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The effects of fasting in Ramadan

2. Fluid and electrolyte balance

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1. Fluid intake, urine output and evaporative water loss were measured and fluid balance calculated in sixteen subjects for 1 d before Ramadan, during weeks 1–5 of fasting and on the 10th day after the end of Ramadan.

2. Plasma osmolality at 06.00 hours, the beginning of the fast, at 18.00 hours, before breaking the fast and at 19.00 hours, 1 h after breaking the fast, and urine osmolality during the day and night were measured before, during and after Ramadan.

3. All subjects developed an initial negative fluid balance which was maximum at the beginning of week 3 of fasting and that deficit was compensated for during the later weeks.

4. Compensation was brought about by an increase in urine concentration, a decrease in urine volume by day, and salt retention.

5. No significant changes were observed in plasma osmolality during the days of fasting and the 'setting' of plasma osmolality during Ramadan also was not changed.

6. It was concluded that healthy young adults maintain good control of fluid and electroytes during Ramadan.

During the Islamic lunar month of Ramadan millions of moslems in the tropics abstain, among other things, from drinking and eating from dawn to sunset. At night they take fluids and meals rich in carbohydrates.

McCance & Widdowson (1937) described the responses of human volunteers to dehydration during salt depletion. Haberner, Dashe & Solomon (1964) investigated the responses of normal subjects to prolonged high fluid intake. Veverbrants & Arky (1969) and Chinn, Brown, Fraser, Heron, Lever, Murchison & Robertson (1970) studied the effects of energy deprivation and refeeding on water and electrolyte excretion in subjects maintained on a constant electrolyte and fluid intake. As far as we know, the pattern in Ramadan of 12 h energy deprivation and dehydration followed by 12 h of refeeding and rehydration, over a period of 30 d, has not been studied before.

In this paper we will report on the fluid and electrolyte homoeostasis; effects of fasting Ramadan on plasma lipids and uric acid have been reported separately (Gumaa, Mustafa, Mahmoud & Gader, 1978).

MATERIALS AND METHODS

Sixteen male Sudanese students aged 20–22 years, all healthy as evident by medical history and clinical examination, volunteered for this study. They were all conscientious moslems who observed fasting rigidly. They were all studied on the day before Ramadan (week 0) and then divided into two groups, one studied on the 1st day and the other on the 3rd day of every week of fasting. Because of the small number of subjects investigated the results

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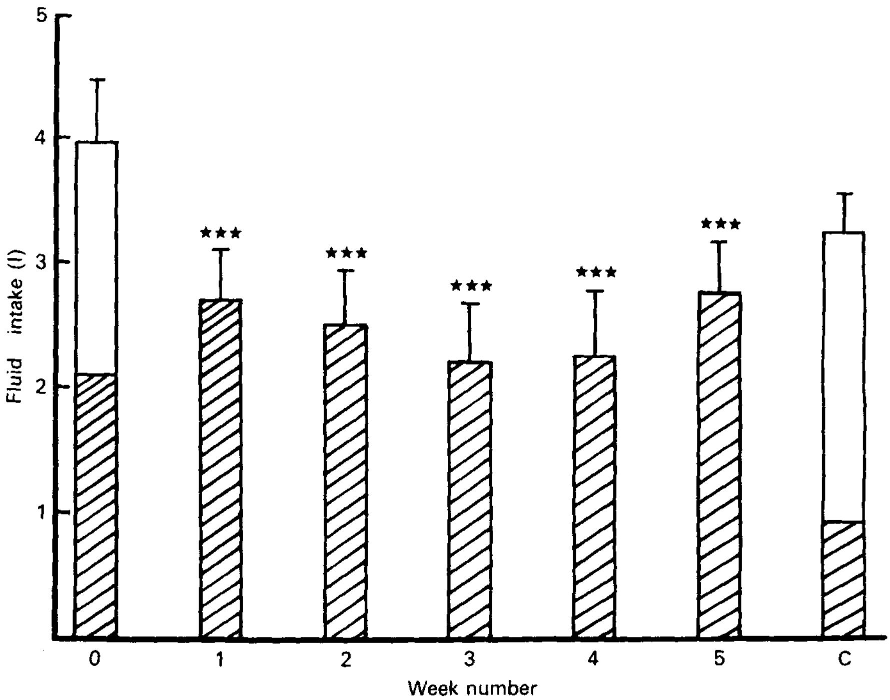

Fig. 1. Fluid intake (l) for healthy adult male volunteers for a 24 h period with the fluid intake during the day (□) and at night (▨). The fluid intake for the 24 h before fasting (week 0) and for the 24 h in weeks 1–5 of fasting were compared to the fluid intake in a 24 h period after Ramadan, control (C). *** $P < 0.001$. Mean values and standard deviations represented by vertical bars.

