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Oxidative Stress and Ramadan Observance; a Possible Influence of Associated Dieting

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ABSTRACT

Introduction: The effects of Ramadan observance and any associated dietary restriction upon oxidative stress are not well known. The topic has thus been examined in a brief systematic review of available literature concerning non-athletic but otherwise healthy subjects, patients with selected clinical conditions, and in athletes.

Methods: Ovid/Medline and Google searches were supplemented by a perusal of reference lists in papers thus identified.

Results: Ramadan observance and associated dietary restrictions are generally associated with a decrease of body mass in non-athletic adults, and in patients with conditions such as obesity, metabolic syndrome, diabetes mellitus and hypertension. During Ramadan, measures of oxidative stress (particularly malondialdehyde and F2 isoprostanes) are consistently decreased, antioxidant status (particularly levels of peroxidases, uric acid and reduced glutathione) are enhanced and inflammatory reactions (particularly c-reactive protein, IL-6 and TNF-a) are decreased in association with decreases in body mass. Perhaps because of lower initial body weights and greater dietary control during Ramadan, changes of oxidant status are more variable in athletes; in 3 of 7 studies, Ramadan observance had little effect on oxidant status, and in 2 reports there was some deterioration. In 3 of 4 studies where athletes underwent short-term dieting, there was also no improvement of antioxidant status.

Conclusion: Ramadan observance and any associated dieting reduce oxidative stress in non-athletic individuals, apparently in association with decreases of body mass. In athletes, oxidant levels are generally unchanged during Ramadan, and if food intake is maintained they may even increase. More information is needed upon possible adverse health consequences, but chronic risks are probably small because any changes are limited to one month per year.

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Introduction

Several reviews have examined many of the implications of Ramadan observance for both competitive athletes and non-athletic individuals, including changes in physiological responses and physical performance (1, 2), as well as clinical issues such as a possible increase in the risk of physical injuries (3) and an altered risk of various chronic diseases. There is a growing recognition that dietary restrictions can reduce oxidative stress in sedentary people (4), benefitting conditions such as diabetes mellitus. However, there is only limited information concerning possible interactions between the repeated intermittent fasts and alterations in the timing and size of meals during Ramadan observance and the extent of oxidative stress and inflammatory response associated with the continuation of vigorous exercise and training. A Ramadan-related increase of c-reactive protein was reported in judokas (5), but there was a decrease of oxidative stress relative to controls in soccer players who observed Ramadan (6), and no significant change of oxidative stress was seen in either middle distance runners (7) or recreational body builders (8).

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Under resting conditions, the level of oxidative stress depends upon a balance between the generation of peroxides in the mitochondria, and their breakdown by peroxidases (9). An increase of metabolic rate increases peroxide formation, but the regular training of an athlete also increases the activity of peroxidases (10, 11), so that often the oxidant status of the well-trained individual compares favourably with that of a non-athletic person. Exercise-related factors that can increase oxidative stress include muscle contractions of an intensity that temporarily occludes local blood flow, visceral under-perfusion (12), and the inflammatory response associated with physical injury of the muscles (13). A moderate restriction of energy intake can decrease oxidative stress, at least in those who are initially obese (14). However, there is sometimes an increased ingestion of lipids during Ramadan, and this could increase oxidative stress (15). Likewise, any reduction in the intake of micronutrients could diminish the activity of various anti-oxidant enzymes, and thus increase oxidative stress (16).

