al., 2013 [16]	√	X	√	√



Aloui et al., 2013 [17]	X	X	X	√
Aloui et al., 2013 [59]	X	X	X	X
Aziz et al., 2010 [8]	X	X	√	X
Aziz et al., 2010 [60]	X	X	√	√
Bigard et al., 1998 [61]	√	X	X	X
Bouhlef et al., 2006 [22]	X	X	X	√
Bouhlef et al., 2013 [62]	X	√	√	X
Brisswalter et al., 2011 [5]	X	√	√	√
Chaouachi et al., 2009 [19]	√	X	√	√
Chennaoui et al., 2009 [63]	X	X	√	X
Chtourou et al., 2011 [18]	X	X	√	√
Chtourou et al., 2012 [21]	X	X	√	√
Fall et al., 2007 [64]	X	X	X	X
Faye et al., 2005 [7]	X	X	X	X
Girard & Farooq, 2011 [65]	√	X	X	X
Gueye et al., 2003 [31]	X	√	√	√
Guvenc, 2011 [20]	√	X	√	√
Hammouda et al., 2012 [66]	X	X	√	√
Hosseini et al., 2013 [67]	√	X	√	X
Karli et al., 2007 [68]	√	X	√	√
Lofti et al., 2010 [69]	√	X	X	X
Meckel et al., 2008 [30]	X	X	√	X
Memari et al., 2011 [70]	√	X	√	X
Mirzaei et al., 2012 [71]	√	X	√	√
Ramadan et al., 1999 [11]	X	X	X	√
Ramadan & Barac-Nieto, 2002 [12]	X	X	X	√
Ramadan et al., 2002 [13]	X	X	X	√
Rebaï et al., 2013 [72] ‡	√	X	√	√
Souissi et al., 2007 [43]	√	X	X	X
Stannard & Thompson, 2008 [6]	X	X	X	√
Sweileh et al., 1992 [42]	X	X	X	X
Sweileh et al., 1990 [73]	X	X	X	X
Tayebi et al., 2010 [74]	X	√	√	X
Trabelsi et al., 2013 [34]	X	√	√	√
Trabelsi et al., 2012 [75] ‡‡	√	√	√	√
Trabelsi et al., 2012 [76]	X	√	√	X
Wilson et al., 2009 [32]	√	X	X	√
Zarrouk et al., 2012 [77]	X	X	√	X
Zerguini et al., 2007 [78]	√	X	√	X

**Table 1:** Ramadan training-related studies that did not meet the all the four criteria set to be included as a validated study in this review.

FAS: Ramadan Fasting Group; non-FAS: Non-Fasting Group; √: Criterion Met; X: Criterion was Not Met

‡There was no control group since both of the training groups in the study exercised in the fasted state.

‡‡No exercise performance measures were taken in the study.

## Studies Examining the Effects of Ramadan on Training-Induced Adaptations

Given the potential negative effects of Ramadan observance on training-induced adaptations, it is rather surprising that in the studies that have fulfilled the criteria set (Table 2), majority of them have indicated equivalent improvements in training-induced adaptations by both FAS and non-FAS individuals [9,36-38].

Kirkendall and colleagues [38] were among the first to examine the impact of Ramadan fasting on exercise performance across the entire Ramadan period. Their study showed that Ramadan fasting did not negatively affect the different variables tested in their subjects, that consisted of a large sample of young soccer players undergoing a coach-designed and training programme. Physical performances in speed, power, agility and aerobic endurance significantly improved when tested after Ramadan and more importantly, the magnitude of improvements were similar in both FAS and non-FAS groups. The investigators suggested that the changes in exercise performance observed in both groups were most likely due to training-induced effects and familiarity to the tests [38]. In another study, after 4 weeks of training together as a group, FAS subjects improved to a greater extent, albeit not significantly, than non-FAS subjects during a 2 mile run time-trial [37]. There was no significant differences in both groups' dietary intake, but the authors argued that the higher fitness level at pre-Ramadan reduction in the FAS subjects' body mass may have contributed to the greater improvements made in the FAS group [37]. Nonetheless, it could be reasoned that the equivalent improvements made by FAS and non-FAS subjects in Kirkendall et al., [38] and Havenetidis [37] studies were due to the fact that these studies were conducted in training camp conditions where all of the subjects' food, fluid, sleep and training load were well managed and monitored closely by the management and coaching staff. Thus in such situations, it can be argued that the FAS subjects' Ramadan negative-associated behaviors such as chronic sleep debt, poor dietary intake and low training load were averted, or at least minimized, which resulted in equivalent improvements in FAS compared to the non-FAS group.

In another Ramadan training study, investigators showed no difference in aerobic performance between pre- and post-Ramadan in young soccer players [36]. In this study, the players involved were not residing in a training camp setting, but were "free-living". Ratings of perceived intensity, an indirect indicator of the subjects' internal training load, that were taken at the end of the high-intensity interval training sessions performed throughout the study, showed no significant differences between FAS and non-FAS subjects [36]. This finding of equivalent perceived effort during training sessions is however not universally observed [9,37]. It should also be mentioned that the study's investigators had taken deliberate and specific steps to ensure that FAS and non-FAS subjects performed their exercise runs to equivalent effort as much as possible [36]. This included organizing the training as a single group session to exert peer-pressure on the FAS subjects; and providing feedback on their running times to ensure correct pacing and effort during the runs. The investigators also ensured that the duration of session was shortened (< 60 min) to prevent the influence of insufficient endogenous muscle glycogen as a possible limiting factor to exercise performance. The session was also conducted towards the later part of the day and was deliberately timed to end close to *iftar* (time to break day's fast) so as to provide somewhat of a "psychological" edge to the FAS subjects [36]. Nonetheless, a major limitation of this study [36] study was that only ~40% of the total number of training sessions was controlled while the other 60% consisted of sports-specific training sessions which was under the purview of the team's coaching staff. Hence, it cannot be ascertained that training intensity is the only factor that primarily influenced the outcome of the study's observations.

Study	Subjects' characteristics	Detailed training programme during Ramadan month	Magnitude (in %) and direction of change (↑, ↓ or ↕) from Pre- to Post-Ramadan test			Remarks / Conclusion
			Test	FAS	Non-FAS	

Aziz et al., [36]	Males, 18 ± 1 y. National youth soccer players. FAS (n = 10) and non-FAS (n = 8).  Players were free-living subjects. They were from the same squad and trained together.	F	6 sessions per week	Beep (number of shuttles)	0.9, ↔	0.9, ↔	No significant improvements made in both the FAS and non-FAS groups as a result of training. No significant differences between FAS and non-FAS for Beep test at pre- and post-RAM.  Training stimuli (external): Similar between groups Training responses (internal): Session-RPE post aerobic and sprint sessions were similar between FAS and non-FAS groups Dietary intake: Similar between groups Sleep pattern: Not reported  <b>Note:</b> Only 40% of study's total training sessions were controlled.
		I	High to maximal				
		Ti	Progressive duration of 30-50 min per session				
		T	Football-specific, high-intensity aerobic runs, and short all-out sprints				
Aziz et al., [9]	Males, 18 ± 1 y. College and club level team-sports athletes. FAS (n = 10) and non-FAS (n = 10).  Players were free living subjects. They were from the same squad and trained together.	F	3 sessions per week	Aerobic power (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	12, ↑	11, ↑	Significant improvements made by both FAS and non-FAS as a result of training. No significant differences in improvements made for aerobic and anaerobic performance between FAS and non-FAS groups.  Training stimuli: Similar between groups Training responses: Blood lactate, HR and RPE were generally similar between FAS and non-FAS groups Dietary intake: Similar between groups Sleep pattern: Not reported  Note: Players were training for 7 weeks where Ramadan month falls within this period.
		I	Maximal efforts, >100%VO <sub>2max</sub>				
		Ti	Progressive duration of 30-60 min per session				
		T	Repeated 30 s Wingate cycle bouts (from 4 to 10 bouts with 2-4 min recovery)				
Havenetidis [37]	Males, 23 ± 3 y. Military cadets who were club runners. FAS (n = 10) and non-FAS (n = 10).  Cadets were residing in a military camp and were from the same club and trained together.	F	4 sessions per week	2-mile running time (min)	2.9, ↑	1.6, ↑	Significant improvements made by both FAS and non-FAS as a result of training. The 2 mile run time performance was better in FAS than non-FAS but the difference was not statically significant.  Training stimuli: Similar between groups Training responses: Not reported Dietary intake: Similar between groups Sleep pattern: Not reported
		I	~ 70% individual's HR <sub>max</sub>				
		Ti	Progressive duration of between 45-55 min				
		T	Continuous steady-state runs				

Kinugasa et al., [41]	Males, 13-14 y. Trained soccer players. FAS ( $n = 9$ ) and non-FAS ( $n = 11$ ).  Players were residing in a sports school environment. They were from the same squad and trained together.	F	5 sessions per week	20m sprint (s)	-0.3, ↔	-1.2, ↔	No significant differences between FAS and non-FAS for 20 m sprint and Beep test. Broad jump decreased to a greater extent in FAS than non-FAS.  Training stimuli: Similar between groups Training responses: Not reported Dietary intake: Similar between groups Sleep pattern: Not reported
		I	Not reported				
		Ti	Not reported				
		T	Football-specific sessions, aerobic conditioning and strength training	Beep (number of shuttles)	3.4, ↓	3.9, ↓	
				Standing broad jump (cm)	3.9, ↓	-0.4, ↑	
Kirkendall et al., [38]; Leiper et al., [15] and [79]	Males, $18 \pm 1$ y. Club level soccer players. FAS ( $n = 53$ ) and non-FAS ( $n = 32$ ).  Players were residing in a training camp for 10 weeks where Ramadan month falls within this period. Players were from two squads. Players from each squad trained together.	F	6-8 sessions per week	7 x 30 m repeated sprint (s)	-1.4, ↑	-0.6, ↔	Most performance measures showed significant improvements in both FAS and non-FAS as a result of training and/or learning effects. Performance in Beep and dribbling tests were similarly improved in FAS and non-FAS. FAS improved to a greater extent in repeated sprint and vertical jump than in non-FAS group.  Training stimuli: Similar between group Training responses: HR and RPE were generally similar between groups Dietary intake: Similar between groups Sleep pattern: Minimal disruption to sleep hours and pattern in FAS  Note: Performance data are combined from tests conducted in the morning and afternoon.
		I	Low to high				
		Ti	60-90 min per session				
		T	Football-specific with several sessions of aerobic conditioning and strength training	Beep (number of shuttles)	25.3, ↑	16.8, ↑	
				Vertical jump (cm)	6.8, ↑	4.7, ↑	
				Agility (s)	-2.3, ↑	-3.2, ↑	
Kordi et al., [35]	Elite male athletes at local and national level from volleyball, karate, taekwondo and football.  FAS (i.e., athletes training during daytime; $n = 14$ ) and non-FAS (athletes training in the evening period, $n = 20$ ).	F	Not reported	Agility (s)	0.5, ↔	5.7, ↑	There was minimal change in performance measures across Ramadan in both FAS and non-FAS groups, except for a significantly better improvement in agility in non-FAS than in FAS group.  Training stimuli: Not reported Training responses: Not reported Dietary intake: Not reported Sleep pattern: Not reported  <b>Note:</b> Participants were not training together as a group; therefore with greater likelihood of differences in the internal training load or stimulus between groups.
		I	Not reported				
		Ti	Remained unchanged during Ramadan				
		T	Sport-specific skills	Standing broad jump (cm)	0.8, ↔	0.9, ↔	

**Table 2:** Ramadan fasting and training-induced studies.

FAS: Ramadan Fasted Subjects Group; non-FAS: Non-Ramadan Fasted Subjects Group; RAM: Ramadan Month; CON: Control Period; HR: Heart Rate; ↑: Increase; ↓: Decrease; ↔: No Change; F: Frequency; I: Intensity; Ti: Time; T: Type (of exercise)

The investigators followed up their earlier study [36] with a more controlled and systematic training program where the loading of exercise intensity was progressive and incremental in nature [9]. The training programme has also been shown to be effective in enhancing the training individual's aerobic and anaerobic systems. Furthermore, compared to their previous study, all exercise sessions throughout the later study were under the control and scrutiny of the investigators [9]. This study showed that the improvements made by both the FAS and non-FAS groups were similar. Several indicators of training responses such as blood lactate concentration, HR and RPE, were assessed in all subjects during the last session of each training week which allowed a fair comparison between the FAS and non-FAS groups in their responses to the training stimuli. The training responses between FAS and non-FAS groups were not significantly different and the total caloric intake from dietary records taken throughout the study period was similar in both groups. The authors concluded that aerobic and anaerobic adaptations to a high intensity-training program were not adversely affected as a result of Ramadan fasting, possibly because training intensity and daily nutritional intake during the Ramadan month were not compromised [9].