of each week of investigation were averaged and reported as weeks 1–5. They were also studied on the 10th day after Ramadan (control). On the day of the study the urine voided during the day (05.00–18.00 hours) and during the night (18.00–05.00 hours) was collected separately in two labelled plastic containers, their volumes were then measured and a sample was analysed for sodium and potassium ion concentrations and for osmolality. On the day before fasting and the 10th day after Ramadan fluid intake during the day and night was recorded. During Ramadan there was no fluid intake during the day, and at night subjects drank fluid *ad lib.* but they measured their fluid intake. To measure fluid intake subjects were supplied with measuring cylinders and were told to record the information immediately. During Ramadan subjects were weighed at 06.00 and 17.30 hours and weight loss, after correction for urine volume, was considered as evaporative water loss since they defaecated by night. Evaporative water loss by night during Ramadan was difficult to calculate and was calculated after Ramadan by weight loss after correction for fluid intake and urine volume on a night when the subjects abstained from food and did not defaecate. The values were assumed to be the same for 'Ramadan' nights since there was little temperature variation.

Venous blood samples (15 ml) were collected at 06.00, 17.30 (30 min before breaking the fast) and 19.00 hours (1 h after breaking the fast). The blood samples were divided into three tubes for the determination of serum electrolytes and osmolality, and for plasma levels of lipids and uric acid (see Gumaa *et al.* 1978), and blood clotting and fibrinolysin activity (not reported here). Na^+ and K^+ concentrations were determined by a flame photometer, and osmolality by the method of freezing point depression (Knauer microosmometer).

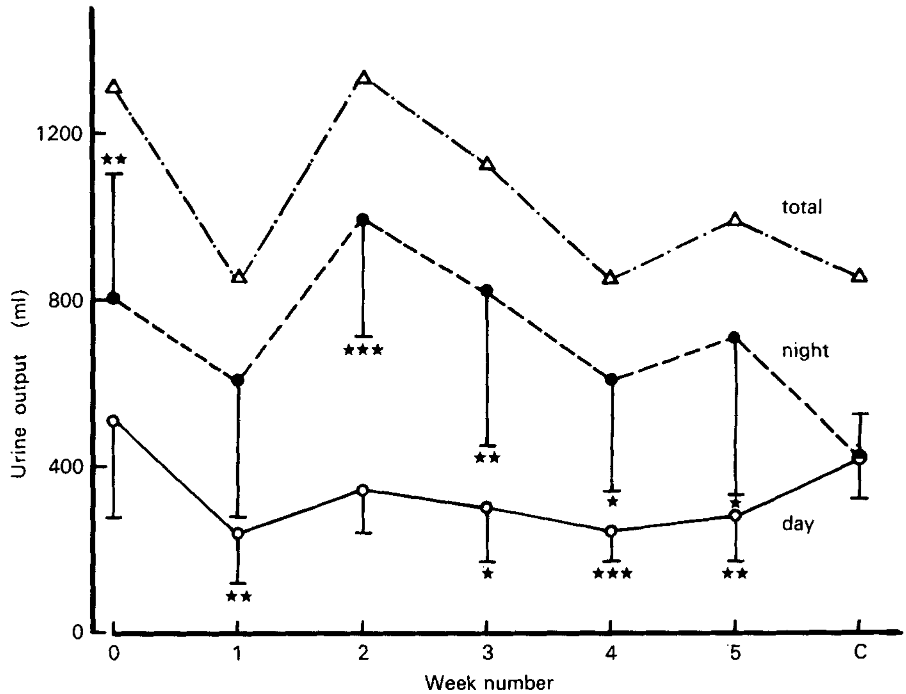

Fig. 2. Total (-·-) urine output (ml) for a 24 h period and urine output (ml) during the day (——) and at night (---) for the day before fasting (week 0), during weeks 1–5 of fasting at Ramadan and control at end of fasting (C). Values of urine output for weeks 0–5 during the day and at night were compared to corresponding urine outputs for C. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Mean values and standard deviations represented by vertical bars.

Statistical analysis

Student's *t* test was used to test the level of significance. Values of $P > 0.05$ were considered not significant.