The extent of change in these several variables during Ramadan depends greatly on the extent to which an individual modifies his or her lifestyle. Many obese people find the daytime fasting of Ramadan a good opportunity to lose excess fat through a decreased food intake, with a resulting decrease in their oxidative stress (14, 17). In contrast, athletes who attempt to maintain a normal training schedule generally begin Ramadan with an optimal body composition, and typically attempt to maintain a normal intake of nutrients by eating two large meals during the hours of darkness. In 15 studies of athletes, 4 groups showed some decrease of energy intake during Ramadan, but in the remaining 11 reports there was no significant change (18). Body mass decreased during Ramadan in 14 of 23 studies of athletes, but this was due more to loss of fluid than to an inadequate energy intake (18). Such dehydration could in itself increase oxidative stress by increasing the production of reactive oxygen species, inactivating antioxidant enzymes or both (19). If the athlete is successful in maintaining energy intake during Ramadan, there is no reason to anticipate that an athlete will develop a deficiency of micro-nutrients. However, in order to ingest the required energy in two rather than three daily meals, there is often an increased intake of fat, which can predispose to oxidative stress (20). Glycogen reserves may also be reduced during Ramadan, particularly if vigorous activities are pursued during the afternoons, and this predisposes to oxidative stress, probably because a substantial proportion of energy expenditure is derived from body fat once glycogen reserves have been depleted (21, 22). Any other dietary changes, such as an increased intake of fresh fruit and vegetables could also modify oxidative stress during Ramadan (23). Plasma amino acids are a potential source of anti-oxidant activity (24), but during Ramadan their concentrations may fall because of increased hepatic gluconeogenesis. Finally, some athletes moderate their training schedule during Ramadan, and this could lead to an associated decrease of peroxidase activity. However, recent research suggests that it is quite feasible for athletes to observe Ramadan and yet maintain a sufficient volume of high level of training to avoid any deterioration in fitness (25-27).

In the light of these issues, the aims of this brief review are thus to examine possible factors that may alter an individual's level of oxidative stress during the observance of Ramadan, particularly alterations in the timing and size of meals and the effects of any associated deliberate dieting. Available empirical evidence on this question is evaluated for both non-athletic and athletic individuals.

Material and methods

Search procedures

A systematic search of Ovid-Medline from 1946 to March 2017 linking the terms Ramadan observance and dietary restriction to oxidative stress yielded only two reports on human subjects (28, 29), and one of these two articles referred to patients in the second trimester of pregnancy rather than to exercisers (29). However, substantial additional information on Ramadan observance and other forms of short- and medium-term dietary restriction has been gleaned by repeated Google searches, and a careful review of reference lists in the articles that were found. Because the total volume of information was relatively limited, all available studies have been tabulated, but the limitations of individual investigations have been noted in the comments columns of the tables.

A total of 13 studies of oxidative stress and Ramadan observance and 3 other papers on dietary restriction were found for non-athletic but otherwise healthy adults (Table 1). There

Table 1. Oxidative stress in non-athletic but otherwise healthy subjects during Ramadan and other forms of dietary restriction

Author	Subjects	Measures	Response	Comments
		Ramadan		
Akrami Mohajeri et al. (59)	58 healthy adults	Inflammatory chemokines (CXCL1, CXCL10)	Reduced during Ramadan	Small decrease of BMI during Ramadan
Aksungar et al. (60)	Healthy, non-obese young adults (20 M, 20 F) vs. 28 matched volunteers	c-reactive protein, IL-6 and homocysteine	c-reactive protein, IL-6 and homocysteine all reduced by Ramadan observance, with increased HDL/Total cholesterol ratio	Ramadan required 12 h fast per day. Body mass changes not reported
Al Hourani et al. (33)	57 healthy females	Uric acid	No change of uric acid during Ramadan	Significant decrease of body mass
Asgary et al. (61)	50 healthy male adults	Malondialdehyde	Decreased during Ramadan	Body mass not reported
Bahamman et al (36)	8 healthy males	Malondialdehyde	No significant change during Ramadan	Food intake and sleep duration controlled
El Ati et al. (30)	16 healthy young women	Uric acid	Increased during Ramadan	No change of body mass or energy intake during Ramadan, increased proportion of fat and protein
Faris et al. (34)	Healthy adults, 23 M, 27 F	Urinary 15 F_{2t} isoprostane	No significant change during Ramadan, increased after Ramadan	Decrease of body mass during Ramadan, adverse change associated with increase in body mass after Ramadan
Faris et al. (62)	Healthy adults, 23 M, 27 F	IL-1β, IL-6, TNFα	Pro-inflammatory cytokines greatly reduced during Ramadan	Small decrease of body mass during Ramadan
Gumaa (63)	16 healthy males	Uric acid	Increased over Ramadan	Subjects consumed high carbohydrate diet during Ramadan, body mass not reported
Ibrahim et al. (28)	Healthy adults, 9 M, 5 F	Serum malonaldehyde, aspartate aminotransferase, alanine aminotransferase, creatine kinase, red cell MDA, glutathione, glutathione peroxidase, catalase	Red cell MDA reduced on 28th day of Ramadan, no other changes in measures of oxidative stress	Small decrease of body mass and lean body mass
Lahdimawan et al. (64)	30 healthy males	Complement C3, inducible nitric oxide synthase, superoxide dismutase, macrophage TNF-α and IFN-γ	Ramadan altered macrophage regulation and signalling, reducing macrophage oxidative stress	Body mass not reported
Sayedda et al. (32)	20 male medical students	Creatine phosphokinase	Reduction of CPK during Ramadan	Decrease of body mass
Sülü et al. (35)	Healthy adults, 23 M, 22 F	Malondialdehyde, glutathione	Malondialdehyde increased (significant only in F), glutathione decreased in M, increased in F	No change of body mass index during Ramadan
		Other forms of dietary restriction		
Galasetti et al. (37)	Healthy male adults, 9 reduced energy intake, 10 control	F_2 isoprostanes, catalase, myeloperoxidase, IL-6	No differences from control group with 110% energy intake; decreased oxidative stress in both groups	25% reduction of energy intake + exercise for 7 days only

