REQUIREMENTS OF SALT AND WATER DURING SUMMER IN THE TROPICS

by

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Introduction

The normal daily ration of an Indian soldier contains 14·2 g (½ oz) of salt and it is doubled during summer. The salt content of the foodstuffs issued daily in the rations is about 1·6 g, so that a solider consumes about 16 g salt per day ordinarily and 30 g, per day during summer. This extra salt was introduced for the Forces, when the British troops were also stationed in India. They were not well acclimatized to heat and consequently incidence of heat exhaustion in them was quite high. Cases of heat exhaustion were noticed in Indian troops also, though much less in number, whenever the summer was extraordinary hot.

Extra ½ oz of salt ration for summer is consumed compulsorily by the Army but not by the Navy and the Air Force, who are also exposed to quite severe summer conditions especially in machinery spaces of ships and aircrafts on the ground. In spite of this hardly any case of heat exhaustion is noticed in the Navy or the Air Force.

Ingestion of excess salt is not free from ill effects. If too much of it is taken it leads to salt retention, hypertension, oedema and even damage to renal tubules. Dahl[1] has noticed high incidence of hypertension in races who are on high salt diet as compared to those who are on low salt diet. Too little of salt is also dangerous, because its deficiency may lead to decrease in plasma and tissue fluid volumes with accompanying symptoms of heat exhaustion.

There are quite conflicting views in the literature on the subject. Some workers[2] have found that the salt content of normal diet varying from 10—15 g/day is quite enough for men sweating 5—9 *l* daily, whilst others[3] advocate that the dietary salt should be supplemented by 4—6 g/day for sedentary workers and 10—15 g/day for manual workers. Brookhouse gave the R.N.P.R.C. recommendation of salt for the Royal Naval ratings in the tropics to be 20 g/man/day for those working on the deck and 30 g/man/day for those exposed to exceptionally hot environmental conditions. He also quoted Crowden[4] who proposed that to avoid risk of salt deficiency, the salt content of urine should not fall below 7 g/day and that as a guide to medical officers 1 g salt/man/day should be provided for each °F rise in Effective Temperature (E.T.) above 80°F.

Trial on I. N. Ratings

Due to importance of the subject especially for Indians, the work was conducted in the Defence Science Laboratory, New Delhi on 29 I.N. ratings during the months of May and June 1956. They were divided into 5 batches and were maintained on rations supplying 16·2, 11·2, 8·7, 6·2 and 3·1 g of salt daily for the different batches. The subjects were made to march in the sun at a speed of about 3·5 m.p.h. for 2 hours daily. The mean environmental temperature during the studies was 101°F with R.H. 54 per cent and the average daily sweating varied from 3 to 4 litres. The adequacy of salt diet was tested from the changes observed in thiocyanate space, chloride concentration in plasma and chloride excretion in urine at the beginning and after the subjects had been on the restricted salt diet for 7 days. Concentration of salt in arm sweat, was also determined.

The decrease in plasma chloride concentration and thiocyanate space was observed on 3·1 g salt intake (Table 1) when body lost about 13·58 g of salt in 7 days or 1·9 g/day (Table 2). The minimum requirement should, therefore, be (3·1+1·9=)5 g/day. On an intake of 5 g/day, however, the salt losses in urine and sweat will be a little more than those occurring on 3·1 g intake. So the actual requirement will be more than 5 g and will lie between 5 and 6·2 g.

TABLE 1

Mean Plasma Chloride Concentration (mg %) and thiocyanate Space (litres) before and after different quantities of salt intake for a week.

Daily Salt intake	Mean Plasma Chloride				Mean Thiocyanate Space			
	Before mgm %	After mgm %	Difference mgm %	(t) value	Before (litres)	After (litres)	Difference (litres)	(t) value
16·2	589·01	595·32	6·31	1·60	13·28	13·40	0·12	0·25
11·2	589·68	588·00	—1·68	0·48	12·43	13·12	0·69	1·84
8·7	599·25	61··65	2·40	1·26	15·15	15·49	0·34	0·53
6·2	596·90	594·72	—2·18	0·93	15·80	15·85	0·05	00·2
3·1	594·72	586·21	—8·51	3·81*	15·85	13·75	—2·10	6·64†

* Significant at 1% level.
† Significant at 0·1% level.

TABLE 2

Mean body chlorides in thiocyanate Space (g) before and after different quantities of salt intake.

Batch No.	Daily salt intake (gms)	Before	After	Difference	S.E. of difference	(t) value
1	16·16	78·23	79·82	1·59	2·53	0·63
2	11·16	73·25	77·21	3·96	2·39	1·66
3	8·66	114·93	117·43	2·50	3·62	p·68
4	6·19	94·33	94·23	—0·10	1·77	0·05
5	3·12	94·23	80·65	—13·58	1·86*	7·31*

* Significant at 0·1 % level.

