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ORIGINAL COMMUNICATION

Effects on health of fluid restriction during fasting in Ramadan

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During the 9th month (Ramadan) of the Islamic calendar (Hijra) many millions of adult Muslims all over the world fast during the daylight hours. Since Hijra is a lunar calendar, Ramadan occurs at different times in the seasonal year over a 33-year cycle. Fasting during Ramadan is partial because the abstention from food, fluid, tobacco and caffeine is from sunrise to sunset. Several categories of people are exempt or can postpone the Ramadan fast. The effect on health and well being of the month-long intermittent fast and fluid restriction has been studied in various potentially vulnerable groups in addition to normal healthy individuals in many countries. The majority of the studies have found significant metabolic changes, but few health problems arising from the fast. A reduction in drug compliance was an inherent negative aspect of the fast. Common findings of the studies reviewed were increased irritability and incidences of headaches with sleep deprivation and lassitude prevalent. A small body mass loss is a frequent, but not universal, outcome of Ramadan. During the daylight hours of Ramadan fasting, practising Muslims are undoubtedly dehydrating, but it is not clear whether they are chronically hypohydrated during the month of Ramadan. No detrimental effects on health have as yet been directly attributed to negative water balance at the levels that may be produced during Ramadan.
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Introduction

During the religious festival of Ramadan, the majority of adult, practising Muslims refrain from eating, drinking, smoking and sexual relationships during the hours of daylight throughout the lunar month. Since the Islamic calendar is lunar, the start of the Islamic year advances 11 days each year compared with the seasonal year; therefore, Ramadan occurs at different times of the seasonal year over a 33-year cycle (Sakr, 1975; Richards, 1998). This can result in the Ramadan fast being undertaken in markedly different environmental conditions between years in the same country. In addition, the time of sunrise and sunset varies between 12 h at the equator and about 22 h at the 64° of latitude in summertime. For people living in the polar regions, it is recommended, however, that they take the fasting times as those prescribed at Mecca and Medina, or from the nearest temperate zones (Muazzam & Khaleque, 1959; Sakr, 1975; Malhotra *et al*, 1989).

Not only is the eating pattern greatly altered during the Ramadan period, but the amount and type of food eaten during the night may also be significantly different to that usually consumed during the rest of the year. In many cultures, special festival foods that are richer in fat and protein than the usual diet, or that contain large quantities of sugar, are eaten (Sakr, 1975; El Ati *et al*, 1995), while in other countries factors such as poverty ensure that the Ramadan fast results in a reduction in energy intake and a loss of body fat (Angel & Schwartz, 1975; Chandalia *et al*, 1987; Hallack & Nomani, 1988).

The annual Ramadan fast is not obligatory for all Muslims, for there are several categories of healthy people and patients who are exempt (prepubertal children; the insane), or who can postpone the Ramadan fast (the acutely ill; women during menstruation, pregnancy, post-childbirth confinement and lactation; travellers) or who are unable to fast (the chronically ill; the frail elderly), but who are encouraged to feed a needy individual during the month of Ramadan

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(Sakr, 1975). The list of groups excused, although primarily expressing specific religious beliefs, may also include empirical knowledge on the adverse effects of fasting on health, from a period long before there was a clinical rationale. However, because of local tradition or a variety of personal reasons, many individuals who have the right to be excused decide to observe the fast.

The interaction of these variables involved in the intermittent fast during Ramadan has led to a complex picture, which has led to concern regarding the possibility of an exacerbation of health problems (Prentice *et al*, 1983; Aslam & Healy, 1986; Schmahl *et al*, 1988; Karaagaoglu & Yucecan, 2000; Qaisi, 2001). The observed signs and symptoms may be the result of fasting or dehydration or both. The separation or, much more difficult, the quantification of the effects of the two pathogenic factors is frequently very difficult or impossible. Thus, in this review, all health effects of intermittent fasting and dehydration during Ramadan are systematically listed, especially as such a review is not available and the spectrum of effects may well contain some hitherto unknown effects of intermittent dehydration.