Continuous of Table 1.				
Lee et al. (39)	52 healthy females	Urinary malondialdehyde, 8-isoprostaglandin F_{2a}(8-isoPGF), 8-hydroxdeoxyyguanosine, 1,n6-ethenodeoxyadenosine	Decrease of malondialdehyde and 8-isoPGF	Fasting 7.2 (3-11 days), 7.5% decrease of body mass
Velthuis-te Wierik et al. (38)	24 non-obese M (16 experimental, 8 control)	Catalase, glutathione peroxidase. Superoxide dismutase	No change with dieting	20% reduction of energy intake for 10 weeks, 7.4 kg decrease of body mass

Note: M: male, F: female, BMI: body mass index, CXCL: a specific chemokine, HDL: high-density lipoprotein, IFN: interferon, IL: interleukin, MDA: malondialdehyde, PGF: prostaglandin F, TFN: tumour necrosis factor.

were also 17 relevant studies of patients with various clinical conditions, 10 in relation to Ramadan observance, and 7 with other forms of dietary restriction (Table 2). Athletes were discussed in 11 reports, (7 in regard to Ramadan observance, 3 in competitors deliberately making short-term reductions in their body mass, and 1 involving longer-term dieting (Table 3).

Table 2. Studies of oxidant stress in individuals with clinical conditions during Ramadan obervance and during other types of dietary restriction