This factor of training intensity and/or load as the key to enhancing training-induced adaptations during Ramadan was further reinforced with the observations from a longitudinal field-study [39]. In that study, five FAS and five non-FAS professional football players were tracked over a total of 12 weeks period (four week before-, four week during- and four weeks after-Ramadan month). The players' aerobic fitness (as determined from HR and blood lactate post-intermittent running at submaximal intensity) was assessed at the end of every four weeks and their training load (i.e., session-RPE x exercise duration; [40]) was recorded throughout the period. All players were training together as a team throughout the 12 weeks. The FAS players' aerobic fitness increased from before- to during-Ramadan, followed by a decreased from during- to after-Ramadan periods. The FAS players' up- and down-swings in aerobic fitness levels paralleled closely to their training load pattern throughout the 12 weeks while no such trends was observed in the non-FAS players. The study's authors rationalized that the changing in aerobic fitness in FAS subjects was mostly influenced by the changes in players' internal training load and therefore recommended that coaches should try to maintain the intensity of training sessions during Ramadan fasting to alleviate the perturbations of Ramadan fast on players' physical condition [39].

The more recent studies have provided persuasive evidence that improvements of similar magnitude could also be made in FAS as compared to non-FAS subjects, who were not residing in a training camp setting i.e., "free-living" [9,35,36]. These research indicated that the fundamental similarities or the consistent underlying themes of these studies that have shown equivalent degree of training-induced adaptations or improvements in FAS individuals as compared to non-FAS individuals during Ramadan are that:

- i) Total dietary intake over the Ramadan was similar compared to the non-Ramadan period in FAS subjects,
- ii) FAS individuals' sleep hours over the Ramadan period were minimally affected, and
- iii) Training load or stimuli in FAS individuals throughout the Ramadan period were high and/or were maintained at the same levels as in the non-Ramadan period, or was equivalent to the non-FAS subjects.

This indicates that when these conditions remain stable, the impact of Ramadan fasting and its associated perturbations will be minimized so that fasted training Muslim athletes can obtain the same training-induced benefits as their non-fasting training counterparts.

Readers should however be aware of the inherent limitations of studies listed in Table 2. For instance, although the training program in the Aziz et al., [9] study was well-designed, the exercise sessions were held merely three times a week, on every alternate day, and

performed indoors under cool environmental conditions. This meant that subjects had ample time to recover adequately (both physiologically and mentally) from the previous exercise session and thus the overall physical stress imposed on the athletes throughout the period of study might not be as intense as that expected of some elite athletes who could be training twice a day on most days of the week. Hence, it is still not known if similar magnitude of improvements can be obtained in subjects who fast during Ramadan under more 'elite-like' or very intense training programme. For example, frequency of training could be up to six days a week with two sessions a day, which is clearly the norm for majority of elite athletes. It is foreseeable that such a regime would then challenge or even sap the fasted individual's physiological and psychological resources at a faster rate, and possibly exert pressure on the individual's recovery capability – which in turn could lead to excessive stress or overtraining during Ramadan month. This could result in adverse training-induced adaptations. This hypothesis certainly warrants further research. Several of the studies listed in Table 2 [35,41] also provided insufficient information about their training program and therefore the training volume or load that the FAS and non-FAS subjects had been exposed to is not known. Instead, authors simply stated that both the FAS and non-FAS groups performed their "normal" or typical training during the Ramadan month. More importantly, these studies did not provide any information about the exercise responses of both groups who were presumably exposed to the "same" training program and thus, the subsequent training loads experienced by both the FAS and non-FAS subjects was assumed to be equivalent. The internal stimuli (i.e., physical and mental stress) experienced by different individuals vary widely from the same external training load (i.e., quantity of training) imposed upon the individuals [36]. Therefore, training responses information such as HR, blood lactate and RPE, are important before determining that FAS and non-FAS subjects' training loads were equivalent. The differences in responses during exercise for the same training stimuli are even more important when it is an accepted fact that FAS subjects are possibly at a physiological and/or mental disadvantage as compared to non-FAS subjects at pre-, during and post-exercise during daytime fasting in Ramadan. Hence, future research need to take into account subjects' exercise responses when examining the impact of daytime fasting during Ramadan on the magnitude of training-induced adaptations during Ramadan, before arriving at their conclusions.

From Table 2, only one study showed a decline in training-induced adaptations during Ramadan [41]. This study was conducted on young footballers where the student-athletes showed reduction in aerobic endurance (via Beep test) and lower limb power (via standing broad jump test) after the Ramadan month compared to before the Ramadan month. The decline in performance is an unexpected finding since the players in the study were all full-time residents in the sport-school and thus should be coping well with the perturbations of Ramadan or at least, being monitored closely such as the participants in the study of Kirkendall et al., [38]. Explanations for these differences are not apparent but noted that subjects in Kirkendall et al., [38] were in the competitive phase and were thus training for a major competition to be held just after the Ramadan month and players in the study of Kinugasa et al., [41] were in their post-competition mode. It is plausible that the motivation levels of the fasted individuals (i.e., competing for a place in the final squad vs. routine training) may play a major part in contributing to the observed difference between findings of the cited studies. Additionally, in Kinugasa et al., [41] study, the training programme, training responses and other important variables such as dietary intake were not adequately reported and thus further limit the applicability of the study's findings.

The study reported by Kirkendall et al., [38] is worthy of close research scrutiny. Apart from pre- and post-Ramadan tests, the investigators undertook additional test measures within the Ramadan month, which provided some interesting observations of effects of Ramadan fasting on exercise performance. The authors showed that exercise performance during Ramadan was poorer during the first week of the Ramadan month but progressed and improved towards the later part of the month, followed by improvements in performance above pre-Ramadan levels at post-Ramadan [38]. These data indicate that fasted individuals were primarily affected

by the perturbations of Ramadan during the early part and they were able to cope well with fasting as the Ramadan days progressed. This argument is in line with previous studies which showed that performances and other measures such as metabolic and physiological variables stabilized during the last week of Ramadan as compared to the performances observed during the early part of Ramadan [22,41-43]. It is apparent that individuals learn to better adjust their behaviors and adopt various coping strategies as Ramadan progresses, i.e., a habituation effect [28,38,42]. The practical implication here is that coaches should be aware of such physical and/or physiological trends on the fasted individual's exercise response and performances during training in early Ramadan and therefore to be more flexible in their training program. Coaches and fasting athletes themselves should not be overly concerned with the relatively poorer quality of exercise performance, especially during the first week Ramadan month training sessions as performance will be expected to improve to baseline or pre-Ramadan levels during the later part of the Ramadan month.

### **Explanations for the Equivalent Training-Induced Adaptations Whilst Observing Ramadan Fast**

It would be of interest to speculate how it was possible for the FAS subjects to achieve the same degree of improvements as to their non-FAS counterparts, given the less than ideal conditions of the FAS subjects whilst exercising throughout the Ramadan month. In both Aziz et al., studies [9,36], training sessions ended very close to the time of the day's breaking of fast such that the fasted athletes were able to get access to food and fluid without restriction within an hour post-exercise for all the sessions, i.e., *iftar* meals. Thus, whilst the exercise or training sessions were conducted in the less than ideal 'physiological' conditions of fasting, the post-recovery situations of these sessions were not compromised. Rather, this ability to consume nutrients within the "window of opportunity" period for recovery [44] is important as the process of adaptations does not commence until nutrients and rest period are available [45]. Indeed muscle biopsy studies have clearly demonstrated that the intracellular signaling mechanisms regulating muscle protein synthesis and hence the subsequent cellular adaptations from aerobic and resistance exercise are enhanced during recovery in the fed vs. in the fasted state [46,47]. In summary, in both Aziz et al., studies [9,36], even though the actual 'physical' performance of the training sessions were not ideal, the recovery process of the exercised muscles in these studies was, however, close to optimal, which consequently might have led to the similar magnitude in training-induced adaptations between the FAS and non-FAS subjects in the two studies. This finding has important implications for athletes and coaches when they plan their daytime training session during the Ramadan month.

Perhaps, it may be argued that there is minimal impact of Ramadan fasting on acute exercise performance and subsequently, there is no adverse influence on training-induced adaptations over the Ramadan month, albeit specifically in trained individuals only. This view is supported by the findings of a study examining the impact of Ramadan fasting on acute endurance exercise consisting of a 60 min time-trial run [8]. In the study, it was elegantly demonstrated that relatively less fit fasting Muslim individuals performed much poorly compared to aerobically fitter fasting Muslims [8]. Indeed, there is support to suggest that well-trained individuals do possess enhanced cardiovascular and metabolic reserve capabilities to be utilised during exercise. For example, they have enhanced muscle glycogen storage, higher body water stores and greater physical tolerance level [48] and/or greater psycho-physical attributes such as self-motivation, determination, etc., than less fit or less trained individuals [49]. Thus, it may be reasoned that fitter fasting individuals were able to cope, both physiologically and mentally, better with the perturbations associated with chronic Ramadan fasting. This will consequently put these same individuals, as compared to their less fit counterparts, in excellent physiological condition to possibly counteract or at least minimize the adverse impact of Ramadan fasting on training-induced adaptations.

Interestingly, within the context of metabolism during acute exercise and impact on the subsequent training-induced adaptations, there is evidence to indicate that exercise and

training conducted in the fasted state may even be beneficial [46]. Exercising in the fasted state or more specifically, in the low endogenous carbohydrate state, can enhance oxidative or cellular adaptations although the actual amount of work done during the fasted session is expected to be relatively less as compared to the amount of work done in the non-fasted state. It was reasoned that when the muscle exercises in a 'carbohydrate-filled' condition, there is less of an energy imbalance during the exercise which means less metabolic activation of signalling pathways. On the other hand, the "fasted" muscles are compelled to produce the same amount of work with much less endogenous resources and thus would experience a greater metabolic stress and/or homeostatic disturbances relative to the muscle of non-fasted individuals. This would then create relatively stronger stimuli within the fasted muscles that could accelerate and/or amplify the cellular adaptations processes. This concept of "working harder with less resources" is akin to other training ergogenic modalities such as low-to-moderate exercises in hypoxia or occlusion resistance training using low loads [50,51].

This view of the possibility of high efficacy of training-induced adaptations in Ramadan fasted muscles is supported by experimental studies in humans. Stannard and colleagues [52] discovered that overnight-fasted training had greater training-induced increase in peak power and maximal aerobic power (or  $VO_{2max}$ ) than acutely carbohydrate-fed state, mostly likely via enhanced muscle oxidative capacity. They also showed that chronic exercise in the fasted state enhanced storage of resting muscle glycogen concentration, which is clearly beneficial to fasted exercising individuals during Ramadan [52]. De Bock and colleagues [53] also showed similarities in the percentage of improvements made in  $VO_{2max}$  whether the subjects were training in the fasted or carbohydrate-fed state over a period of 6 weeks. The mechanisms for the above observations are unclear but muscles functioning in the fasted or glycogen depleted state seems to promote exercise-induced intramyocellular lipid degradation, which could indirectly enhance exercise performance adaptations by reducing the usage of the limited availability of endogenous muscle glycogen within fasted muscles [54,55]. Additionally, others have also shown that exercising with low endogenous carbohydrate state will lead to a greater activation of signaling proteins and pathways (e.g. peroxisome proliferator-activated receptor- $\gamma$  coactivator-1, adenosine-5'-phosphate-activated protein kinase) involved in increasing the activities of enzymes, which are contributors to energy metabolism and mitochondrial biogenesis [56,57]. Nonetheless, it should be kept in mind that these cited studies were non-Ramadan related studies and hence were conducted in exercising fasted subjects who were solely deprived of food but not fluids. The impact of Ramadan fasting and all of its associated perturbations such as dehydration, sleep and mood swings were also, not accounted for in these studies, and as such, further experimental studies in actual Ramadan fasting individuals are needed to confirm the assertion that exercise in this state could potentially be advantageous.

## Conclusion

Much of the Ramadan fasting literature has primarily focused on acute exercise performance rather than on chronic exercise training programme and the subsequent impact on training-induced adaptations. Based on the findings of the few studies that met the criteria established in this review, it can be concluded that adaptations to training whilst observing Ramadan could be of the same percentage or magnitude as that of non-Ramadan periods if nutrients intake and training stimuli (exercise load/intensity) were maintained at levels that are similar to that in non-Ramadan period. Coaches and fasting Muslim athletes must take the appropriate steps and measures [58] to ensure that these factors are not compromised during Ramadan so as to maximize their training-induced adaptations. Further studies are required to examine the chronic effects of training while observing daytime fasting during Ramadan in well-trained Muslim athletes.

## Disclaimer

The above statements are those of the personal views of the authors (NFD and VTWL) and are not the official view of the Ministry of Defence, Brunei Darussalam.