Potential health concerns of Ramadan diet restrictions in healthy individuals

Energy balance

Generally, meal frequency is reduced during Ramadan fasting, which it has been found often leads to reduced energy intake and loss of body mass and body fat (Angel & Schwartz, 1975; Hallack & Nomani, 1988). Many researchers have confirmed that lipid, carbohydrate, protein and hormone metabolism changes occur during fasting. Hallack and Nomani (1988), using hypoenergetic diets with different fat and carbohydrate levels, demonstrated that in a group of 16 healthy male subjects energy intake was reduced when subjects were restricted to only two meals per day, although they were allowed to eat as much as they wished at each mealtime. Nevertheless, Frost and Pirani (1987) found that there was a significant increase in energy, fat, carbohydrate and protein intake during Ramadan in the group of Saudi-Arabians they studied. There are many studies that have shown a definite loss of body mass, body fat and/or a decrease in energy intake during the intermittent month-long fast (Muazzam & Khaleque, 1959; Born *et al*, 1979; Husain *et al*, 1987; Schmahl *et al*, 1988; Sweileh *et al*, 1992; Bigard *et al*, 1998). However, as might be expected from such a diverse variety of cultures and customs, there are as many studies that have shown either no significant loss of body mass (Laajam, 1990; El Ati *et al*, 1995; Afifi, 1997; Ramadan *et al*, 1999; Leiper & Prastowo, 2000) or a slight increase during Ramadan (Frost & Pirani, 1987). In general, any loss in body mass is usually relatively small (Table 1) and it may also be attributed to a decrease of glycogen-bound water stores, extracellular volume contraction secondary to a lower sodium intake, and a moderate degree of hypohydration with little loss of body tissue.

Psychosomatic alterations

A number of studies have investigated the effect on mood and irritability of individuals during the Ramadan fast. These studies invariably show a decease in subjective feelings of alertness, and an increase in lethargy and irritability during the daytime fast (Afifi, 1997; Kadri *et al*, 2000; Roky *et al*, 2000). Cognitive function has also been shown to be decreased (Ali & Amir, 1989), although this is not a universal finding (Roky *et al*, 2000). Part of this mood change is caused by alterations in normal circadian rhythms, with individuals becoming more active through the evening and night (Taoudi Benchekroun *et al*, 1999), and sleep deprivation (Husain *et al*, 1987; Bogdan *et al*, 2001; Roky *et al*, 2001). However, the effects of restrictions on smoking tobacco, ingesting caffeine and energy and fluid intake must also contribute to this general feeling.

A frequently cited problem of Ramadan fasting is an increased incidence of headaches (Awada & al Jumah, 1999). Examination of 2982 patients who attended clinics in the Kashmir Valley complaining of headaches or cranial neuralgia resulted in a diagnosis of tension headaches in 67% of the cases and migraine in 14%. Irritable-related stress was

Table 1 Body mass change during Ramadan

Number	*Sex*	*Body mass before Ramadan (kg)*	*Body mass at the end of Ramadan (kg)*	*Body mass loss (kg)*	*Reference*
17	m	73.1	71.1	3.0	Bigard *et al* (1998)
12	m	68.6	66.8	1.8	Born *et al* (1979)
16	f	59.3	58.6	0.7	El Ati *et al* (1995)
24	m	69.5	67.7	1.8	Fedail *et al* (1982)
16	m	66.2	63.8	2.4	Hallack *et al* (1988)
12	m	62.9	60.4	2.5	Husain *et al* (1987)
9	f	49.9	46.7	3.2	Husain *et al* (1987)
13	m+f	55.4	54.0	1.4	Muazzam and Khaleque (1959)
6	m	71.5	70.5	1.0	Ramadan *et al* (1999)
7	m	77.4	76.5	0.9	Ramadan *et al* (1999)
27	m	73.9	70.3	3.6	Schmahl *et al* (1988)
15	m	74.9	72.3	2.6	Zebidi *et al* (1990)