RESULTS

Fluid intake

Total fluid intake showed considerable individual variation both in the control day at the end of Ramadan (2400–3885 ml/d) and during Ramadan (1400–3520 ml/d). Total fluid intake during the weeks of fasting was lower when compared to the prefasting level or to the fluid intake at the end of Ramadan. This was in spite of the significantly higher fluid intake at night ($P < 0.001$) during Ramadan when compared to the intake at the end of fasting (Fig. 1). Fluid intake during the night before fasting was higher than the intake at the end of Ramadan and indicated that the subjects voluntarily increased their fluid intake in anticipation of fasting the next morning.

Urine output

Urine output during the days of fasting was significantly lower ($P < 0.05$–< 0.001) than the prefasting level or the level at the end of fasting, and progressively decreased as fasting proceeded (Fig. 2). Urine output at night during Ramadan was significantly higher ($P < 0.05$–< 0.001) than urine volume in the control night at the end of Ramadan but decreased during the last 2 weeks of fasting.

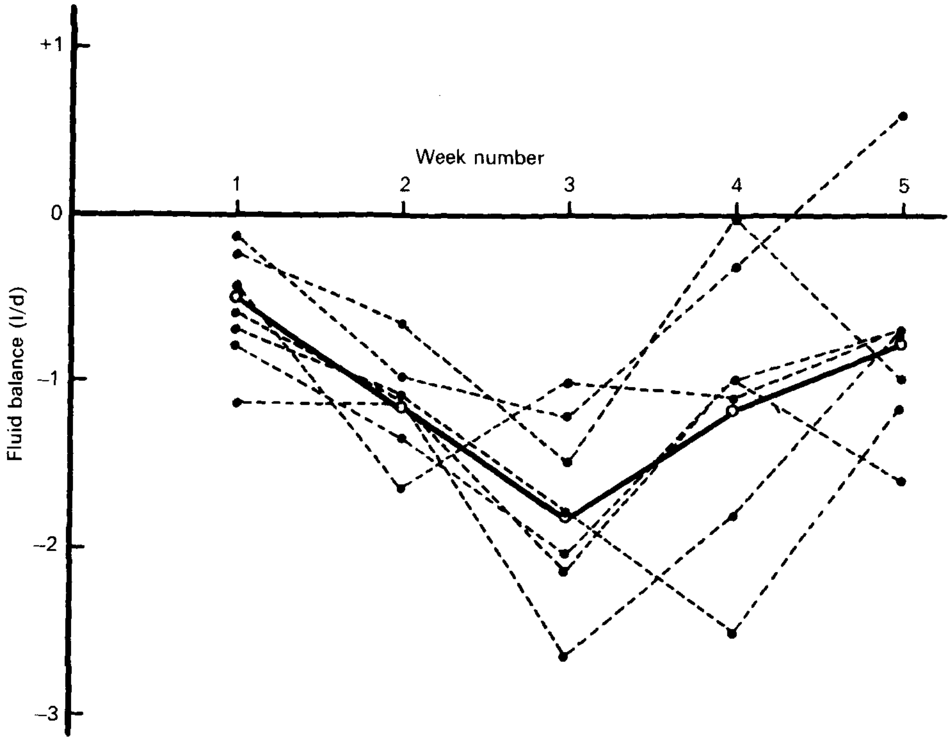

Fig. 3. Fluid balance (l) of seven healthy adult male volunteers calculated from fluid intake, urine output and evaporative water loss for weeks 1–5 of fasting during Ramadan (——). Mean values.

Fluid balance

From fluid intake, urine output and evaporative water loss fluid balance was calculated and illustrated in Fig. 3. It can be seen that the maximum fluid deficit occurred at the beginning of the 3rd week and was 1–2·75 l, equivalent to a mean loss of total body-weight of $2{\cdot}7 \pm 0{\cdot}6\,\%$. This negative fluid balance was slowly corrected during the final 2 weeks.

Serum osmolality

Early morning serum osmolality before fasting did not change significantly during weeks of fasting. During the days of fasting the serum osmolality was slightly lower at 06.00 hours than at 18.00 hours and also slightly higher than after breaking the fast. The changes were not statistically significant (Table 1).

Urine concentration

The concentrating ability of the kidneys was calculated by dividing the mean urine osmolality during the day or night by the serum osmolality at the end of the day or night respectively (Fig. 4). It can be seen that the concentration of the urine during the day was greater than at night and increased progressively during fasting. There was also a significant increase ($P < 0{\cdot}05$–$< 0{\cdot}001$) in the concentration at night during the last week of fasting. In spite of the increasing urine concentration during Ramadan the total daily urine excretion of Na^+ remained significantly lower ($P < 0{\cdot}05$–$< 0{\cdot}001$) in most fasting weeks particularly during the daytime when compared to the prefasting level. Total K excretion, however, remained unchanged (Fig. 5).