Author	Subjects	Measures	Response	Comments
		Ramadan		
Al-Shafei (65)	40 hypertensive patients, 40 controls	Malondialdehyde, glutathione	Malondialdehyde decreased 25, 23%, glutathione increased 57, 53% during Ramadan	Body mass changes not reported
Al-Shafei (23)	40 diabetic patients, 40 controls	Malondialdehyde, glutathione	Malondialdehyde decreased 47, 54$, glutathione increased 59. 53% during Ramadan	Body mass changes not reported
Asemi et al. (66)	27 F with polycystic ovary syndrome	Plasma NO levels, glutathione, c-reactive protein	NO and glutathione levels increased relative to pre-Ramadan values	No change in body mass, glucose homeostasis or lipid parameters
El Gendy et al. (67)	20 older diabetic patients, 20 controls	Malonaldehyde, glutathione	Malonaldehyde reduced 40, 58%, glutathione increased 241, 139% during Ramadan	No significant change of body mass, responses unaltered by vitamin E supplements
Khajafi et al. (40)	56 patients with stable cardiac disease (45 M, 11F)	c-reactive protein	ns. trend to decrease of c-reactive protein during Ramadan	No significant change of body mass
Nematy et al. (41)	38 M, 44 F with coronary or cerebrovascular disease or metabolic syndrome	c-reactive protein homocysteine	Unchanged by Ramadan	No significant change of food intake
Ozturk et al. (29)	Women in second trimester of pregnancy, 42 fasting, 30 non-fasting	Total antioxidant status, Total oxidant status, oxidative stress index	Total antioxidant status higher in those observing Ramadan	No difference of weight gain in those observing Ramadan
Radhakishun et al. (68)	25 ethnic obese adolescents	c-reactive protein	Decrease of c-reactive protein during Ramadan	No change of BMI
Shariatpanahi et al. (69)	65 adult M with metabolic syndrome	c-reactive protein	Decreased during Ramadan	Decrease of BMI
ünalacak et al. (70)	10 obese males, 10 males with normal BMI	IL-2, IL-8, TNF-α	Inflammatory cytokines all reduced in Ramadan in both groups	Decrease of BMI in both groups during Ramadan
		Dieting		
Bastard et al. (71)	21 obese women, 8 controls	IL-6, TNF-α, c reactive protein	Decrease of IL-6 but not TNF-α or c-reactive protein in obese women after dieting	3 weeks very low energy diet

Continuous of Table 2.

Buchowski et al. (14)	Obese women (20 test, 20 control)	F_2-isoprostane, c-reactive protein	F_2 isoprostane fell within 5 days	25% reduction of energy intake
Heilbronn et al. (72)	40 overweight adults	Protein carbonyls, DNA damage assessed by comet-tail formation	No change of protein carbonyls but decrease of DNA damage in all intervention groups	25% energy deficit vs. energy deficit + exercise, vs. very low energy diet vs. control
Johnson et al. (73)	10 obese subjects with asthma	8-isoprostane, nitrotyrosine, protein carbonyls, 4-hydroxynonenal, uric acid, TNF-α	All markers improved with dieting	80% reduction of food intake alternate days for 8 weeks
Meydani et al. (74)	46 overweight adults	Glutathione peroxidase, superoxide dismutase, catalase, plasma protein carbonyls, 8-epi-prostaglandin F2α	Glutathione peroxidaseincreased, plasma protein carbonyls decreased with diet	10% or 30% energy restriction for 6 months
Tchernof et al. (75)	25 obese postmenopausal women	c-reactive protein	32% decrease in c-reactive protein	14.5 kg average decrease body mass over 14 months
Wycherley et al. (76)	29 obese diabetic adults (16 diet, 13 diet + exercise)	Malondialdehyde	Malondialdehyde reduced in both groups	12 week restricted diet (5 MJ/d)

Note: M: male, F: female, BMI: body mass index DNA: desoxy-ribonucleic acid, IL: interleukin, MJ: megajoules, NO: nitric oxide, ns: non-significant, TNF: tumour necrosis factor

Table 3. Studies of oxidant stress in athletes during the observance of Ramadan, when "making weight," and during periods of deliberate dieting

Author	Subjects	Measures	Response	Comments
		Ramadan		
Abedelmalek et al. (42)	9 young males	IL-12 production during exercise (Wingate test)	Reduced IL-12 production during Ramadan	2.5 kg loss of body mass during Ramadan
Bouhlel et al. (44)	10 young moderately-trained male boxers	Malondialdehyde, total oxidants, catalase; c-reactive protein, IL-6, homocysteine	Ramadan observance had no effect on oxidant stress or inflammatory markers, either before or after repeated sprinting	Small decrease of body mass and lean tissue mass
Chaouachi et al. (5)	15 elite male judoka	Blood vitamin A and E content, c-reactive protein, homocysteine	57% increase of c-reactive protein by end of Ramadan; increase of vitamin A, decrease of vitamin E.	No change of energy intake or training; 12-13 h daily fast for Ramadan
Chennaoui, et al. (7)	8 male middle distance runners	c-reactive protein IL-6	133% increase of IL-6 during Ramadan, but ns. trend to decrease of c-reactive protein	No change of body mass, 13 h daily fast
Hammouda et al. (43)	20 male adolescent soccer players	Total antioxidant status, uric acid, creatine phosphokinase following YoYo intermittent exercise	CPK, TAS and uric acid higher morning than evening during Ramadan; evening shows significant decrease	Decrease of body mass during Ramadan
Maughan et al. (6)	78 male adolescent soccer players, 48 observing Ramadan	c-reactive protein	Decrease of creactive protein in fasting and non-fasting subjects, but more persistent in those fasting	0.7 kg decrease of body mass in observant subjects
Trabelsi et al. (8)	16 male recreational body builders, 8 fed normally during Ramadan	Uric acid, c-reactive protein	No change of c-reactive protein, but increase of uric acid during Ramadan	Food intake unchanged