considered to be the main factor leading to tension headaches, while Ramadan fasting appeared as the prime precipitating factor for migraines (Shah & Nafee, 1999). In the study of Awada and al Jumah (1999) looking at the incidence of headaches in a group of 116 hospital staff in Saudia Arabia, 41% of the 91 respondents who fasted reported having a headache compared to the 8% of those 25 staff who did not fast. Headache frequency increased with duration of the fast and affected mainly those individuals who were normally prone to having headaches. Tension headaches accounted for the majority of cases (78%). The authors suggested that although lack of sleep, hypoglycaemia, and dehydration might have caused some of these incidents, caffeine withdrawal appeared to be the main contributory factor. Another study investigating the effect of the 25 h fast of Yom Kippur identified that of the 211 Israeli hospital staff who fasted, 39% developed headaches while only 7% of 169 staff members who did not fast reported headaches (Mosek & Korczyn, 1995). The number of headache sufferers increased in direct relation to the duration of the fast. Headaches were rated as being mild to moderate in intensity and individuals who were prone to headaches were more likely to develop fasting-induced headaches (66% and 29%, respectively). The investigators in this study considered that caffeine and nicotine withdrawal and oversleeping did not have an influence on headache development in their subjects, but fasting *per se* was the main contributor to inducing the headaches (Mosek & Korczyn, 1995) but they did not appear to consider the possibility of acute dehydration as a factor.

Accident and emergency cases

An increased number of Muslims attended the Accident and Emergency department of a British hospital during the month of Ramadan compared to similar time periods before and after Ramadan (Langford *et al*, 1994). This finding may be the result of the mood changes (Afifi, 1997; Kadri *et al*, 2000; Roky *et al*, 2000) and decrease in cognitive function (Ali & Amir, 1989) resulting from the alteration in dietary habit during Ramadan. Interestingly, a retrospective examination of all road traffic casualties seen at a local hospital in Al-Ain City, United Arab Emirates, over a 12-month period, found that there was a greater number of injuries during Ramadan than during other months (Bener *et al*, 1992).

Drug compliance

In a group of 750 Ramadan fasting adults in Turkey who were studied by questionnaire, 187 recorded some type of health problem during the fast (Karaagaoglu and Yucecan, 2000). Within this group of people who became ill, 60% were normally taking prescribed drugs and 32% were on diets relating to their health. During Ramadan, 10 and 19% of these two respective groups stopped taking their drugs and did not regularly adhere to their diets. Of 81 Asian Muslim patients questioned, 37 were found to have changed their drug dosage pattern while fasting, 35 had missed doses, eight took their tablets at different times and four took all their medications as one single daily dose after breaking fast in the evening (Aslam & Healy, 1986).

Occupational heat stress

One study highlighted the detrimental effect that the Ramadan fast could have on Muslim labourers carrying out light-to-moderate physical work in an industrial setting (Schmahl *et al*, 1988). In all, 32 males, mainly of Turkish origin, working in a chemical factory in Germany were studied during Ramadan in June 1983, when the daylight lasted for 18 h daily. These workers lost an average of 3.6 kg of body mass during the month of intermittent fasting and several of their biochemical parameters suggested that they were significantly hypohydrated. Five of these labours had such severe health problems that they had to interrupt their observance of Ramadan because they could not continue working and fasting.