Table 1. *Serum osmolality (mosm/l) of samples taken from healthy adult male volunteers at* 06.00 *hours (A),* 18.00 *hours (B) and* 19.00 *hours (T)* 1 *d before fasting, during weeks* 1–5 *of fasting and at the end of fasting (C)**

(Mean values and standard deviations)

		Osmolality					
		A		B		T	
Week no.	No. of subjects	Mean	SD	Mean	SD	Mean	SD
0	12	281	3·91	299	7·67	—	—
1	12	274	8·25	285	4·41	279	10·62
2	12	282	6·10	292	5·70	308	7·92
3	12	292	4·91	296	8·23	309	4·20
4	12	287	8·89	289	5·38	281	8·10
5	12	287	8·50	307	6·81	292	6·68
C	8	288	4·16	295	5·86	—	—

* Comparison of values for sampling times A *v.* B *v.* T for weeks 1–5 to those for week 0 were not statistically significant ($P < 0·05$).

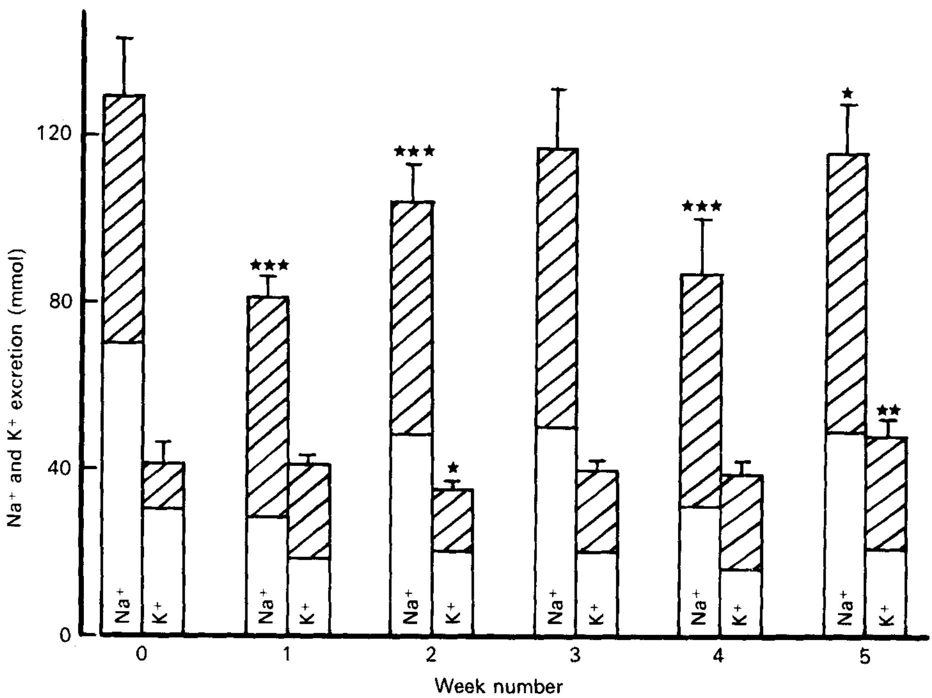

Fig. 4. Urinary excretion of sodium and potassium ions (mmol) for healthy adult male volunteers for a 24 h period on the day before fasting (week 0) and for a 24 h period during each week of fasting at Ramadan. Prefasting urinary excretion was compared to that of weeks 1–5. □, Day; ▨, night. * $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$. Mean values and standard deviations represented by vertical bars.