## References

1. Shephard RJ (2012) The impact of Ramadan observance upon athletic performance. *Nutrients* 4: 491-505.
2. Aziz AR, Png, W (2008) Practical tips to exercise training during the Ramadan fasting month. *ISN Bulletin* 1: 13-19.
3. Chaouachi A, Leiper JB, Chtourou H, Aziz AR, Chamari K (2012) The effects of Ramadan intermittent fasting on athletic performance: recommendations for the maintenance of physical fitness. *J Sports Sci* 30: 53-73.
4. Aziz AR, Chia MY, Low CY, Slater GJ, Png W, et al. (2012) Conducting an acute intense interval exercise session during the Ramadan fasting month: what is the optimal time of the day? *Chronobiol Int* 29: 1139-1150.
5. Brisswalter J, Bouhlef E, Falola JM, Abbiss CR, Vallier JM, et al. (2011) Effects of Ramadan intermittent fasting on middle-distance running performance in well-trained runners. *Clin J Sport Med* 21: 422-427.
6. Stannard SR, Thompson MW (2008) The effect of participation in Ramadan on substrate selection during submaximal cycling exercise. *J Sci Med Sport* 11: 510-517.
7. Faye J, Fall A, Badji L, Cisse F, Stephan H, et al. (2005) [Effects of Ramadan fast on weight, performance and glycemia during training for resistance]. *Dakar Med* 50: 146-151.
8. Aziz AR, Wahid MF, Png W, Jesuvadian CV (2010) Effects of Ramadan fasting on 60 min of endurance running performance in moderately trained men. *Br J Sports Med* 44: 516-521.
9. Aziz AR, Slater GJ, Chia MYH, Teh KC (2012) Effects of Ramadan fasting on training induced adaptations to a seven-week high-intensity interval exercise programme. *Science and Sports* 27: 31-38.
10. Beneke R, Leithäuser RM, Ochentel O (2011) Blood lactate diagnostics in exercise testing and training. *Int J Sports Physiol Perform* 6: 8-24.
11. Ramadan J, Telahoun G, Al-Zaid NS, Barac-Nieto M (1999) Responses to exercise, fluid, and energy balances during Ramadan in sedentary and active males. *Nutrition* 15: 735-739.
12. Ramadan JM, Barac-Nieto M (2000) Cardio-respiratory responses to moderately heavy aerobic exercise during the Ramadan fasts. *Saudi Med J* 21: 238-244.
13. Ramadan J (2002) Does fasting during Ramadan alter body composition, blood constituents and physical performance? *Med Princ Pract* 11: 41-46.
14. Waterhouse J, Alabed H, Edwards B, Reilly T (2009) Changes in sleep, mood and subjective and objective responses to physical performance during the daytime in Ramadan. *Biological Rhythm Research*. 40: 367-383.
15. Leiper JB, Watson P, Evans G, Dvorak J (2008) Intensity of a training session during Ramadan in fasting and non-fasting Tunisian youth football players. *J Sports Sci* 26: 71-79.
16. Aloui A, Chaouachi A, Chtourou H, Wong del P, Haddad M, et al. (2013) Effects of Ramadan on the diurnal variations of repeated-sprint performances. *Int J Sports Physiol Perform* 8: 254-262.
17. Aloui A, Chtourou H, Hammouda O, Souissi H, Chaouchi A, et al., (2013) Effects of Ramadan on the diurnal variations of physical performance and perceived exertion in adolescent soccer players. *Biological Rhythm Research* 44: 869-875.
18. Chtourou H, Hammouda O, Souissi H, Chamari K, Chaouachi A, et al. (2011) The effect of ramadan fasting on physical performances, mood state and perceived exertion in young footballers. *Asian J Sports Med* 2: 177-185.
19. Chaouachi A, Coutts AJ, Chamari K, Wong del P, Chaouachi M, et al. (2009) Effect of Ramadan intermittent fasting on aerobic and anaerobic performance and perception of fatigue in male elite judo athletes. *J Strength Cond Res* 23: 2702-2709.
20. Güvenç A (2011) Effects of ramadan fasting on body composition, aerobic performance and lactate, heart rate and perceptual responses in young soccer players. *J Hum Kinet* 29: 79-91.
21. Chtourou H, Hammouda O, Chaouachi A, Chamari K, Souissi N (2012) The effect of time-of-day and Ramadan fasting on anaerobic performances. *Int J Sports Med* 33: 142-147.
22. Bouhlef E, Salhi Z, Bouhlef H, Mdella S, Amamou A, et al. (2006) Effect of Ramadan fasting on fuel oxidation during exercise in trained male rugby players. *Diabetes Metab* 32: 617-624.
23. Chaouachi A, Chamari K, Roky R, Wong P, Mbazaa A, et al. (2008) Lipid profiles of judo athletes during Ramadan. *Int J Sports Med* 29: 282-288.
24. Lunt JA, Allen PS, Brauer M, Swinamer D, Treiber EO, et al. (1986) An evaluation of the effect of fasting on the exercise-induced changes in pH and Pi/PCr from skeletal muscle. *Magn Reson Med* 3: 946-952.
25. Shirreffs SM, Merson SJ, Fraser SM, Archer DT (2004) The effects of fluid restriction on hydration status and subjective feelings in man. *Br J Nutr* 91: 951-958.
26. Judelson DA, Maresh CM, Anderson JM, Armstrong LE, Casa DJ, et al. (2007) Hydration and muscular performance: does fluid balance affect strength, power and high-intensity endurance? *Sports Med* 37: 907-921.
27. Mujika I, Chaouachi A, Chamari K (2010) Precompetition taper and nutritional strategies: special reference to training during Ramadan intermittent fast. *Br J Sports Med* 44: 495-501.

28. Roy J, Hwa OC, Singh R, Aziz AR, Jin CW (2011) Self-generated coping strategies among muslim athletes during ramadan fasting. *J Sports Sci Med* 10: 137-144.
29. Coutts AJ, Chamari K, Rampinini E, Impellizzeri FM (2008) Monitoring training in football: measuring and periodising training. In: Dellal A (ed.). *From training to performance in soccer*. Paris, France: De Boeck Universite, Pg: 242-263.
30. Meckel Y, Ismaeel A, Eliakim A (2008) The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. *Eur J Appl Physiol* 102: 651-657.
31. Guéye L, Seck D, Samb A, Cissé F, Camara K, et al., (2003) Physiological adaptations to exercise during a short-term fasting. *Scripta Medica (Brno)* 76: 291-296.
32. Wilson D, Drust B, Reilly T (2009) Is diurnal lifestyle altered during Ramadan in professional Muslim athletes? *Biological Rhythm Research* 40: 385-397.
33. Baar K, McGee S (2008) Optimizing training adaptations by manipulating glycogen. *European Journal of Sport Science* 8: 97-106.
34. Trabelsi K, Stannard SR, Ghilissi Z, Maughan RJ, Kallel C, et al. (2013) Effect of fed- versus fasted state resistance training during Ramadan on body composition and selected metabolic parameters in bodybuilders. *Journal of the International Society of Sports Nutrition* 10: 23.
35. Kordi R, Abdollahi M, Memari AH, Najafabadi MG (2011) Investigating Two Different Training Time Frames during Ramadan Fasting. *Asian J Sports Med* 2: 205-210.
36. Aziz AR, Chia MYH, Singh R, Wahid MF (2011) Effects of Ramadan fasting on perceived exercise intensity during high-intensity interval training sessions in elite youth soccer players. *International Journal of Sports Science and Coaching* 6: 87-98.
37. Havenetidis K (2011) Ramadan fasting and endurance running performance in army officer cadets. *International Review of the Armed Forces Medical Services* 84: 68-72.
38. Kirkendall DT, Leiper JB, Bartagi Z, Dvorak J, Zerguini Y (2008) The influence of Ramadan on physical performance measures in young Muslim footballers. *J Sports Sci* 26: 15-27.
39. Mirza LA, Aziz AR, Wahid MF, Chia MYH (2011) Impact of Ramadan fasting in submaximal running performance of professional football players. *Conference Handbook of the 4th Asian Football Confederation Conference 2011, Science & Football Medicine, 18th - 20th March, Kuala Lumpur, Malaysia*, pg: 209.
40. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, et al. (2001) A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109-115.
41. Kinugasa T, Nair G, Aziz AR (2010) Effects of Ramadan fasting on physical performance and psychological characteristics in youth soccer players. In Chia MYH, Wang J, Balasekaran G, Chatzisarantis N (eds.). *Proceedings of the III International Conference of Physical Education and Sports Science, 25th – 28th May, National Institute of Education, Nanyang Technological University, Singapore*. Pg: 292-297.
42. Sweileh N, Schnitzler A, Hunter GR, Davis B (1992) Body composition and energy metabolism in resting and exercising muslims during Ramadan fast. *J Sports Med Phys Fitness* 32: 156-163.
43. Souissi N, Souissi H, Sahli S, Tabka Z, Dogui M, et al. (2007) Effect of Ramadan on the diurnal variation in short-term high power output. *Chronobiol Int* 24: 991-1007.
44. Burke LM, King C (2012) Ramadan fasting and the goals of sports nutrition around exercise. *J Sports Sci* 30: 21-31.
45. Ivy L (2004) Timing and optimization of dietary supplements for recovery and performance. *Journal of Exercise Science and Fitness* 2: 79-84.
46. Harber MP, Konopka AR, Jemiolo B, Trappe SW, Trappe TA, et al. (2010) Muscle protein synthesis and gene expression during recovery from aerobic exercise in the fasted and fed states. *American Journal of Physiology, Regulatory, Integrative and Comparative Physiology* 299: 1254-1262.
47. Reidy PT, Konopka AR, Hinkley JM, Udem MK, Harber MP (2013) The effect of feeding during recovery from aerobic exercise on skeletal muscle intracellular signalling. *International Journal of Sport Nutrition and Exercise (on line print in press)*.
48. Shibayama H, Ebashi H (1980) Characteristics of well-trained athletes in prolonged exercise from the viewpoint of aerobic power. *J Hum Ergol (Tokyo)* 9: 55-68.
49. Connaughton D, Hanton S, Jones G, Wadey R (2008) Mental toughness research: key issues in the area. *International Journal of Sport Psychology* 39: 192–204.
50. Faiss R, Léger B, Vesin JM, Fournier PE, Eggel Y, et al. (2013) Significant molecular and systemic adaptations after repeated sprint training in hypoxia. *PLoS One* 8: 56522.
51. Pope ZK, Willardson JM, Schoenfeld BJ (2013) Exercise and blood flow restriction. *J Strength Cond Res* 27: 2914-2926.
52. Stannard SR, Buckley AJ, Edge JA, Thompson MW (2010) Adaptations to skeletal muscle with endurance exercise training in the acutely fed versus overnight-fasted state. *J Sci Med Sport* 13: 465-469.
53. De Bock K, Derave W, Eijnde BO, Hesselink MK, Koninckx E, et al. (2008) Effect of training in the fasted state on metabolic responses during exercise with carbohydrate intake. *J Appl Physiol* (1985) 104: 1045-1055.