Obstetrics

A reduction in energy or fluid intake by the pregnant mother may produce detrimental effects on foetal growth. Evidence of increased metabolic stress in pregnant women undergoing the Ramadan fast has been recorded in two studies (Prentice *et al*, 1983; Malhotra *et al*, 1989). Women in late pregnancy showed the phenomenon of 'accelerated starvation' during Ramadan, characterized by low serum levels of glucose and alanine, and especially high levels of free fatty acids and beta-hydroxybutyrate. The additional metabolic stress of Ramadan fasting in pregnancy and during lactation has the potential to cause retardation of foetal (Tyson *et al*, 1976; Prentice *et al*, 1984; Picciano, 1996) and neonatal growth and development, respectively (Prentice *et al*, 1984; Heird, 1996). In Saudi Arabia, the ratio of low-birthweight babies born during the festival months of Ramadan and Hajj was significantly higher than in the non-festival months (Opaneye *et al*, 1990). This contrasts with the finding of Cross *et al* (1990), who could find no obvious effect of Ramadan fasting on the mean birth weight or prevalence of low-birthweight babies at full term in a cohort of 13,351 deliveries that occurred between 1964 and 1984 in a British hospital.

In several countries, fasting by breastfeeding mothers of infants is common during Ramadan (Prentice *et al*, 1983; Ertem *et al*, 2001). A Turkish study that surveyed 129 breastfeeding mothers of infants aged 6 months or younger from an impoverished city area found that 28 mothers considered that the volume of breast milk they produced was reduced during the Ramadan fast and 30 mothers increased the amount of solid supplements they gave their children during Ramadan (Ertem *et al*, 2001). In 10 lactating Gambian women, the total breast milk output during Ramadan was not different from that during a comparable period before or after Ramadan. However, fasting caused changes in milk osmolality, and lactose and potassium concentrations indicative of a marked disturbance of milk synthesis (Prentice *et al*, 1984). Both authors concluded that child health care providers should find religious and culturally appropriate methods to combat the possible unfavourable effects of intermittent fasting for infants and children.

Potential health concerns of Ramadan diet restrictions in patients

Diabetes

Owing to the relationship between fasting and hypoglycaemia, diabetics who undertake Ramadan fasting have been considered as a highly vulnerable group. Several clinical studies have examined the effect of the daytime fast on hypoglycaemic control of non-insulin-dependent diabetics (NIDD).

In one large study, 365 Ramadan fasting diabetic Moroccans were compared with 177 nonfasting patients (Belkhadir *et al*, 1993). At the end of Ramadan, there were no significant differences between the nonfasting and fasting groups, respectively, in serum fructosamine concentration (4.00 and 3.81 mmol/l), total glycated haemoglobin level (14.7 and 13.3%) or the number of reported hypoglycaemic events (11 and 13). Body mass tended to increase over the period of Ramadan (0.5 and 0.75 kg, respectively), while serum creatinine levels increased, inferring that overall the subjects were hypohydrated at the end of Ramadan.

Several other studies have shown stable or a slight improvement in fasting blood sugar during the Ramadan fast (Mafauzy *et al*, 1990; Katibi *et al*, 2001). Other studies have proposed that improvement in glycaemic control can only be detected in patients who show a decrease in body mass caused by the intermittent Ramadan fast (Ch'ng *et al*, 1989; Laajam, 1990). While the general consensus from the clinical studies undertaken appears to be that most established NIDD patients can cope with the intermittent fasting during Ramadan, medical practitioners must make their patients aware of the potential hazards involved and should consider the use of longer acting drugs during fasting (Garcia-Bunuel, 1989). At least one report, however, has cautioned against Ramadan fasting for any diabetics, because they identified several diabetic patients, some of whom were insulin-dependent, who lost diabetic control due to the change in dietary habits and omission of drugs during Ramadan (Tang & Rolfe, 1989).

Acute coronary heart disease

There appears to be no obvious increase in acute coronary heart disease events associated with Ramadan (Temizhan *et al*, 1999), although there is one anecdotal remark from Sudan pointing to a noticeable increase of angina pectoris during Ramadan (Gumaa *et al*, 1978). However, a few claims have been made that the fast of Ramadan has several benefits in reducing the likelihood of cardiovascular disease. Ramadan fasting has been shown to increase HDL cholesterol, while either lowering LDL cholesterol (Adlouni *et al*, 1997) or not affecting the levels of other cholesterol fractions (Maislos *et al*, 1993). Some of the apolipoprotein fractions associated with diminished risk of atherogenesis have also been shown to increase during Ramadan fasting (Adlouni *et al*, 1998).