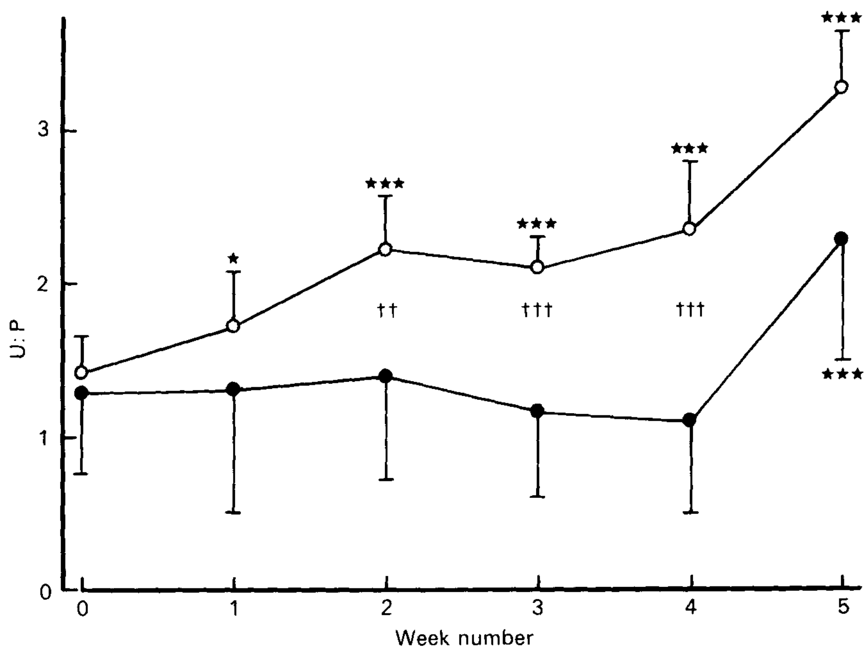

Fig. 5. Urine : plasma osmolality (U : P) during the day (○) and at night (●) before fasting (week ○) and for weeks 1–5 of fasting at Ramadan. Prefasting day or night values were compared to the corresponding values for weeks 1–5. * $P < 0{\cdot}05$, *** $P < 0{\cdot}001$. Values of corresponding days and nights were also compared. †† $P < 0{\cdot}01$, ††† $P < 0{\cdot}001$. Mean values and standard deviations represented by vertical bars.

DISCUSSION

In this study we observed considerable individual variations in the habits of fluid intake and urine output volumes, similar to those observed by Khogali, Yousif & Abdel Wahab (1970) in a comparable population. All the subjects partly compensated for fluid deprivation during the day by an increased fluid intake at night (Fig. 1). However, the total fluid intake during Ramadan remained lower than normal and together with the diuresis at night (Fig. 2) a negative fluid balance developed in all subjects (Fig. 3). The extent of the negative fluid balance should be considered in relation to the fact that subjects in the tropics have a lower total body water (Khogali *et al.* 1970). From the 3rd week of fasting the negative fluid balance was compensated gradually. The factors that contributed to this compensation were: (*a*) increased urine concentration, (*b*) decreased urine volume, (*c*) a decrease in the extent of diuresis in response to increased water intake by night, and (*d*) a decreased total excretion of Na during fasting.

Both the increased urine concentration capacity and the decreased urine volume by day are consistent with increased antidiuretic hormone (AHD) secretion (Segar & Moore, 1968). The extent of urine concentrating capacity as shown in (Fig. 4) underestimates the actual value since the urine osmolality used for calculation was the mean rather than the maximum urine osmolality reached especially since plasma osmolality did not change much during the day.

The pattern of decreased diuresis in response to water intake at night in the later weeks observed in this study was similar to that observed by McCance & Widdowson (1937) in salt-deficient subjects. In this study we observed a decrease in total excretion of Na^+ during Ramadan particularly during the day (Fig. 4). Veverbrants & Arky (1969) and Chinn *et al.* (1970) established that energy deprivation alone causes natriuresis while carbohydratefeeding causes salt retention. In our subjects therefore the decrease in Na^+ excretion is probably due to fluid deprivation. Leaf, Batter, Santos & Wrong (1953) observed that the injection of ADH into human subjects resulted in an increase in Na excretion when the subjects were well hydrated and a decrease in Na excretion when the subjects were dehydrated. Whether the decrease in Na excretion noted in this study was due to increased endogenous ADH levels in subjects with water deficit or whether it was consequent to changes in the level of salt-retaining or salt-releasing hormones remains to be elucidated. It is pertinent to note that volume depletion may cause accelerated absorption of Na in proximal convoluted tubules (Weiner, Weinman, Kashgarian & Hayslett, 1971).

The insignificant changes in the levels of serum osmolality (Table 1), in spite of the day-to-night variation in fluid intake, confirm the finding of Haberner *et al.* (1964) that the 'setting' of serum osmolality is not affected by variation in fluid intake. From the present investigation there was no evidence of sudden changes in serum osmolality to explain the common complaints of nausea, vomiting and lethargy among fasting subjects on breaking the fast in the evening. It is possible that these complaints were due to the effects of ingesting large volumes of fluid on an empty stomach.

In Sudan, where this study was carried out, there is a high prevalence of urinary tract calculi. The high extent of urine concentration reached during fasting and the increased level of serum uric acid reported from this same study (Gumaa *et al.* 1978) could both contribute to crystal formation leading to urinary tract calculi.

One reservation about this study is that the subjects were healthy young adults leading a sedentary life and the homoeostatic mechanisms of elderly, sick subjects or those involved in hard work may not be as good. Also, the temperature recorded during the study was $32 \pm 1{\cdot}7^\circ$ and temperatures may reach 40° and above sometimes during Ramadan and then disturbances might be more severe.

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