Continuous of Table 3.

Athletes reducing body mass to meet specific weight category				
Degoute et al. (45)	20 judoka, 10 lost 5% body mass	Uric acid	Greater increase with exercise in those losing 5% body mass	5% loss of body mass for one week prior to competition
Finaud et al. (46)	20 male judoka, 10 reducing body mass by 5% in week before competition	Conjugated diene accumulation	Competition causes similar change of oxidant stress in 2 groups	5% loss of body mass for one week prior to competition
Suzuki et al. (47)	16 female judoka, 8 reducing body mass	Oxidative burst activity of neutrophils	Decrease of neutrophil phagocytic activity with decrease of body mass	3.2 kg loss of mass in experimental group, no change in controls
Deliberate dieting				
Rankin et al. (47)	20 trained male cyclists	Glutathione, glutathione peroxidase	Glutathione antioxidant system enhanced with dieting	4 days restricted energy intake with protein supplements; negative nitrogen balance, 2.7 kg decrease of body mass

Note: CPK: creato-phophokinase, IL: interleukin, TAS: total antioxidant status

Results

Markers of oxidative stress, anti-oxidant status and inflammatory reactions

A wide variety of methods have been used to assess oxidant stress, antioxidant status and inflammatory reactions in empirical studies of Ramadan and other forms of dietary restriction (Table 1-3). In 44 studies, the most popular markers of oxidative stress were levels of malondialdehyde (11 studies) and F2 isoprostanes (5 studies). The commonest assessments of antioxidant status were the activity of peroxidases (7 studies), and concentrations of uric acid (6 studies) and reduced glutathione (7 studies). The most frequently used indices of inflammatory reactions were concentrations of c-reactive protein (12 studies), IL-6 (6 studies) and TNF-a (5 studies).

The wide variety of methodologies limits the possibility of making comparisons between reports. In general, conclusions do not seem to have been affected by the technique that was used, but care is needed in interpretation of changes in uric acid and IL-6 concentrations. Thus, in one study an increase in uric acid levels seems to have been due to an increased intake of protein rather than an enhanced anti-oxidant status during Ramadan (30). In a second study, an increased concentration of IL-6 could reflect attempts to mobilize intramuscular carbohydrate stores rather than an inflammatory reaction (31).

Non-athletic subjects

In 8 of 13 studies on non-athletic subjects, oxidant status was improved during Ramadan observance (Table 1), and in one other report, creatine phosphokinase levels were reduced (32). However, in one of these studies (30), an increase of uric acid could possibly reflect an increased protein intake rather than an alteration of oxidative stress. One investigation found no change of uric acid concentrations despite a significant decrease of body mass (33), and a second report found no change of urinary 15 F2t isoprostane levels during Ramadan, despite a small decrease of body mass (34). Following Ramadan, this same group of subjects showed an increase of urinary 15 F2t isoprostane over initial resting levels, associated with an increase of body mass that occurred at this time (34). Another investigation (35) found that during Ramadan there was an increase of malondialdehyde in female subjects, and an increase of glutathione levels in the females, but a decrease in the male subjects. A final report (36) examined 8 healthy men where both dietary intake and sleep were controlled during Ramadan; this investigation found no significant changes of malondialdehyde levels during Ramadan.