Peptic ulcer complications

In a retrospective clinical study in Turkey, a slight but significantly increased rate of peptic ulcer complications was observed during Ramadan, compared with an equivalent period before Ramadan (Donderici *et al*, 1994).

Urolithiasis

In a western region of Saudi Arabia, an area with a high prevalence of urolithiasis, the effect of climatic changes, Ramadan fasting and pilgrimage festival on the occurrence of urinary stone colic in males was evaluated retrospectively (Al-Hadramy, 1997). There was a strong positive correlation between environmental temperature and the rate of urinary stone colic, but there was no significant change related to Ramadan or the Hajj.

Renal transplant patients

Daytime dehydration will induce a degree of stress on the concentrating ability of the kidneys. A group of 43 renal transplant patients, whose kidney function was assessed as being stable, demonstrated excellent concentration ability after a daylong Ramadan fast. A mean (range) urine osmolality of 826 (729–1000), mosm/kg at the end of the fast was similar to the mean 873 mosm/kg urine osmolality produced by a group of healthy, age-matched controls who had fasted for the same time (Rashed *et al*, 1989). In a similar study carried out in Saudi Arabia, 17 kidney transplant patients with normal functional ability and six with impaired but stable renal function were examined 1 week before, weekly during, and 1 week after the Ramadan fast (Abdalla *et al*, 1998). Urinary and serum biochemistry and haematocrit showed no significant changes. The authors concluded that it was safe for most Muslim renal patients to undertake the Ramadan fast 1 year after kidney transplantation. However, given the deteriorating effect of chronic hypohydration on renal function in animals with impaired renal function (Bouby & Fernandes, 2003), the number of transplanted patients with impaired but stable renal function is probably too small to draw definite conclusions.

Potential health concerns of intermittent dehydration and chronic hypohydration

In normal life, total body water content is subject to minor fluctuations throughout the day, but the water content of adults normally remains relatively constant on a daily basis. Body water is unavoidably lost to the environment as urine, in faeces and as respiratory and insensible transcutaneous water losses. Water may also be lost as sweat if body temperature is raised above that which can be maintained by non sweating mechanisms. Fluid intake occurs in the form of food and drinks, with the sensation of thirst underpinning drinking behaviour (Fitzsimons, 1972). Individuals usually ingest more fluid than they require to match obligatory water losses and the excess water intake is excreted by the kidneys as dilute urine. Drinking tends to be associated with eating and, in situations where access to food is restricted, fluid intake is often voluntarily reduced (Brown, 1947; de Castro, 1988). In situations where normal drinking and eating habits are altered, individuals may ingest significantly less fluid than usual, as they become more reliant on stimuli relating to actual body water deficit (Fitzsimons, 1972). The sensation of thirst in man may not be sufficient to induce drinking up to hypohydration levels equivalent to 2% of the body mass (Greenleaf, 1992) and in some situations to a 5% body mass loss (Brown, 1947).

Intermittent dehydration

During the daylight hours of Ramadan fasting, practising Muslims are undoubtedly dehydrating at a rate that is determined by the loss of body water minus the amount of metabolic water that is produced over this period. Acute changes in total body water are best characterized by repeated measurements of body mass. However, with small losses in body mass over a long period, any other changes in body composition may bias the calculation. Moreover, changes in functional water volume may be more important clinically than gross differences in total body water (Kampmann *et al*, 2003).