54. McConell G (2009) Does training fasted make you fast? *J Appl Physiol* (1985) 106: 1757-1758.
55. Hawley JA, Burke LM (2010) Carbohydrate availability and training adaptation: effects on cell metabolism. *Exerc Sport Sci Rev* 38: 152-160.
56. Van Proeyen K, De Bock K, Hespel P (2011) Training in the fasted state facilitates re-activation of eEF2 activity during recovery from endurance exercise. *Eur J Appl Physiol* 111: 1297-1305.
57. Van Proeyen K, Szlufcik K, Nielens H, Ramaekers M, Hespel P (2011) Beneficial metabolic adaptations due to endurance exercise training in the fasted state. *J Appl Physiol* (1985) 110: 236-245.
58. Shephard RJ (2013) Ramadan and Sport: Minimizing Effects Upon the Observant Athlete. *Sports Med*.
59. Aloui A, Chtourou H, Masmoudi L, Chaouchi A, Chamari K, Souissi N (2013) Effects of Ramadan fasting on male judokas' performances in specific and non-specific judo tasks. *Biological Rhythm Research* 44: 645-654.
60. Aziz AR, Chia MYH, Wahid MF, Png W, Wong JTY, et al. (2010) Effects of Ramadan fasting on maximal bench press strength performance in trained athletes. In Chia M, Wang J, Balasekaran G, Chatzisarantis N, eds., *Proceedings to the III International Conference of Physical Education and Sports Science, 25th – 28th May, National Institute of Education, Nanyang Technological University, Singapore*, pp. 101-107.
61. Bigard AX, Boussif M, Chalabi H, Guezennec CY (1998) Alterations in muscular performance and orthostatic tolerance during Ramadan. *Aviat Space Environ Med* 69: 341-346.
62. Bouhlel H, Shephard RJ, Gmada N, Aouichaoui C, Peres G, et al. (2013) Effect of Ramadan observance on maximal muscular performance of trained men. *Clin J Sport Med* 23: 222-227.
63. Chennaoui M, Desgorges F, Drogou C, Boudjemaa B, Tomaszewski A, et al. (2009) Effects of Ramadan fasting on physical performance and metabolic, hormonal, and inflammatory parameters in middle-distance runners. *Appl Physiol Nutr Metab* 34: 587-594.
64. Fall A, Sarr M, Mandengue S-H, Badji L, Samb A, Guéye L, et al. (2007) Effects of prolonged water and food restriction (ramadan) on performance and cardiovascular responses during incremental exercise in tropical climate. *Science and Sports* 22: 50-53.
65. Girard O, Farooq A (2011) Effects of Ramadan fasting on repeated sprint ability in young children. *Science and Sports* 27: 237-240.
66. Hammouda O, Chtourou H, Farjallah MA, Davenne D, Souissi N (2012) The effect of Ramadan fasting on the diurnal variations in aerobic and anaerobic performances in Tunisian youth soccer players, *Biological Rhythm Research* 43: 177-190.
67. Attarzadeh Hosseini SR, Hejazi K (2013) The effects of ramadan fasting and physical activity on blood hematological-biochemical parameters. *Iran J Basic Med Sci* 16: 845-849.
68. Karli U, Guvenc A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan Fasting on Anaerobic Performance and Recovery Following Short time High Intensity Exercise. *J Sports Sci Med* 6: 490-497.
69. Loffi S, Madani M, Tazi A, Boumahmaza M, Talbi M (2010) Variation of cognitive functions and glycemia during physical exercise in Ramadan fasting. *Rev Neurol (Paris)* 166: 721-726.
70. Memari AH, Kordi R, Panahi N, Nikookar LR, Abdollahi M, et al. (2011) Effect of ramadan fasting on body composition and physical performance in female athletes. *Asian J Sports Med* 2: 161-166.
71. Mirzaei B, Rahmani-Nia F, Moghadam MG, Ziyaolhagh SJ, Rezaei A (2012) The effect of ramadan fasting on biochemical and performance parameters in collegiate wrestlers. *Iran J Basic Med Sci* 15: 1215-1220.
72. Rebai H, Chtourou H, Zarrouk N, Harzallah A, Kanoun I, et al. (2013) Reducing Resistance Training Volume during Ramadan Improves Muscle Strength and Power in Football Players. *Int J Sports Med*.
73. Sweileh N, Hunter G, Schnitzler A (1990) The effects of Ramadan fasting on maximum oxygen uptake and maximum performance. *Journal of the Islamic Medical Association* 22: 148-153.
74. Tayebi SM, Niaki AG, Hanachi P, Ghaziani FG (2010) The effect of Ramadan fasting and weight-lifting training on plasma volume, glucose and lipids profile of male weight-lifters. *Iranian Journal of Basic Medical Sciences* 13: 57-62.
75. Trabelsi K, el Abed K, Stannard SR, Jammoussi K, Zeghal KM, et al. (2012) Effects of fed- versus fasted-state aerobic training during Ramadan on body composition and some metabolic parameters in physically active men. *Int J Sport Nutr Exerc Metab* 22: 11-18.
76. Trabelsi K, Stannard SR, Maughan RJ, Jammoussi K, Zeghal K, et al. (2012) Effect of resistance training during Ramadan on body composition and markers of renal function, metabolism, inflammation, and immunity in recreational bodybuilders. *Int J Sport Nutr Exerc Metab* 22: 267-275.
77. Zarrouk N, Hug F, Hammouda O, Rebai H, Tabka Z, Dogui M, Bouhlel E (2013) Effect of Ramadan intermittent fasting on body composition and neuromuscular performance in young athletes: a pilot study. *Biological Rhythm Research* 44: 697-709.
78. Zerguini Y, Kirkendall D, Junge A, Dvorak J (2007) Impact of Ramadan on physical performance in professional soccer players. *Br J Sports Med* 41: 398-400.
79. Leiper JB, Junge A, Maughan RJ, Zerguini Y, Dvorak J (2008) Alteration of subjective feelings in football players undertaking their usual training and match schedule during the Ramadan fast. *J Sports Sci* 26: 55-69.

## Chapter 22

# Recommendations for Optimal Competitive Exercise Performance and Effective Training-Induced Adaptations When Ramadan Fasting

Vivienna Tzia Woon Lim<sup>1</sup>, Nurhayatul Filzah Damit<sup>1</sup> and Abdul Rashid Aziz<sup>2,3</sup>

<sup>1</sup>Performance Optimisation Centre, Ministry of Defence, Brunei Darussalam

<sup>2</sup>Sports Science Centre, Singapore Sports Institute, Singapore Sports Council, Singapore

<sup>3</sup>Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore

\***Corresponding author:** Abdul Rashid AZIZ, Sports Science Centre, Singapore Sports Institute, Singapore Sports Council, 230 Stadium Boulevard, 397 799 Singapore, Tel: +65 – 6500 5477; E-mail: [abdul\\_rashid\\_aziz@ssc.gov.sg](mailto:abdul_rashid_aziz@ssc.gov.sg)

## Abstract

The act of fasting is mandatory for every able-bodied Muslim individual to show their faith in Islam. Fasting Muslim athletes who train and compete during Ramadan face challenges to perform at their optimum level with the restriction of food and fluid from sunrise to sundown, as well as alterations to sleep patterns. Some studies reported that the exercise performances of the athletes were adversely affected by Ramadan fasting. This review recommends the application of the FITT (i.e., frequency, intensity, time and type) principles of exercise in the modifications to training, nutrition and hydration while considering the rest and recovery factor as well as the psychological and cognitive status of the fasting Muslim athletes during Ramadan. Ideal twice-a-day training session models, which incorporate the different physical and behavioral aspects, are proposed for the athletes in this review in order to minimize the negative impact of Ramadan on their performances. This review will act as a useful guide for coaches and fasting athletes to carefully and strategically plan their training program to generate the most optimal level of competitive and training performance during Ramadan.

**Keywords:** Diet; FITT Principles; Hydration; Nutrition; Rest and Recovery; Training

## Introduction

Ramadan fasting is not merely the act of restricting food and fluid alone but is also an intensely spiritual time, with strict adherence to the fast and an increased devotion to prayers. During Ramadan, Muslims further engage in additional daily mass prayers called *Taraweeh*, performed after breaking of the day's fast that can last between 2-2.5 h. In addition to religious activities, Ramadan is also a time for family with much of the night devoted to social activities and a corresponding relaxation of the work schedule during the day [1]. Muslims are only allowed to ingest food and fluid during nocturnal period of the

day and they primarily consume their meals at two sittings: once before sunrise called the 'Sahur' meal (just prior to the start of day's fast), and the other is after sunset, immediately upon the break of the day's fast which is known as 'Iftar' meal.

During the Ramadan month, in predominantly Muslim societies such as countries in the Middle East region, Ramadan fasting and its associated activities become the primary focus and much of the daily activities and routines revolve around the act of fasting. For example, the start of the working day is delayed and working hours are shortened. Sporting activities such as football league matches are played after *Iftar*, and the period between this meal and the competition is generally 2-3 h. However, in other contemporary societies, this is clearly not the case and thus Muslim individuals in these countries will have to adapt and suit their behavior to the majority of society accordingly. International competitions or major sports events scheduling do not take Ramadan into account and many Muslim athletes are compelled to fast despite the expected challenging physical requirements during these events [2,3]. Perturbations that are commonly associated with Ramadan fasting such as dehydration, substrate limitation, sleep deficit, mood swings and feeling of lethargy could influence optimal cognitive and physical performances [4-6]. Behavioral modifications include meal re-scheduling and disturbances in sleep patterns could be deemed as additional stress imposed on the athletes. This may also lead to drastic shift in the individual diurnal circadian rhythm resulting in a negative impact on an athlete's physiology and lifestyle [7]. Thus, perturbations associated with fasting could negatively impact optimal competitive performance and training-induced adaptations in Muslim athletes [4,5,8]. Nonetheless, there are published studies indicating no adverse impact of Ramadan fasting on exercise performance, albeit sleep, food and fluid and training stimulus of subjects in these studies were not adversely affected [9-11]. This clearly suggested that Muslims in these studies may have adopted or undertaken some behavioral, social or psychological strategies that are compatible with the perturbations associated with Ramadan fasting [2,8,11].

The paper will briefly identify these strategies and suggest several practical recommendations on how Muslim athletes may try to overcome and/or circumvent the challenges of Ramadan fasting whilst training and competing at the same time. The recommendations provided in this paper aim to assist coaches and athletes to plan and organize their preparations for optimal competitive and training performance during Ramadan.

## Whether to Fast or Not to Fast

It is easy for external parties to suggest that Muslim athletes to simply forgo their act of fasting during the period of heavy training and competition. To Muslims in modern contemporary societies, fasting during Ramadan may well be accepted and viewed as a personal choice of the individual. However, it must be emphasized that Ramadan fasting is one of the fundamental tenets of being a Muslim, and in some secular societies, Ramadan fasting is not an option or an individual's choice but a mandatory act that reflects the individual's faith to his or her God. Thus, for a devout Muslim, the act of fasting must be followed. Indeed, even if a person does not comply with the requirement of performing the mandatory five prayers a day, the person is more than likely to observe the fast [12]. There is a documented case of a fasted Muslim individual who was involved in an accident and the medical emergency practitioner has advised for an infusion of saline. The individual then asked whether such an insertion would invalidate his fast; and commented that he rather died than 'break' his fast [13]. In the sporting world, Ali Karimi, the famous Iranian football player, was sacked from his club because he did not show respect to his religion, teammates and coach by refusing to perform the Ramadan fast without a valid health reason [14].

## Modifications to Training

One of the simplest ways to reduce the adverse impact of Ramadan fasting is to modify

the athlete's training program. One of the training variables that can be manipulated to improve or maintain exercise performance during the month of Ramadan is the time-of-day of training.

### **Time-of-day**

The available options for coaches and athletes to schedule training sessions are: 2-3 h after *sahur*, 1-2 h just before *iftar*, and 2-3 h after *iftar*.

**Training session after *sahur*:** Prior to this session, the athletes would have consumed their *sahur* meals early in the morning, i.e., between 1-2 h before commencing training. Hence at this juncture, he/she would likely to be food- and fluid-filled. While in theory, the quality of the session may not be compromised, the training-induced adaptations of the session are not really ideal since post-exercise food and fluid can only be consumed >6-8 h (or longer depending on the duration of the day's fast) later at *iftar*. Indeed, there is no effective recovery from training until nutrients are ingested by the athlete [15]. It could also be that training in the morning may lead to a poorer and less than optimal quality of effort situation since the athlete may likely to "pace" himself during the session to conserve energy. Thus, physically low- to moderate-intensity exercises, which include training for sport-specific skills, tactics and techniques, are usually recommended during this time of day session.

**Training session just before *iftar*:** Training at this time of the day is advantageous since high level of motor coordination and other physical measures such as strength also tend to peak around the late afternoon or early evening period and arousal levels are closer to the optimum level for exercise performance, at least in the non-fasted state [16]. However, the quality of effort during the session during Ramadan is expected to be compromised due to the acute prolonged absence of food and fluid during the day prior to exercise. Furthermore, without nutrition as well as chronic daytime sleepiness, the fasted athletes will likely to experience early onset of fatigue and may face a heightened risk to injury [17]. It must be highlighted to readers that although the quality of training (defined as amount of work done during the session) might be compromised, the cellular effects of the mechanical work done, on the other hand, may be advantageous [9]. This view is supported by the findings that the magnitude of training-induced adaptations in the fasted state (i.e., performed in the afternoon) was equivalent to the same training in the non-fasted state [9]. A possible reason for this lack of difference in training-induced adaptations between chronic training in the fasted and non-fasted state was that post-exercise recovery was not compromised because fasting subjects were able to ingest food and fluid immediately after their training sessions [9]. Thus, if training is to be conducted during the daytime in Ramadan, it is recommended that the session ends just prior to the breaking of the day's fast to allow ingestion of food and fluid within the ideal window period to optimize cellular training-induced adaptations [9,18].

**Training session after *iftar*:** In a recent study, the effects of Ramadan fasting on performance during acute high-intensity exercise sessions were examined at three different times of day: 08:00 h (after *sahur*), 18:00 h (before *iftar*) and 21:00 h (after *iftar*) in well-trained Muslim athletes [19]. This study found that the most optimal time-of-day to perform high-intensity exercise is 1.5 h after the breaking of the day's fast at 21:00 h. Others have also recommended Muslim athletes and coaches to schedule training session to the evening period [1,7]. A survey conducted has also shown that training in the evenings is one of the self-coping strategies predominantly adopted by elite Muslim athletes in Malaysia [2,3]. The major advantage is that session conducted 2-3 h after breaking fast provides the best opportunity to fuel and hydrate before, during and after exercise without restrictions. This is the only session that allows an optimal nutritional intervention that is similar to non-Ramadan training days. Moreover, there is a tendency for the Ramadan fasted individuals to adopt an "evening-type" behavioral profile [6] and hence the evening session is also within,

or close to, the ideal period of the athlete's 24 h clock for performance and psychomotor skill [11]. However, high-intensity exercises performed 1-2 h before bedtime can negatively affect sleep quality [20]. Training late in the evening can affect the athletes' normal sleep-wake cycle as they tend to fall asleep until much later (i.e., increased in sleep latency). This poor sleep quality may further be exacerbated with the need to wake up early to consume the *sahur* meal; which would mean a curtailed sleeping hours for the individual. When this pattern is repeated over days, there will be accumulated sleep debt that could be debilitating to the fasted athlete [21].

While modifying the time-of-day of training during Ramadan is a simple and useful strategy, its overall practicability is still debatable. For example, changing the time to train in a team sport setting where majority of the players are non-Muslims may not be acceptable or even applicable. Furthermore, it must be emphasized that training sessions should be conducted at the same time-of-day as the competition match or event time, regardless of the optimal time for training during Ramadan [22].