Only 9 of the cited 13 reports commented on changes of body mass during Ramadan observance, but in 6 of these 9 studies a decrease of body mass was associated with the intermittent fasting. One report where there was no change of body mass still observed an increase of uric acid concentration during Ramadan (31), but in another study the female participants showed an increase of malondialdehyde, and the men a decrease of glutathione levels during Ramadan (35). The final study (36), where dietary intake was controlled saw no changes in malondialdehyde levels during Ramadan.

In one report where dietary restriction was combined with increased exercise (a 25% reduction of energy intake for 7 days) there was a decrease of oxidative stress, although this was no greater than in a control group that undertook the same exercise without dietary restriction (37). A second study (38) imposed a 20% reduction of energy intake for 12 weeks, but it found no changes in the activities of glutathione, catalase, peroxidase or superoxide dismutase. A third report described responses to fasting for an average of 7.2 days, with a 7.5% decrease of body mass (39); this regimen was associated with decreases in malondialdehyde and 8 iso-prostaglandin F.

Patients with clinical conditions

In patients with clinical conditions, 8 of 10 studies showed an improvement of oxidant status during Ramadan (Table 2). In one of the 2 remaining reports, there was a non-significant trend to a decrease of c-reactive protein during Ramadan (40). The final study showed no change of either c-reactive protein or homocysteine concentrations (41). These last 2 studies showed no significant decrease of body mass or food intake during Ramadan. However, there was also no significant decrease of body mass in 3 of the 7 studies where oxidative stress was reduced during Ramadan. Oxidative stress was reduced in all 7 of the studies where other forms of dietary restriction were imposed (Table 2).

Athletes

In terms of oxidative stress, the response of athletes to Ramadan observance was varied (Table 3). Two reports found an enhanced tolerance of an acute bout of exercise. In 9 physical education students, the production of IL-12 following completion of a Wingate test was less during Ramadan than during the control period (42); in this group, there was also a 2.5 kg decrease of body mass during Ramadan. Hammouda et al. (43) examined the responses of 20 male adolescent soccer players who performed intermittent exercise (a Yo-Yo test) morning and evening before, during and after Ramadan. During Ramadan, the evening data showed an increase in uric acid and total anti-oxidant status as measured by a colorimetric assay. This group also showed a reduction of body mass during Ramadan. Three other studies found no change of oxidant status during Ramadan. Bouhlel et al. (44) examined 10 moderately trained boxers. Their subjects showed a small decrease of body mass and lean tissue mass during Ramadan, but there were no changes in malondialdehyde, homocysteine, total oxidants, catalase; c-reactive protein, or IL-6 concentrations. Maughan et al. (6) studied a group of 78 male adolescent soccer players; 48 of their subjects observed Ramadan, and the other 30 did not. The observant group showed a significant decrease of morning c-reactive protein values during weeks 2 and 4 of Ramadan; a similar decrease of c-reactive protein was seen in the 30 non-observant subjects in week 2, although by week 4, their values were no longer significantly lower than normal. Trabelsi and associates (8) studied 16 recreational body-builders; 8 observed Ramadan, and the remaining 8 followed a normal feeding pattern, but both maintained their normal training pattern during Ramadan. Neither group changed their energy intake. Those observing Ramadan showed a substantial increase of uric acid, but no change of c-reactive protein relative to the control group. In two reports, oxidant status appears to have worsened during Ramadan. Chaouachi et al. (5) studied 15 elite male judoka. There was no change of either energy intake or training during Ramadan, but by the end of Ramadan there was a 57% increase in levels of c-reactive protein and decreased levels of Vitamin E. Chennaoui et al. (7) followed 8 middle-distance runners. There were no significant changes of body mass during Ramadan, but an increased inflammatory reaction was suggested by increased IL- 6 levels; however, the IL-6 may have been playing a metabolic role, since levels of c-reactive protein were decreased during Ramadan. Three studies examined the effects of "making weight" in judoka who deliberately reduced their body mass in the week prior to competition. Degoutte and associates (45) studied 20 national-level judoka. A half of this group reduced their body mass by 3.8 kg in the week prior to competition, mainly by decreasing their food intake from 11 MJ/d to 7 MJ/d; they showed an increase of uric acid relative to the control group, and this was attributed to increased protein catabolism. A second report from the same laboratory (46) looked at more specific measures of oxidative stress, including the lag phase before free radical induced oxidation, the maximum rate of oxidation, and maximum levels of conjugated dienes. In this study, there were no pre-competitive differences between experimental and control groups, although on the day of competition the maximum rate of oxidation was reduced and the lag phase was increased in both groups of subjects. The third study concerned 16 female judoka, 8 of whom reduced their body mass by an average of 3.2 kg during the week prior to competition (47). Both experimental and control groups showed an increase of oxidative burst activity in their neutrophils during competitive activity, but the weight loss group also showed a reduction of neutrophil phagocytic activity. Rankin and associates (48) limited a group of 20 cyclists to an energy intake of 83 kJ/kg per day with protein supplements (whey or non-hydrolysed casein) for 4 days. This regimen led to a 2.7 kg decrease in body mass, with an increase of lymphocyte total glutathione and erythrocyte glutathione peroxidase. Despite these harbingers of an improved oxidant status, plasma lipid peroxidation was unchanged; possibly, the high initial antioxidant capacity of the athletes did not allow scope for any further improvement in oxidative status.