Water deprivation is functionally characterized by maximum urine concentration. In 20 Malaysian Muslims, urine was collected before, during and after Ramadan fasting each in the morning (0800–1200), afternoon (1200–1600) and overnight (1600–0800) (Cheah *et al*, 1990). The authors found that Ramadan fasting did not affect the overnight urine volume (values not given in the paper) or osmolality (means: 649–781 mosm/kg), indicating that the subjects were probably not subjected to severe water deprivation. Over the morning and afternoon collection periods, however, urine volume, sodium, potassium and total solute excretion were lower, and urinary osmolality was higher during Ramadan than either before or after Ramadan. During Ramadan, the osmolality of the urine samples collected in the afternoon were very high (means: 849–937 mosm/kg), indicating effective water conservation (Shirreffs, 2003) both by maximum urinary concentration and a decreased obligatory urine output. In 16 Sudanese Muslims, daytime urine volume and total daytime urinary sodium excretion were decreased during Ramadan fasting (Mustafa *et al*, 1978). Daytime urine osmolality tended to increase progressively throughout the month of intermittent fasting. At the end of the month of Ramadan, daytime urine osmolality was in the range of maximum urine osmolality and the osmolality of the urine voided overnight was also markedly elevated for the first time, indicating an additional stress due to water deprivation on this day. The mean urine osmolality of spontaneous urine samples from 15 Tunisian Muslims was already very high before (881 mosm/kg) and after (898 mosm/kg) Ramadan fasting hinting at a normal restricted daily fluid intake (Zebidi *et al*, 1990). During Ramadan, urine osmolality was even higher (1023 and 920 mosm/kg) 90 min before breaking their fast.

Several alternatives have been used to give estimates of hydration status of individuals (Shirreffs, 2003). In 12 Muslims fasting for 12–14 h, there was a significant increase in haematocrit (+11%), serum albumin (+4%) and serum creatinine (+12%), indicating hypohydration due to water deprivation (Born *et al*, 1979). Similar findings were observed in 15 fasting Tunisian Muslims, who also showed an average increase in serum urea of 23% (Zebidi *et al*, 1990), and in a group of fasting British Muslims who also demonstrated increases in serum sodium and chloride (Sweileh *et al*, 1992). In Kuwait, a significant increase in serum osmolality, sodium and bicarbonate was observed only in a group of fasting Muslims with sedentary lifestyles, but not in a comparable group of physically active Muslims (Ramadan *et al*, 1999). The authors of that study assumed that the likely higher fluid turnover of the active group allowed more precise regulation of the body fluids than that of the sedentary group (Ramadan *et al*, 1999).

The use of the stable isotopes oxygen-18 or deuterium oxide as tracers for water has meant that a simple and reliable assessment of daily water turnover (ie the volume of water entering and leaving the body daily) can be made in free-living individuals (Leiper *et al*, 2001). However, the correlation between daily water turnover and hypohydration resulting from a deficit of the balance of total or functional water volume is limited. Decreases in daily total fluid intake (in the form of beverages, preformed water in food and the water of oxidation of the diet) or increases in water losses if not adequately corrected obviously lead to dehydration. Estimates of the normal daily water turnover greatly differ in individuals in the countries where studies have been carried out to investigate the effects of Ramadan fasting on fluid balance. The average daily water turnover rate is approximately 2–3 l in healthy humans living normally in temperate environmental conditions (Leiper *et al*, 1996). Augmenting the daily fluid intake will speed the rate of water turnover as urine volume increases (Leiper *et al*, 1996), while exercise of sufficient intensity and duration will promote faster water turnover even in a cool ambient conditions (Leiper *et al*, 2001), and exposure to a hot environment can also accelerate sweating and raise the rate of water turnover (Brown, 1947). In most situations where water turnover rate is altered, the total body water content is usually conserved. In a recent study using an isotopic tracer technique in

Table 2 Fluid balance parameters measured during weekly periods before, during and after Ramadan

Parameter	*Before Ramadan*	*During Ramadan*	*After Ramadan*
Body mass (kg)	58.2 (44.8–74.0)	58.1 (44.0–73.0)	58.0 (45.0–73.0)
Total body water content (l)	31.6 (24.9–37.6)	31.3 (26.6–39.3)	31.3 (25.9–38.3)
Water turnover rate (l/d)	2.28 (1.79–2.96)	1.93 (1.43–2.43)	2.19 (1.16–2.97)
Nonrenal losses (l/d)	1.63 (1.10–1.98)	1.01 (0.68–1.62)	1.34 (1.06–2.51)

Values are median and range. Data adapted from Leiper and Prastowo (2000).