### **FITT principle for training**

In regards to modifying the training variables during Ramadan, the FITT (i.e., Frequency, Intensity, Time and Type) principles of exercise have not been widely discussed by researchers. Below are the specific recommendations for each component of the FITT principles during exercise for training in the Ramadan fasted state.

**Frequency:** Twice a day training sessions are the norms for elite athletes. Such a frequency can be taxing for the Muslim athletes during Ramadan, especially for the second session of the day when resources are expected to be depleted (e.g., low muscle glycogen, dehydration and accumulated fatigue) after the first session. Nonetheless, such frequency of sessions can be kept the same during Ramadan period if coaches and athletes are able to convert one of the two training sessions to a less physically taxing session. For example, the first session in the daytime could be an easy run (low- to moderate-intensity) for the endurance athlete, or a tactical or set-play session for team sports athletes. It would be more ideal if the session is an "indoor training" such as video analysis and feedback on previous matches or of opponents', psychological counseling, education or career talks.

**Intensity:** Intensity refers to how hard an athlete works relative to his maximum capacity or capability [23]. Ramadan fasting occurs only once a year and athletes may require some time to adjust to the perturbations associated with the change in behavior, especially during the first few days of the month. The most significant perturbations have been reported to be during first week of Ramadan [22] and many athletes reported increased feelings of fatigue especially during the initial first few days of fast [2,3]. This is caused by the initial abrupt shift in many metabolic and physiological variables which tend to revert to normal levels or stabilize towards the later part of the Ramadan month [24,25]. Researchers have therefore proposed the concept of tapering to allow gradual adaptation or acclimatization to changes during Ramadan [26]. It was suggested that athletes train at relatively lower training load or intensity with reduced duration at the beginning of Ramadan to dissipate accumulated fatigue and maximize adaptation, and subsequently progressively increasing the training load towards the later part of Ramadan [26]. This tapering method would allow athletes to better adjust themselves to both the stress of physical training and to fasting regime. Another strategy is to commence the act of fasting (or at least partial fasting) in a step-wise manner over a few days or up to two weeks prior to the official start of Ramadan, while gradually introducing appropriate coping strategies. This is similar to the method used in anticipation of major change in time zone where people slowly adapt by changing their major sleep period over a course of a week prior to international travel [22,27]. In summary, it is emphasized that athletes should maintain the training intensity or load during Ramadan equivalent to that before Ramadan [4,26,28].

**Time (or duration of exercise):** Regardless of intensity, it is important that sessions during the daytime in Ramadan do not last longer than 75 min (including warm-up and cool-down phases). Such duration usually means that hypoglycemia does not develop in fasted subjects, and more importantly, endogenous muscle glycogen will not deplete and limit exercise capacity [29]. Previous research has clearly shown that performance and capacity during moderate- to high-intensity exercises that are longer than 90 min tended to be limited by endogenous (both liver and muscle) glycogen [30] and possibly dehydration as well, which can lead to poor thermoregulatory processes. There is also evidence to suggest that fasted players faced greater risks to injury when fatigue levels were elevated [17]. Indeed, empirical studies suggest that players encountered higher risk for musculoskeletal injuries when they experienced greater level of fatigue [31,32], vis-à-vis Ramadan fasted athletes who are exerting themselves late during the match. Whilst this cannot be done during competition, coaches should consciously plan for the duration of the training sessions and allow for more frequent rest periods during session. Thus, it is reasonable to recommend that the duration of daytime physical training sessions during Ramadan should be kept as short as possible, without compromising the coach's objective of the session.

**Type of exercise performed:** If the athlete trains two sessions a day, it is best to convert one of the sessions to a less physically taxing session. As previously mentioned, the first daytime session could be an easy (low- to moderate-intensity) session or alternatively, a non-physical session. In addition, coaches will need to vary and be flexible with their training program during Ramadan period. Aerobic exercises, which are of low- and moderate-intensity as well as training for psychomotor skills can be conducted in the daytime while high-intensity training session should preferably be scheduled in the evening period. If daytime training is imperative, the high-intensity session should be performed just before the breaking of the day's fast, rather than in the morning. It is also important to schedule some form of strength or resistance session, at least once a week in order to reduce total protein loss and preserve muscle mass [8].

Overall, it is important that coaches are flexible in their training programs and closely monitor the athlete's responses to the training stimuli to ensure that the athlete is not physically overstressed. However, a reduction in training intensity could lead to a state of detraining and coaches should be aware of possible detraining effects during Ramadan. As previously suggested, the coaches could then plan a tapering period (especially by reducing training volume).

## **Warm-ups protocols**

Although warming-up is critical prior to any training or competitive session, it gains more importance during Ramadan sessions for several reasons. Firstly, warm-up is useful in helping to reduce "sleep inertia" in fasted players who are planning to exercise soon after waking up from their daytime naps. Given that the mental state of readiness to train of Ramadan fasted athletes has been observed to be less than ideal [33,34], a well-planned warm-up can assist to 'psych' the athletes for optimal activation state for training or competition preparedness [35]. It is also important that the coach and athlete carefully manage the execution of the warm-up session so as not to 'over-do' the session. Too much or excessive warm-up can also lead to accumulative fatigue and too long a duration will increase heat exposure (gain in body temperature) and sweat loss (loss in body water); all of which could compromise the fasted individual's thermoregulation processes later during the match or session, especially when exercising in a hot and humid environment. In the case of an evening session, a prolonged warm-up will clearly reduce the time available for the primary activity. Interestingly, a recent study showed that a 5 RM leg press maximal strength-type warm-up appears to result in better reaction times, jumping power and sprinting performance during a match simulation exercise compared to a traditional specific warm-up in soccer players [36]. The "strength" warm-up also elicited a lower core temperature and blood lactate responses during the simulation match.



Shephard (2012) recommended that a higher intensity of exercise is required during the warm-up session in the fasted state [8]. Given the relatively lower resting blood glucose concentration prior to exercise typically observed in the fasted state, it was argued that a high-intensity warm-up can help promote the rapid breakdown of liver glycogen and the mobilized glucose could then subsequently be used as supplementary fuel for muscular contractions during the primary or main activity of the session [8]. However, this was observed in the non-fasting state and should be studied during Ramadan. In summary, it is recommended that the warm-up session should be of appropriate intensity between ~60-70%  $VO_{2max}$  but short duration of 10 min or less, followed by several minutes of recovery [35].

### **Training environment**

Training sessions should preferably be carried out in a cool, shaded place as much and as often as possible. Exercising in a hot and humid environmental will result in a greater thermoregulatory challenge to the fasted athletes, whom have been shown to possess poorer sweating ability [33]. These conditions are further exacerbated given that Ramadan fasted subjects are likely to be hypohydrated and with the inability to replace sweat loss, can lead to a higher muscle glycogen usage compared to the same exercise in cooler environment [37]. Clearly, exercising in cooler conditions will help reduce these debilitating effects of heat on physiological and perceptual responses, which are factors that could lead to poorer exercise performance [1,4].

### **Training organization**

There is a tendency for fasted Muslims to do less work than what they are actually capable of performing during exercise due to their self-perceived higher ratings of effort for the same amount of work done in the non-fasted state [22]. Consequently, it is suggested that the coach should dictate the amount of work to be performed by the athlete during the session in terms of the number of repetitions, sets, trials, rest period, speed of run and amount of weights lifted. This is because the athlete will perform to his own discretion, which will likely lead to a relatively lower amount of work done [4]. It is also recommended that the fasting and non-fasting athletes exercise together as a group, which helps create a positive 'peer-pressure' situation among the athletes [38]. Coaches should also provide verbal encouragements as much as possible to the players. Coaches should always emphasize and encourage the athletes to focus on the quality of their performance or execution of the exercises or skills throughout the training sessions. To further help ensure a high quality of effort throughout the entire session, the coach should provide more frequent, but shorter duration rest breaks in between exercises.

### **Pre-Ramadan training initiatives**

**Fitness levels:** The rapid onset of fatigue among Ramadan fasted athletes can reduce quality of performance and/or increase the risk to injury. Thus, another strategy to attenuate early fatigue is to make the Muslim fasted athletes as fit as possible when approaching Ramadan. This strategy is often ignored by coaches but was clearly evident in a classic study where investigators examined the effects of Ramadan fasting on high-intensity endurance performance [33]. The investigators demonstrated that exercise performances of fitter fasted Muslims were less likely to be negatively affected by Ramadan fasting (and even if adversely influenced, the magnitude of impact is much less than in Muslims who have poorer fitness) [33]. Apparently, the physically fitter Muslims are able to cope better with perturbations of Ramadan fasting. This was indirectly supported by previous study showing that active fasted Muslims are able to conserve more body water as compared to less active ones [39]. Performance of well-trained athletes may be less affected by hypohydration than that of untrained individuals [40]. Trained individual is able to store more glycogen within the working muscles. Trained individuals are characterized with high levels of tolerance to

fatigue, positive attitude and greater mental strength than untrained individuals. In short, by making the athletes fitter, the fasted Muslim athletes will face the physical challenges of training and competing whilst fasting with greater self-confidence [33].

**“Habituation” to Ramadan fasting:** In a recent study, subjects were made to exercise in a hypohydrated state on several occasions [41]. Whilst performance in the hypohydrated state was much lower compared to performance in the euhydrated state, the decline in performance in the later hypohydrated trials was progressively attenuated. The investigators argued that in the later trials, subjects seemed to be “habituated” or have somewhat adapted to the physical and mental stress of exercising in the hypohydrated state and hence performance was less adversely affected [41]. In the same manner, it can be reasoned that fasting individual can also habituate himself to cope with exercises in the less than optimal Ramadan fasted state. For example, the Muslim athlete could practice the fast during the year out of the period of Ramadan, especially during the month before fasting, which could habituate the individual to Ramadan observance later on.

### **Regular monitoring of training variables**

An important strategy is to regularly monitor the fasted athletes’ responses throughout the Ramadan period so as to have a better understanding of how the athletes are coping with both fasting and training at the same time [1,26]. The key challenge for the coach and management staff is to determine those useful variables that will provide insightful information of the athlete’s status, but are yet practical, non-invasive and simple to measure. Below are some possibilities suggested:

**Training intensity and/or load:** It is worthwhile to assess the athlete’s training intensity and/or load during Ramadan fasting to ensure that the fasted athletes are provided with sufficient training stimuli. This is to ensure that they do not suffer from detraining [26] and at the same time, to not overly stress them until they have overreached or overtrained. In this regard, measuring the athlete’s subjective perceived ratings of the session using the categorical Borg’s RPE 1-10 scale [42] is a simple and practical tool to track the physical load that the fasted individuals are experiencing over all the training sessions performed during the Ramadan month [38]. When these values are compared with the non-fasted players, the difference or similarity observed may allow the coaching staff to determine the overall physical and mental stress that the fasted athletes are experiencing. A consistently high RPE during low-intensity training can help detect early signs of overly physical fatigue where coaching staff can make adjustments to the individual’s training stimulus accordingly [1]. Obviously, there are other measures that can also be taken to assess the training loads of individuals such as mileage covered, total amount of weight lifted and percentage of maximal heart rate; however, using session-RPE and duration of training to assess training load are much simpler and practical [43].

**Readiness to train:** While the session-RPE helps to provide inputs on what the athlete is experiencing during training, the coaches can also do a simple assessment of the athlete’s willingness and desire to train as well as fatigue levels prior to training. Previous study has used a simple visual analogue scale, with word descriptors anchored at both ends of the 100 mm line that expressed the two most extreme ratings of the variable [44]. The athlete simply mark his perceived physical and mental conditions (i.e., defined as the athlete’s readiness to train) along this line, just prior to the commencement of exercise. A consistently low or poor response over several consecutive training sessions would flag something has gone amiss with the fasted athlete. The coaching staff could then conduct a more detailed follow-up investigation on the athlete e.g., clinical assessments to determine the cause of the poor pre-exercise attitude.

### **Modifications to Nutrition**

The absence of nutrients for a prolonged period of time can result in hypoglycemia and lowers the amount of endogenous glycogen concentration. Thus, the most fundamental

issue with nutrition is that the athlete will need to take into account the type, amount and the time of day of food ingestion in order to optimize the endogenous substrates storage for future use during exercise. Therefore, the same FITT principle used in training will be applied to the modifications of dietary intake during Ramadan.

### **FITT principle for nutrition**

Below are the specific recommendations for each component of the FITT principles for nutrition during exercise in the Ramadan fasted state.

**Frequency:** During Ramadan, there is evidence to indicate that meal frequency is reduced from 3-4 meal sittings to only twice a day [45]. This is not ideal for training and competing athletes because fasted individual's daily caloric intake over the 24 h period during Ramadan should be similar to that consumed during the non-Ramadan month. It is thus recommended that Ramadan's *sahur* meal to be matched with the normal lunch; Ramadan's *iftar* meal to dinner; and Ramadan's night snack with the typical morning breakfast [4]. Thus, matching the typical three main meals during the normal non-Ramadan period to Ramadan meals sittings will help in ensuring that the athletes will likely to consume sufficient amount of calories over the 24 h period during Ramadan.