Discussion

Commonly, Ramadan observance is associated with a small decrease in body mass. The literature is relatively consistent in showing that with such a scenario, as with other forms of dieting, oxidative stress is reduced in non-athletic but otherwise healthy adults, and in patients with various clinical conditions. However, most athletes enter the season of Ramadan with a low body fat content. In this group, efforts are often made to maintain a normal food intake during the intermittent fasting, and there may be little or no change in body mass. Athletes thus usually show no decrease of oxidant status over Ramadan, and in some competitors there may even be a small immediate increase of oxidative stress.

A prolonged increase of oxidative stress and/or a pro-inflammatory reaction could predispose to diabetes mellitus and the metabolic syndrome (49, 50), atherosclerosis (40, 51, 52), and carcinogenesis (53), with an acceleration of aging (54-56). However, the limited magnitude of the changes observed in those athletes where oxidative stress was increased, and the relatively short-term nature of the changes associated with Ramadan observance reduces the probability of substantial long-term adverse health effects. The main adverse effect of any increase in oxidant levels is likely to be upon the duration of muscle soreness, which is normally linked to increased creatine kinase activity and a pro-inflammatory reaction (Table 3). To the extent that creatine kinase release is a normal component of the response to resistance training, it is possible that changes in oxidant status may also be associated with an altered response to muscular training. However, there do not as yet seem to be any studies of delayed onset muscle soreness during Ramadan, and the one available small study of recreational body builders found no significant difference in gains of lean tissue between those who observed Ramadan and those who did not (8).

One important lifestyle recommendation for athletes observing Ramadan (1) would be to minimize oxidative stress by a compensatory increase in the intake of energy and fluids during the hours of darkness, building glycogen stores by eating a carbohydrate-rich diet at the evening meal, and eating a slowly digested lipid pre-dawn meal. Where possible, training sessions should be timed when plasma protein levels are likely to be high, and when the athlete is not competing, daytime reserves of glycogen and fluid should be conserved by resting in a cool environment. Although many athletes choose to take antioxidant supplements, there is little convincing evidence that these are helpful if the diet already contains adequate fruit and vegetables (57); such supplements may even reduce some of the health promoting effects of physical activity such as increased peroxidase activity and a reduced resistance to insulin (58).

Conclusion

Ramadan observance commonly has a beneficial impact on oxidative stress in non-athletic individuals, apparently because of associated dieting and a reduction in body fat. Ramadan is less likely to enhance oxidant status in athletes, particularly if a normal food intake is maintained. However, there is as yet little evidence that the observance of Ramadan by an athlete imposes sufficient oxidative stress to have a long-term adverse impact upon health.

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