Malaysian Muslims (Leiper & Prastowo, 2000), it was demonstrated that total body water content was conserved during Ramadan although daily water turnover was reduced (Table 2). The decrease in water turnover in this study appeared to be due to a reduction in recorded fluid intake, but euhydration was maintained by a drop in nonrenal losses (Leiper & Prastowo, 2000). The daily mean (range) water turnover rates of 5.2 (3.2–9.0) l have been recorded in a group of Gambian women carrying out heavy agricultural work for more than 7 h in hot ambient conditions (Singh *et al*, 1989). Others have shown, however, that water turnover in hot desert conditions can be similar to that occurring in cooler environments if individuals are relatively inactive and they seek shade (Brown, 1947).

Most Muslims with a predominantly sedentary occupation have few problems or relevant clinical symptoms connected with Ramadan fasting. Physiologic studies show, however, that Ramadan fasting leads to impairment in muscular performance and to a decrease in orthostatic tolerance (Bigard *et al*, 1998). In those Muslims with psychosomatic complaints or headaches during Ramadan, intermittent dehydration may be a more important pathogenic factor than intermittent energy restriction. However, if fasting is extended (eg up to 18 h) on a daily basis and work is physically demanding, or has to carried out in a hot environment, complaints of tiredness, dizziness and nausea may become so predominant that both fasting and working have to stop to allow the individual to recover (Schmahl *et al*, 1988).

Chronic hypohydration

An actual decrease in total body water content is the most reliable measure of hypohydration and this can now be accurately and safely determined in humans using stable isotopes of water (Schoeller, 1996). For example, in the study by Leiper and Prastowo (2000) using deuterium oxide as a water tracer, it was demonstrated that total body water content was conserved during Ramadan although daily water turnover was reduced (Table 2). Theoretically, a cumulative negative water balance of more than 3% of total body water is indicative of hypohydration. To our knowledge, there are no valid data of total daily water intake and output of Muslims during Ramadan fasting in the literature. In an early study (Muazzam & Khaleque, 1959), a body mass loss over the month of Ramadan of 1.4 kg was reported and this loss was equated with a drop in 24 h urinary volume during this period. However, the mean urinary output only dropped from 1.4 l/d before Ramadan to 1.2 l/d during Ramadan, and this lower excretion rate was established by day 10 of the fast before there was any sign of body mass loss. There was no change in haemoglobin levels or of pulse rate seen throughout the study. A group of Sudanese Muslims showed signs that their hydration status was progressively stressed during Ramadan; at the end of the fasting month, the mean daytime urine osmolality was about maximum, however the urine passed through the night was fairly dilute. This suggests that there was compensation for daytime dehydration by increased drinking during the night, which prevented the individuals from becoming chronically dehydrated. A similar observation was made in Malaysian Muslims, who before, during and after Ramadan showed a relatively similar overnight urine osmolality that was well below the renal concentration maximum (Cheah *et al*, 1990). In one study observing a group of Tunisian Muslims, however, the daytime mean urine osmolality collected before and after Ramadan was already in the range of maximal renal concentration ability (Zebidi *et al*, 1990). Fasting during Ramadan led to a further increase in daytime urine osmolality. In this instance, chronic hypohydration during Ramadan appears to be a possibility, but as the osmolality of the overnight urine was not measured this hypothesis cannot be verified (Zebidi *et al*, 1990).