**Intensity (or amount):** Athlete should ensure that his total energy intake is able to support the energy requirement for performance and recovery as well as satisfy the overall needs for food and fluid for the day. The recommended amount of important nutrients including carbohydrate and protein for athletes has been previously outlined [18]. There is documentary evidence of athletes consuming five to six small meals over the day. For such athletes, it may be necessary to adopt the practice of over-consumption over the two meals sittings during Ramadan to maintain the necessary sufficient calories. These athletes may also need to consume nutrient-dense food to be able to obtain the same calories with less frequent meals. There are studies suggesting that some Muslims do not consume their *sahur* meals [3,46,47]. This is not an acceptable practice and should not be condoned because without ingesting *sahur*, the body will be in the fasted state for a much longer duration than necessary which will likely compromise daytime exercise performance. *Sahur* is the last opportunity for fasted athletes to be able to put nutrients in their body and hence the athlete who is planning to fast should take full advantage of this meal.

**Timing:** Athletes should be reminded to consume their *sahur* meal as close as possible to sunrise just before the commencement of the day's fast while *iftar* to be taken immediately at sunset once allowable to break from fasting [4]. This strategy will ensure that the body is in the 'fasted state' for the shortest period possible. It is well established that the best time to consume food and fluid for recovery is the period immediately after exercise, especially after heavy training. There is a 'window of opportunity' for higher rates of glycogen storage during first 2-4 h post-exercise [18]. Thus, this supports the argument that if heavy training is to be conducted during the daytime in Ramadan, the session should be timed such that it ends just prior to the breaking of the day's fast to allow unrestricted ingestion of food and fluid for enhanced post-exercise recovery [9,18].

**Type:** There are three main types of nutrients that the physical body needs on a daily basis: carbohydrates, proteins and fats. A recent review, however, suggested that during Ramadan, there was a greater tendency for Muslims to consume a greater amount of fats and at the same time reduce their carbohydrate intake [45]. A possible reason for this is that Muslims tended to choose dense-nutrient food to compensate for the fewer meal sittings over the 24 h period. Nonetheless, food taken by athletes for *iftar* and *sahur* should contain predominantly nutrients of carbohydrate and protein.

In regard to the "ideal" types or composition of food for athletes during Ramadan, it is recommended that low Glycemic Index (GI) food is taken for the breaking of the day's fast meals (*iftar*), especially when athletes plan to exercise soon after the post-prandial period.

Previous studies have shown that consuming low GI meals from 0.25-4 h of consuming the meals can lead to an increase in the availability of carbohydrate and a greater carbohydrate oxidation throughout the exercise period, leading to enhancement in endurance performance [48-50]. These studies' authors argued that the ingestion of low GI meals slowly released the endogenous sugars into the blood stream and thus sustained the body's energy production towards the later part of the endurance exercise, which could theoretically improve performance. This seems ideal if the Ramadan fasted individual is planning to partake in prolonged strenuous exercise after *iftar*. In contrast, it is likely that high GI meal is beneficial when consumed for the *sahur* meal. The high GI meal will lead to higher peaks of glycaemia and insulin responses. This will then result in a relatively greater muscle glycogen being stored during the post-absorptive fasting period as compared to consuming a low or normal mixed GI meal [51,52]. The enhanced levels of endogenous glycogen stored during the first few hours of the post-absorptive period can then be subsequently used as energy substrate during exercise much later (i.e., 8-10 h after *sahur*).

Other studies, however, have proposed slightly different strategies. For example, it has been suggested that fasting individuals should consume a high carbohydrate diet for the *iftar* meal (for the previous evening) to maximize the muscle glycogen stores and then consume food high in fats for the *sahur* meal (on the day of the event) in attempt to slow down the rate of ingestion and thus gastric emptying [8]. It is reasoned that this strategy will reduce the feelings of hunger during the fasting period and at the same time sustain the endogenous energy substrate until exercise commences during the daytime. Muslims traditionally consume fruits, dates and milk when breaking their fast. Although this advice has been recommended since the ancient times, the scientific evidence for this practice is not clear. Nonetheless, it has recently been shown that the date fruit is an advantageous nutrient because it is a low GI food and it is caloric-dense [53]. Milk contains a high amount of protein and recent studies have indicated that adding a small amount of protein to carbohydrate clearly has been shown to further enhance absorption of carbohydrate and thus storage of muscle glycogen [54]. Additionally, the ingested protein will promote amino acid re-synthesis and muscle re-building [55]. Protein is critical as previous studies have shown that ingestion of this nutrient helps to maintain lean mass integrity with greater efficacy, even in those who do not perform resistance training [56]. This is important given that there is a real concern of 'detraining' effects, specifically muscle-wasting due to possibly substantial reduction in the overall training stimulus and/or lower caloric intake during the Ramadan month [26]. Thus, the combination of low GI meal and protein (i.e., dates and milk) seems to provide the best mixed meal during *iftar*, although scientific experimental studies are required to confirm this assertion. Whilst all the different nutritional strategies highlighted above are theoretically plausible, there is no direct experimental evidence available to support that they are better than consuming a normal diet during the Ramadan period.

## **Regular monitoring of nutritional-related variables**

As with training, there are also several variables that need to be monitored in regard to nutritional aspects of the Ramadan fasted athletes. These are:

**Body composition and/or body mass:** Ideally, all athletes should be monitoring their body fat levels throughout the Ramadan period. This will help them make accurate decisions on their caloric intake over the Ramadan month. However, if equipment and expertise are not easily available to assess the athlete's body composition, then the simple recording of athlete's daily body mass upon waking up in the morning can be useful. Daily body mass typically varies within 1.0-1.5 kg, and hence any change in magnitude above or below this value accumulated over several days might be an early warning. For example, gradual lowering of body mass over several consecutive days might indicate that the athlete may be losing lean mass (from detraining effects) and/or is not consuming sufficient calories or not

hydrating adequately over the days. On the other hand, a gradual increase in body mass could be due to higher caloric intake. Thus, monitoring of a simple variable such as body mass allows the coaching staff to detect responses in the athlete's status and investigate any observed discrepancy.

**Blood glucose concentration:** Given the prolonged period of acute fasting (>12 h), there is a possibility that some individuals may experience hypoglycemia [46]. Thus, it is imperative that coaches or athletes assess the blood glucose concentration during Ramadan fasting to routinely check if any individual is susceptible to low blood sugar levels. Perhaps, periodic assessing, every 2-3 h during the first few days of Ramadan fast is encouraged. Technological advancement has made measuring blood glucose concentration less cumbersome and portable, where self-assessment is easy.

**Sports supplements:** These “food” are portable and hence are easily accessible when urgently required, e.g., when breaking fast at competition or training sites where nutrients are not easily available. Supplements also made ingestion easier as they are compact and allow faster absorption of nutrients into the body, especially when the need to exercise soon after the breaking of the day's fast is of utmost importance. This may be particularly useful for fasted athletes who have prevailing gastrointestinal problems [18]. However, food supplements should be used sparingly because of their relatively higher costs involved and due to the need to obtain a well-balanced dietary intake.

## Modifications to Hydration

The inability to ingest fluid many hours before exercise may lead to athletes training in hypohydrated state at pre-exercise. This hypohydrated state is made worse during exercise in the daytime during Ramadan, since the individual is not able to ingest fluid throughout the exercise, leading to acute dehydration [57]. Research has shown that pre-exercise hypohydration as little as ~1-2% of body mass can reduce performance of short duration, high-intensity exercises [1]. Exercises of longer duration or in a heat stress environment are more likely to be affected at lower levels of hypohydration, and of subsequent dehydration as a result of exertion during exercise.

The amount of sweat loss at the end of an exercise session varies between less than 0.5% to more than 3% for different individuals for the same exercise. It must be highlighted that dehydration, even for a small magnitude, example 1% of body mass, has been shown to increase the individual's subjective perception of fatigue, and decrease his levels of alertness and concentration [58]. In fact, it is reasonable to argue that for the Ramadan fasted individual, the lack of acute fluid intake before and during exercise will result in greater physiological consequence than that of food intake, especially if the exercise is performed in a hot and humid environment. The main aim of the hydration strategies during Ramadan is to minimize pre-exercise hypohydration and fluid loss (i.e., dehydration) during exercise session. Additionally, the coach and athlete need to be aware of the different environmental conditions that can exacerbate the effects of hypo- and de-hydration during exercise, and take these into considerations when planning for the volume of fluid to be ingested, prior to the start of day's fast.

### FITT principle for hydration

Similarly, as in the case of nutrition, the FITT (frequency, intensity (or amount), timing and type) principles of hydration need to be taken into consideration when trying to optimize the exercise performance of the athletes during training or competition in Ramadan.

**Frequency:** It is recommended that athletes hyper-hydrate themselves during the permissible period between *iftar* and *sahur*. During this period, athletes are advised to spread the fluid consumed throughout the available time, with frequent small amounts of drinks rather than ingesting large volumes in a single seating. This “grazing” pattern of

fluid ingestion will help to retain greater fluid and reduce unnecessary urine losses. Fluid consumption should be paced at a rate of ~200 ml for every 30 min [4]. Fluid retention is further enhanced when osmotically active agents such as sodium salts are added to the ingested food and drinks [59]. Nonetheless, it must be highlighted that too much fluid consumed in total volume can potentially lead to disrupted sleep because of the frequent need to use the bathroom throughout the night. Another possibility of increasing fluid retention is to consume fluid together with glycerol, which helps to retain the fluid in the body [59]. This method however, is deemed as illegal for competitive athletes, and hence will not be discussed further here.

**Intensity (or amount):** The European Food Safety Authority recommended that the total water intake over 24 h is ~2.5 L per day for adult individuals living in temperate climate [60]. There is no suggested value for individuals in equatorial region, but a volume of ~3.0 L per day seems reasonable, and probably Ramadan fasted athletes may require a slightly higher volume [4]. Ideally, the total volume of fluid to be ingested should be preset to the specific individual needs. Therefore, it may be useful to obtain a more individualized fluid requirement over the 24 h period during Ramadan. To do this, the athlete can simply weigh himself before and after a typical training session to obtain the estimated amount of fluid loss from sweating during exercise (this should be trialed out in the non-Ramadan period). The formula is as follows:  $\text{Sweat loss} = \text{Change in body mass} + \text{Fluid intake during exercise} - \text{Urine output}$  [61]. This calculated fluid requirement can be used to determine the individual's total volume for the day during Ramadan.

**Timing:** Similar to the nutritional strategy, the athlete is encouraged to ingest fluid as soon as permissible and also to ingest as much as possible throughout the nocturnal period until the commencement of the day's fast, using the above-mentioned grazing technique.

**Type:** While plain water is acceptable, it is unlikely that many athletes would want to consume only water throughout the period between *iftar* and *sahur*. Thus, fluid should be of varying flavors to promote voluntary consumption of as much fluid as possible. Athlete should also consume only a small amount of coffee and tea since they are diuretic which promote fluid excretion rather than retention.

## Hydration status monitoring

Simple markers of hydration status, including urine frequency and color, can be used to monitor the hydration status of the athlete on a daily basis. Frequent assessment of urine color, either daily upon waking and/or throughout the day will, to some extent, help athletes and coaching staff assess the hydration status of the individual. A normal dehydrated individual will have a light yellow urine color, whilst a darker yellow urine color implies a greater state of hypohydration [62]. Such information, combined with data on body mass, can provide a more accurate assessment of the fasted individual's hydration status.

## Cooling techniques

During daytime training, fasted subjects are not able to consume fluid before, during and after exercise, and are therefore hypohydrated at pre-exercise and experience dehydration during exercise. These conditions will compromise thermoregulatory process that could affect exercise performance. Thus, external cooling techniques such as ice baths, cold towels, plunge pools and ice vests can be used before, during and after exercise to reduce the impact of heat generated and hence attenuate thermoregulatory concerns [63,64]. Coaches and athletes should also choose appropriate clothing that allows better dissipation of sweat produced and promotes cooling during exercise in the Ramadan fasted state [1].

## Mouth-rinsing strategy

Fasted Muslim athletes have been observed to rinse their mouth frequently during training [34]. Anecdotal evidence indicated that this simple strategy seems to provide

subjective relief, albeit only temporary. This view is supported by a recent study showing that mouth-rinsing with either carbohydrate or water at every 10 min intervals during a ~55 min time-trial cycling performance in the Ramadan fasted state led to a better endurance performance when compared to no-mouth rinsing exercise trial [65]. Nevertheless, additional studies are required to confirm these findings.

## Rest and Recovery

Athletes must pay close attention to lifestyle and behavioral factors that may be affected during Ramadan in order to balance all social, religious obligations and sport activities with proper rest and sleep. During Ramadan, Muslims usually wake up early at pre-dawn and with the added social and religious activities that take place after sunset, can lead to ~1-2 h of sleep lost per day [21]. When this acute sleep debt occurs over consecutive days, the accumulation of sleep loss will eventually lead to chronic sleep deprivation, which in turn could affect physical and mental performance directly or indirectly via mood swings or feelings of lethargy [6]. Hence, rest and recovery gain greater importance in the athlete's overall training program during Ramadan. In a recent study, albeit not on Ramadan fasted athletes, investigators compelled a group of basketball players to extend their sleeping hours beyond their normal habitual hours [66]. Following two weeks of the "extra sleep", there were significant improvements in the players' sprint times, free-throw accuracy and levels of vigor and positive moods. These results suggested that increasing the amount of sleep may positively influence exercise performance [66]. In summary, chronic sleeping deficits in fasted athletes must be avoided at all cost and sleep management strategies must be implemented to ensure adequate rest and recovery during Ramadan. Below are additional steps or behavioral patterns that athletes can adopt to enhance their overall rest and recovery situation during Ramadan.

### Minimising uneventful physical exertion during daytime

Ramadan fasted athletes should minimize any unnecessary physical exertion during the daytime period to limit the use of precious available endogenous resources such as muscle and liver glycogen, and blood glucose. This is also to prevent the occurrence of accumulative physical fatigue, which could hamper exercise during the later part of the day.

### Afternoon and/or planned naps

Non-Ramadan studies showed that daytime naps increased acute alertness and neuro-behavioral functions [67]. Sprint performance was also enhanced following a 30 min afternoon nap [68]. Ramadan fasted athletes are therefore recommended to take afternoon or planned naps at appropriate time during the daytime because of the reduced sleeping hours at night. Planned naps for 30-40 min can significantly improve alertness. However, it is advised to best avoid prolonged (>60 min) daytime naps and/or naps close to bedtime as this will tend to disturb nocturnal sleep and make it more difficult for the individuals to adjust to the changing biological clock [69]. It is also suggested that vigorous exercise and complex coordinated movements should not be planned within an hour after a long daytime nap, as 'sleep inertia' or grogginess is present upon waking, although an appropriate warm-up may help to alleviate this condition (see Modifications to Training section). Afternoon naps will also aid Ramadan fasted athletes to take their minds off food and fluid, and thus 'shortening' the time towards *iftar*. Otherwise, fasted athletes can sleep ~1 h earlier in the evening instead of taking naps during the day [4].

### Onset and duration of sleep

As previously highlighted, exercise in the evenings should also be timed sufficiently in advance of bedtime to reduce sleep latency, which is the duration for an individual to fall asleep. Wilson et al., (2009) recommended a simple strategy where athletes should extend their sleeping hours until mid-afternoon period before waking up [70]. This means that the

athlete will not be involved in any substantial physical exertion and this helps to conserve the limited acute energy resources available to athletes who are planning to exercise later during the day. Psychologically, this will also reduce the duration of feeling of hunger and thirst.

Ideally, the sleep schedule designed for Muslim athletes should be individualized based on chronotype [71]. Thus, if athletes are the morning types, they should sleep earlier in the evening while if they train more towards the evening, thus their sleep time would be later in the evening. Athletes should take steps to ensure that their sleep routines are not disrupted. Coaches should ensure that all briefings and team discussions do not siphon away the athlete's sleeping time. Another strategy is to prepare for the new shift in sleeping pattern gradually approaching the Ramadan month [27]. For example, several days prior to Ramadan, the athlete can start to progressively get used to a new sleep-wake cycle according to the regime that they will experience during the month of Ramadan. This includes progressively shifting their sleeping and eating schedules to match those in the fasting month [8,22]. Interestingly, a recent report highlighted the potential use of red light laser treatment to enhance sleep quality. The study's researchers showed that 30 min of daily exposure to red light therapy laser for two weeks enhanced various indicators of sleep and daytime sleepiness [72]. This study demonstrated an innovative, non-invasive and more importantly, non-pharmaceutical method to enhance sleep, which may be potentially beneficial for use in Ramadan fasted individuals.

### **Sleep quantity and quality**

Several common-sense strategies can be easily implemented to ensure optimal sleep quantity and quality during Ramadan. Firstly, athletes should be encouraged to take daytime naps to compensate for the shorter nocturnal sleep hours. Secondly, the athlete may need to plan a fixed sleep schedule to ensure that sleep hours are maintained throughout the fasting month [1]. Diligent daily recording of sleep pattern into a daily logbook, such as time to bed and time of awake, is useful to monitor the athlete's sleep pattern. However, the data obtained during the Ramadan period need to be compared with data from the non-Ramadan period to allow an accurate assessment of the subject's sleep needs. Others have also used validated sleep questionnaires to assess the fasted athletes' daytime sleepiness [33]. Athletes must realize the importance of sleep as part of their overall rest and recovery strategies, and prioritize sleep time over their evening social activities to increase sleep time [66].

### **Education on the importance of adequate sleep**

In a recent survey, it was found that fatigue-related injuries were related to less than 6 h of sleep in the evening prior to the occurrence of the injury [73]. Hence, coaches and athletes should also be educated on the importance and benefits of sleep as a primary form of recovery as part of the athlete's overall training program. They must also be aware of the sleep needs of the athlete and the impact of nocturnal meals and physical activity on sleep architecture including those situations and/or factors which can worsen sleep loss (e.g., pre- and post-competition insomnia, heavy evening training sessions or social activities, etc). This is important because a previous study has shown that athletes tended to misjudge the amount of sleep required to perform at their peak level [66]. Thus, a general educational program should be made available to all Ramadan fasting athletes and coaches focusing on the importance of sleep [71].

### **Psychological and Cognitive Impact**

Optimal cognitive functioning helps athletes in concentration; learning and remembering new skills; reacting appropriately to stimuli; solving problems or decision-makings; all of which are useful in many sports. Thus, impairment to the cognitive function can affect the outcome of a competition, or in the worst case, result in injury [74]. Physical and mental performance, including cognitive function, fluctuates across the day during Ramadan due



to changes in the circadian rhythm of the body [1]. Several recommendations are compiled to help reduce the negative effects of Ramadan on the cognitive and mental performance of athletes.

- Coaches and non-Muslim teammates should try to provide every support possible to Muslim athletes who have indicated the desire to fast. Emotional support from non-Muslim teammates and coaches is very important for a more cohesive team dynamics. Coaches can make some effort to appreciate and understand why the Muslims fast, and what the Muslim athletes are going through [11]. This may help the coach plan and organize the athlete's training program to better suit the fasting athlete's Ramadan regime [11]. Furthermore, knowing that the coach is fully supportive of his decision will strengthen the fasted athlete's conviction to do his best and maximize his effort in training and competition.
- In contrast to Chamari et al., (2012), it has been reported that fasting athletes actually experienced less stress during Ramadan [2]. This could be due to the athlete's personal spiritual belief and the act of Ramadan fasting itself, where a Muslim individual is expected to engage in daily prayers, sacrifice and self-control, which can lead to a positive state of mind. Fasted athletes should be encouraged to regulate and mobilize their emotions and psychological resources towards a more positive approach which can enhance his sporting performance. Additionally, there were reports stating that Muslim athletes felt much stronger or "more powerful" when competing in the Ramadan fasted state [75]. Apparently, these fasting athletes became more determined, i.e., mentally stronger or possessed a greater level of motivation to do well and perform their best during training or competition whilst in the Ramadan fasted state [3]. Thus, athletes are recommended to maintain an overall positive mental perspective of the Ramadan fast in order to help them cope with the rigors of training during fasting.
- The human circadian system provides coordination of many endogenous physiological and behavioral systems, such as core body temperature and sleep-wake pattern, with each other and with the external environment. The circadian system is entrained to the 24 h day via exposure to the Earth's 24 h light-dark cycle, and some of the peaking of these variables is parallel with peaking in exercise performances [76]. During Ramadan, delay in evening sleep times and early or delayed awake times can significantly alter the natural circadian rhythm and this drastic shift has been touted as one of the contributing factors for the observed negative impact of fasting on exercise performance [1,7]. For example, the athlete may always perform his best in the late afternoon or early evening in non-Ramadan period, but this "top" performance may be delayed to the late evening period during Ramadan due to the drastic shift in his circadian rhythm [24]. Therefore, coaches and athletes should be aware of such disturbances that can cause much variability in their performance and/or capability when planning the athlete's training programs [1].
- Athlete's mood and motivation can also be severely affected during Ramadan. Therefore, it is recommended for the athletes to practice some mental preparation strategies such as task focused concentration, positive expectations, correct execution of task and emotional control, throughout Ramadan. This is to develop proactive coping strategies for improving general resources required to reduce or attenuate the discomfort of fasting during Ramadan [2]. Moreover, in line with the teachings of Islam, the athlete is reminded to adopt a more patient approach in their dealings with any stressful or conflicting situations during Ramadan. This will clearly help the athletes to cope better when fasting and training at the same time. Coaches should also be aware of the variability in performance capacity and/or capability over the day when planning or modifying their training programs [1].
- Interestingly, previous studies have also assessed the fasted individuals' ability to train,

alertness and concentration and other variables as indicators of the fasted individuals' fatigue levels [9,33,44]. These studies have used psychological instruments tests such as the Profile Mood of State to determine the individuals' mood levels prior to exercise.

- Previous Ramadan fasting and exercise studies have shown two consistent findings: i) exercise performance is likely to be poorer during the initial first week of Ramadan month, and ii) performance tends to be better (albeit still lower than during non-Ramadan days) as Ramadan progresses. These findings suggested that Muslim individuals are able to cope with the negative perturbations of Ramadan, if given time to adjust. Thus, in situations where the athlete needs to compete during the first few days of Ramadan, there is clearly a need for the athletes to “familiarize” themselves to exercising in the fasted state. The coach may need to organize simulated matches that compel the athletes to compete or exercise in the “simulated” Ramadan fasted state, in preparation to competitions held during the early part of the fasting month.

## Ideal Twice-A-Day Training Sessions Model for Athletes during Ramadan

Compared to twice-a-day training sessions, a single session per day is not likely to have a great impact on the fasting individuals. Here, we proposed two twice-a-day training sessions models (Figures 1 and 2) that have taken into account majority of the factors and issues which have been discussed in the preceding sections of this paper. Note that the proposed timings below are based on the assumption that the duration of the Ramadan fasting is ~13-14 h per day, and thus some modifications of the exact timings are certainly required for those residing in the Western hemisphere where the daily fasting duration may last up to ~18 h.

A.M.			Noon	P.M.			P.M.	P.M./ A.M.
05:00 - 05:30 h	06:00 - 08:00 h	08:00 - 10:00 h	11:00 - 12:00 h	12:00 - 17:30 h	17:30 - 19:15 h	19:15 - 20:00 h	20:30 - 22:00 h	23:00 - 05:00 h
Eat & drink ( <b>Sahur meal</b> )	Sleep/ Rest	Train (non-physically challenging / technical exercise session)	Day nap	Rest	Rest	Eat & drink ( <b>iftar meal</b> )	Train (high-intensity exercise) and Eat & drink	Sleep
Daylight						Darkness		

**Figure 1:** Model A for a suggested twice-a-day training sessions for Muslim athletes during Ramadan. Model modified from Reilly and Waterhouse (2007) [27].

A.M.			Noon	P.M.			P.M.	P.M./ A.M.
05:00 – 05:30 h	06:00 – 08:00 h	08:00 – 10:00 h	11:00 – 12:00h	12:00 – 17:30h	17:30 – 19:15 h	19:15 – 20:00 h	20:30 – 22:00 h	23:00 – 05:00 h
Eat & drink ( <b>Sahur meal</b> )	Sleep/ Rest	Train (non-physically challenging / technical exercise session)	Day nap	Rest	Train (high-intensity exercise)	Eat & drink ( <b>iftar meal</b> )	Rest and/or Eat & drink	Sleep
Daylight						Darkness		

**Figure 2:** Model B for a suggested twice-a-day training sessions during Ramadan (when training after breaking of the day's fast is not feasible). Model modified from Reilly and Waterhouse (2007) [27].

## Conclusion

Ramadan fasting can have a negative impact on athlete's exercise performance, which can influence training and competitions outcomes. Ramadan observance involves the deprivation of several aspects of one's primary needs, and this review suggests that there is

no single approach but rather, a unison of several strategies to try to circumvent or reduce the adverse perturbations of Ramadan fasting. This includes implementing or applying different aspects of frequency, intensity (amount or volume), timing and types of training, nutrition, sleep, rest, and even personal lifestyle and social behavioral strategies.

## Disclaimer

The above statements are those of the personal views of the authors and are not the official view of the Ministry of Defence, Brunei Darussalam.