In a remarkable study in Gambian women, four dehydrating factors were combined (Prentice *et al*, 1984). This study was undertaken primarily to look at the effect of the fast on lactating mothers' milk output, but several indicators of hydration status were also measured. The study involved 10 Gambian mothers who were breastfeeding their infants and 10 nonlactating women from the same area, all of whom continued to carry out their normal strenuous agricultural work for approximately 7 h each day in conditions of high thermal stress during the Ramadan fast. Although the authors state that there was a gradual reduction in body mass over the entire study period, total body water content of the lactating mothers was at least conserved, and may have been slightly increased, during Ramadan (Table 3). The body water content on the nonlactating group was only measured during Ramadan (Table 3), but the values are quite similar to that of the lactating group, suggesting that none of

Table 3 Mean values for fluid balance parameters in lactating (Lact) and nonlactating (NL) women measured over a 24 h period before, during and after Ramadan

	Before Ramadan		*During Ramadan*		*After Ramadan*	
Parameter	*Lact*	*NL*	*Lact*	*NL*	*Lact*	*NL*
Body mass (kg)	50.9	51.6	—	—	—	—
Body water content (% of body mass)	63.0	—	64.3	61.0	63.2	—
Body mass loss, 0700–1900 h						
(kg)	—	—	2.5	2.0	—	—
(% of total body mass)	—	—	4.9	3.8	—	—
(% of total body water)	—	—	7.6	6.2	—	—
Water turnover rate (l/d)	6.93	—	6.40	4.44	5.56	—

Data adapted from Prentice *et al* (1984).

Table 4 Mean values for 24 h urine parameters in lactating (Lact) and non-lactating (NL) Gambian women before, during and after Ramadan

	Before Ramadan		*During Ramadan*		*After Ramadan*	
Parameter	*Lact*	*NL*	*Lact*	*NL*	*Lact*	*NL*
Volume (l/24 h)	0.93	1.02	0.99	1.30	0.98	1.14
Osmolality (mosm/kg)	596	629	543	457	537	491
Sodium (mmol/l)	110	120	118	97	93	93

Data adapted from the full version of *Clin. Sci.* table 83/4, Prentice *et al* (1984).

the subjects in this study underwent chronic hypohydration during Ramadan. The body mass loss of the subjects during Ramadan was not reported, but the authors considered that the majority of the loss was due to reductions in adipose tissue, as a consequence of a decrease in energy intake. The daily mean water turnover rate of the non lactating women in this study was 4.4 l/d, which was only measured during Ramadan, and appears to be slightly slower than the median (range) 5.2 (3.2–9.0) l/d that Singh *et al* (1989) determined in a similar group of Gambian women carrying out much the same heavy agricultural work in comparable environmental conditions. The daily mean water turnover in the lactating mothers in this study was over 6 l/d before and during Ramadan (Table 3), while the mean urine output was almost 1 l/d (Table 4). Both the lactating and nonlactating women undertaking the intermittent fast of Ramadan developed a distinct acute dehydration before breaking the fast each day (Prentice *et al*, 1984). This was characterized by a body mass loss of 2.5 and 2.0 kg, respectively and an estimated 7.6 and 6.2% loss of total body water, respectively. There were also significantly increased levels of serum osmolality, sodium and uric acid, and high urine osmolalities in both groups. However, the osmolality of the morning urine collections were relatively low, indicating that no chronic hypohydration developed in either fasting group. Obviously, some individuals would develop a greater degree of acute intermittent dehydration, while it would be less for others. The authors of this study did not discuss any of the possible health effects of acute intermittent dehydration, except that it interfered with the normal process of breast-milk synthesis and secretion (Prentice *et al*, 1984).

Every year, millions of Muslims undergo Ramadan fasting all over the world in very different circumstances, resulting in some cases in additional dehydration stress. No detrimental effects on health have as yet been directly attributed to intermittent negative water balance at the levels that may be produced during Ramadan. However, epidemiological research is still sparse in this field, and it will be extremely interesting to see if the traditional exemptions from Ramadan fasting have also a modern scientific basis.

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