## References

1. Maughan RJ, Zerguini Y, Chalabi H, Dvorak J (2012) Achieving optimum sports performance during Ramadan: some practical recommendations. *J Sports Sci* 30: 109-117.
2. Roy J, Ooi CH, Singh R, Aziz AR, Chai WJ (2011) Self-generated coping strategies among Muslim athletes during Ramadan fasting. *Journal of Sports Science and Medicine* 10: 137- 144.
3. Singh R, Ooi CH, Roy J, Chai WJ, Ismail SM, et al. (2011) Subjective perception of sports performance, training, sleep and dietary patterns of Malaysian junior Muslim athletes during Ramadan intermittent fasting. *Asian Journal of Sports Medicine* 2: 167-176.
4. Aziz AR, Png W (2008) Practical tips to exercise training during the Ramadan fasting month. *ISN Bulletin* 1: 13-19.
5. Chaouachi A, Leiper JB, Souissi N, Coutts AJ, Chamari K (2009) Effects of Ramadan intermittent fasting on sports performance and training: a review. *Int J Sports Physiol Perform* 4: 419-434.
6. Roky R, Houti I, Moussamih S, Qotbi S, Aadil N (2004) Physiological and chronobiological changes during Ramadan intermittent fasting. *Ann Nutr Metab* 48: 296-303.
7. Waterhouse J (2010) Effects of Ramadan on physical performance: chronobiological considerations. *Br J Sports Med* 44: 509-515.
8. Shephard RJ (2012) The impact of Ramadan observance upon athletic performance. *Nutrients* 4: 491-505.
9. Aziz AR, Slater GJ, Chia MYH, Teh KC (2012) Effects of Ramadan fasting on training induced adaptations to a seven-week high-intensity interval exercise programme. *Science and Sports* 27: 31-38.
10. Karli U, Guvenç A, Aslan A, Hazir T, Acikada C (2007) Influence of Ramadan fasting on anaerobic performance and recovery following short-time high intensity exercise. *Journal of Sports Science and Medicine* 6: 490-497.
11. Kirkendall DT, Chaouachi A, Aziz AR, Chamari K (2012) Strategies for maintaining fitness and performance during Ramadan. *J Sports Sci* 30: 103-108.
12. Keenan KL, Yeni S (2003) Ramadan advertising in Egypt: a content analysis with elaboration on select items. *Journal of Media and Religion* 2: 109-117.
13. Erbay H, Alan S, Kadıoğlu S (2010) A case study from the perspective of medical ethics: refusal of treatment in an ambulance. *J Med Ethics* 36: 652-655.
14. Peck T (2010) No fasting, no football: Asia's Maradona fired for violating Ramadan. *The Independent*.
15. John L Ivy (2004) Timing and optimization of dietary supplements for recovery and performance. *Journal of Exercise Science and Fitness* 2: 79-84.
16. Drust B, Waterhouse J, Atkinson G, Edwards B, Reilly T (2005) Circadian rhythms in sports performance – an update. *Chronobiology International* 22: 22-44.
17. Chamari K, Haddad M, Wong del P, Dellal A, Chaouachi A (2012) Injury rates in professional soccer players during Ramadan. *J Sports Sci* 30: 93-102.
18. Burke LM, King C (2012) Ramadan fasting and the goals of sports nutrition around exercise. *J Sports Sci* 30: 21-31.
19. Aziz AR, Chia MY, Low CY, Slater GJ, Png W, et al. (2012) Conducting an acute intense interval exercise session during the Ramadan fasting month: what is the optimal time of the day? *Chronobiol Int* 29: 1139-1150.
20. van Straten A, Cuijpers P (2009) Self-help therapy for insomnia: a meta-analysis. *Sleep Med Rev* 13: 61-71.
21. Herrera CP (2012) Total sleep time in Muslim football players is reduced during Ramadan: a pilot study on the standardized assessment of subjective sleep-wake patterns in athletes. *J Sports Sci* 30: 85-91.
22. Chaouachi A, Leiper JB, Chtourou H, Aziz AR, Chamari K (2012) The effects of Ramadan intermittent fasting on athletic performance: recommendations for the maintenance of physical fitness. *J Sports Sci* 30: 53-73.
23. Bosquet L, Léger L, Legros P (2002) Methods to determine aerobic endurance. *Sports Med* 32: 675-700.

24. Souissi N, Souissi H, Sahli S, Tabka Z, Dogui M, et al. (2007) Effect of Ramadan on the diurnal variation in short-term high power output. *Chronobiol Int* 24: 991-1007.
25. Sweileh N, Schnitzler A, Hunter GR, Davis B (1992) Body composition and energy metabolism in resting and exercising muslims during Ramadan fast. *J Sports Med Phys Fitness* 32: 156-163.
26. Mujika I, Chaouachi A, Chamari K (2010) Precompetition taper and nutritional strategies: special reference to training during Ramadan intermittent fast. *Br J Sports Med* 44: 495-501.
27. Reilly T, Waterhouse J (2007) Altered sleep-wake cycles and food intake: the Ramadan model. *Physiol Behav* 90: 219-228.
28. Zarrouk N, Hug F, Hammouda O, Rebai H, Tabka Z, et al. (2012) Effect of Ramadan intermittent fasting on body composition and neuromuscular performance in young athletes: a pilot study. *Biological Rhythm Research* 1-13.
29. Hawley JA, Palmer GS, Noakes TD (1997) Effects of 3 days of carbohydrate supplementation on muscle glycogen content and utilisation during a 1-h cycling performance. *Eur J Appl Physiol Occup Physiol* 75: 407-412.
30. Costill DL, Gollnick PD, Jansson ED, Saltin B, Stein EM (1973) Glycogen depletion pattern in human muscle fibres during distance running. *Acta Physiol Scand* 89: 374-383.
31. Hawkins RD, Hulse MA, Wilkinson C, Hodson A, Gibson M (2001) The association football medical research programme: an audit of injuries in professional football. *Br J Sports Med* 35: 43-47.
32. Rahnama N, Reilly T, Lees A, Graham-Smith P (2003) Muscle fatigue induced by exercise simulating the work rate of competitive soccer. *J Sports Sci* 21: 933-942.
33. Aziz AR, Wahid MF, Png W, Jesuvadian CV (2010) Effects of Ramadan fasting on 60 min of endurance running performance in moderately trained men. *Br J Sports Med* 44: 516-521.
34. Kirkendall DT, Leiper JB, Bartagi Z, Dvorak J, Zerguini Y (2008) The influence of Ramadan on physical performance measures in young Muslim footballers. *J Sports Sci* 26: 15-27.
35. Bishop D (2003) Warm up II: performance changes following active warm up and how to structure the warm up. *Sports Med* 33: 483-498.
36. Zois J, Bishop DJ, Ball K, Aughey RJ (2011) High-intensity warm-ups elicit superior performance to a current soccer warm-up routine. *J Sci Med Sport* 14: 522-528.
37. Mündel T (2008) Exercise heat stress and metabolism. *Med Sport Sci* 53: 121-129.
38. Aziz AR, Chia M, Singh R, Wahid MF (2011) Effects of Ramadan fasting on perceived exercise intensity during high-intensity interval training sessions in elite youth soccer players. *International Journal of Sports Science and Coaching* 6: 87-98.
39. Ramadan JM, Barac-Nieto M (2000) Cardio-respiratory responses to moderately heavy aerobic exercise during the Ramadan fasts. *Saudi Med J* 21: 238-244.
40. Merry TL, Ainslie PN, Walker R, Cotter JD (2008) Fitness alters fluid regulatory but not behavioural responses to hypohydrated exercise. *Physiol Behav* 95: 348-352.
41. James LJ, Flemming J (2013) Repeated familiarization with hypohydration attenuates the decrement in running performance caused by hypohydration. *International Journal of Sport Nutrition and Exercise Metabolism* 23: 6.
42. Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, et al. (2001) A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109-115.
43. Borresen J, Lambert MI (2009) The quantification of training load, the training response and the effect on performance. *Sports Med* 39: 779-795.
44. Leiper JB, Watson P, Evans G, Dvorak J (2008) Intensity of a training session during Ramadan in fasting and non-fasting Tunisian youth football players. *J Sports Sci* 26: 71-79.
45. Sadeghirad B, Motaghipisheh S, Kolehdoost F, Zahedi MJ, Haghdoost AA (2012) Islamic fasting and weight loss: a systematic review and meta-analysis. *Public Health Nutr* .
46. Faye J, Fall A, Badji L, Cisse F, Stephan H, et al. (2005) [Effects of Ramadan fast on weight, performance and glycemia during training for resistance]. *Dakar Med* 50: 146-151.
47. Nakhostin-Roohi B, Barmaki S (2012) Nutritional, sleep and exercise patterns of athletes in Ramadan. *Gazzetta Medica Italiana Archivio per le Scienze Mediche* 171: 131-134.
48. Moore LJ, Midgley AW, Thomas G, Thurlow S, McNaughton LR (2009) The effects of low- and high-glycemic index meals on time trial performance. *Int J Sports Physiol Perform* 4: 331-344.
49. Moore LJ, Midgley AW, Thurlow S, Thomas G, Mc Naughton LR (2010) Effect of the glycaemic index of a pre-exercise meal on metabolism and cycling time trial performance. *J Sci Med Sport* 13: 182-188.
50. Karamanolis IA, Lapidis KS, Volaklis KA, Douda HT, Tokmakidis SP (2011) The effects of pre-exercise glycemic index food on running capacity. *Int J Sports Med* 32: 666-671.

51. Burke LM, Collier GR, Hargreaves M (1993) Muscle glycogen storage after prolonged exercise: effect of the glycemic index of carbohydrate feedings. *J Appl Physiol* 75: 1019-1023.
52. Wee SL, Williams C, Gray S, Horabin J (1999) Influence of high and low glycemic index meals on endurance running capacity. *Med Sci Sports Exerc* 31: 393-399.
53. Miller CJ, Dunn EV, Hashim IB (2002) Glycemic index of 3 varieties of dates. *Saudi Med J* 23: 536-538.
54. Roy BD (2008) Milk: the new sports drink? A review. 931 *J Int Sports Nutr* 5: 15.
55. Paddon-Jones D, Sheffield-Moore M, Katsanos CS, Zhang XJ, Wolfe RR (2006) Differential stimulation of muscle protein synthesis in elderly humans following isocaloric ingestion of amino acids or whey protein. *Exp Gerontol* 41: 215-219.
56. Bohé J, Low JF, Wolfe RR, Rennie MJ (2001) Latency and duration of stimulation of human muscle protein synthesis during continuous infusion of amino acids. *J Physiol* 532: 575-579.
57. Shirreffs SM, Maughan RJ (2008) Water and salt balance in young male football players in training during the holy month of Ramadan. *J Sports Sci* 26: 47-54.
58. Shirreffs SM, Merson SJ, Fraser SM, Archer DT (2004) The effects of fluid restriction on hydration status and subjective feelings in man. *Br J Nutr* 91: 951-958.
59. Goulet ED, Aubertin-Leheudre M, Plante GE, Dionne IJ (2007) A meta-analysis of the effects of glycerol-induced hyperhydration on fluid retention and endurance performance. *Int J Sport Nutr Exerc Metab* 17: 391-410.
60. EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA) (2010) Scientific opinion on dietary reference values for water. European Food Safety Authority (EFSA), Parma, Italy.
61. Coyle EF (2004) Fluid and fuel intake during exercise. *J Sports Sci* 22: 39-55.
62. Samuel N Chevront, Michael N Sawka (2005) Hydration assessment of athletes. *Sports Science Exchange* 97 (Gatorate Sports Science Institute) 18: 1-12.
63. Quod MJ, Martin DT, Laursen PB (2006) Cooling athletes before competition in the heat: comparison of techniques and practical considerations. *Sports Med* 36: 671-682.
64. Ranalli GF, Demartini JK, Casa DJ, McDermott BP, Armstrong LE, et al. (2010) Effect of body cooling on subsequent aerobic and anaerobic exercise performance: a systematic review. *J Strength Cond Res* 24: 3488-3496.
65. Che Muhamed AM, Mohamad NG, Ismail N, Singh R, Aziz AR (2013) Mouth rinsing during exercise in the Ramadan fasted state improves endurance performance. Presented at the American College of Sports Medicine 60th Annual 961 Meeting 2013, May 28th - June 1st, Indianapolis, Indiana, USA. *Official Journal of the American College of Sports Medicine* 45: 473.
66. Mah CD, Mah KE, Kezirian EJ, Dement WC (2011) The effects of sleep extension on the athletic performance of collegiate basketball players. *Sleep* 34: 943-950.
67. Lovato N, Lack L (2010) The effects of napping on cognitive functioning. *Prog Brain Res* 185: 155-166.
68. Waterhouse J, Atkinson G, Edwards B, Reilly T (2007) The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *J Sports Sci* 25: 1557-1566.
69. Shona L Halson (2013) Sleep and the elite athletes. *Sports Science Exchange* 26: 1-4.
70. Wilson D, Drust B, Reilly T (2009) Is diurnal lifestyle altered during Ramadan in professional Muslim athletes? *Biological Rhythm Research* 40: 385-397.
71. Roky R, Herrera CP, Ahmed Q (2012) Sleep in athletes and the effects of Ramadan. *J Sports Sci* 30: 75-84.
72. Zhao J, Tian Y, Nie J, Xu J, Liu D (2012) Red light and the sleep quality and endurance performance of Chinese female basketball players. *J Athl Train* 47: 673-678.
73. Luke A, Lazaro RM, Bergeron MF, Keyser L, Benjamin H, et al. (2011) Sports-related injuries in youth athletes: is overscheduling a risk factor? *Clin J Sport Med* 21: 307-314.
74. Tian HH, Aziz AR, Png W, Wahid MF, Yeo D, et al. (2011) Effects of fasting during ramadan month on cognitive function in muslim athletes. *Asian J Sports Med* 2: 145-153.
75. Cherrin A, Kennedy K (2004) Fasting and Playing. *Sports Illustrated* 101: 15.
76. Reilly T, Edwards B (2007) Altered sleep-wake cycles and physical performance in athletes. *Physiol Behav* 90: 274-284.