It may be mentioned here that one of the subjects was able to keep salt balance even on 3·1 g. of salt/day.

The studies on NaCl excretion in urine showed that when the daily excretion was plotted against the salt intake, the points for intakes of 16·2, 11·2, 8·7 and 6·2 g/day were falling on a straight line but that for 3·1 g. intake was above the line. The line showed a curve at 6·2 g. intake, thereby signifying that it was the minimum requirement (Fig. 1). The daily salt excretion on this intake was

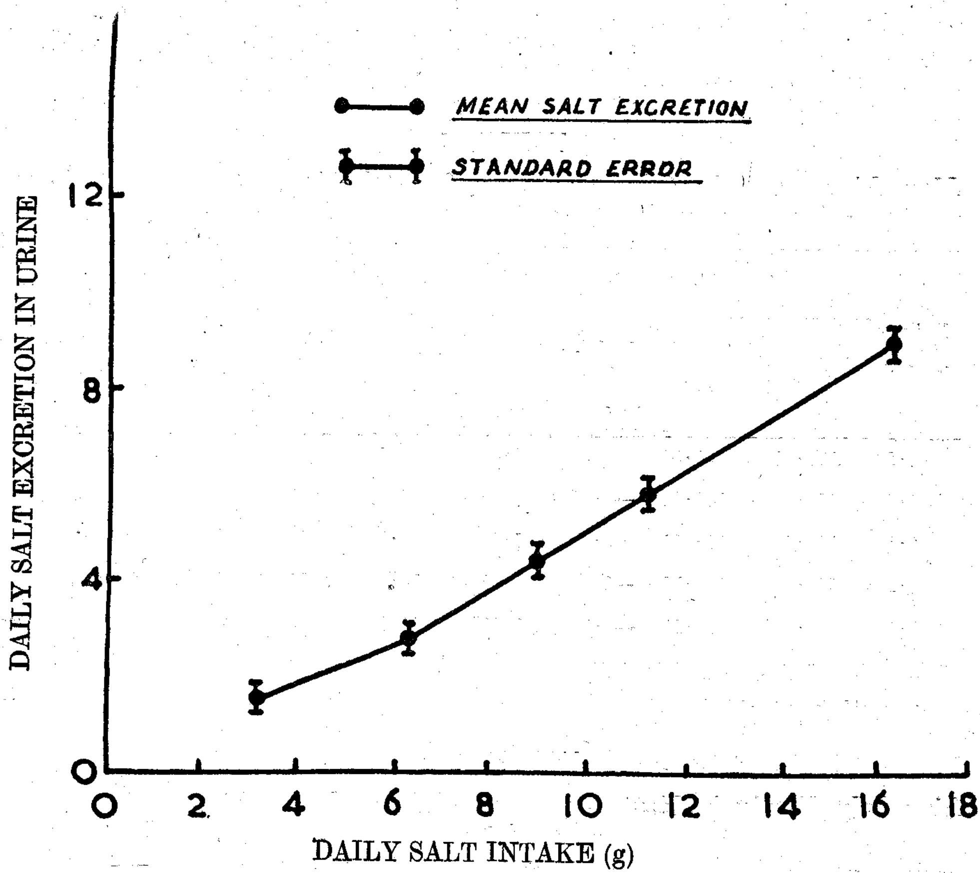

FIG. 1—Mean daily excretion of sodium chloride in urine (different salt intakes).

3·05±0·57 g, the maximum and minimum values being 3·8 and 2 g. respectively. Therefore, it means that NaCl excretion of about 4 or more in urine is the upper safe level for judging salt deficiency in body. Crowden[5] has suggested that urinary chlorides should not fall below 7 g/day. This figure is too high. In our studies this amount was excreted on about 12 g. intake, which is about the double of the minimum requirement.

To determine the salt requirements at higher environmental temperatures, a study was undertaken to determine the relationship of sweat loss, if any, with the environmental temperature. The studies showed that there was significant correlation betweeen the sweat loss and the dry bulb (D.B.) temperature of the environments. No correlation could, however, be obtained between the sweat loss and C.E.T. of the environments. This is because the globe thermometer reading which is used as correction for D.B. temperature of the air in calculation of Corrected Effective Temperature (C.E.T.), does not take into consideration the variability of the emissivity of clothing surfaces and human skin for solar radiation. Therefore, it seems desirable that when work is done in the open sun, the salt requirements should be referred to D. B. temperature rather than E.T. as proposed by Crowden. In our studies the sweat loss during walking was found to increase by 17 g/hr. and the salt loss in sweat by 0·032 g/hr. for every °F in the D. B. temperature of the environments (Fig. 2). On this basis the salt requirement

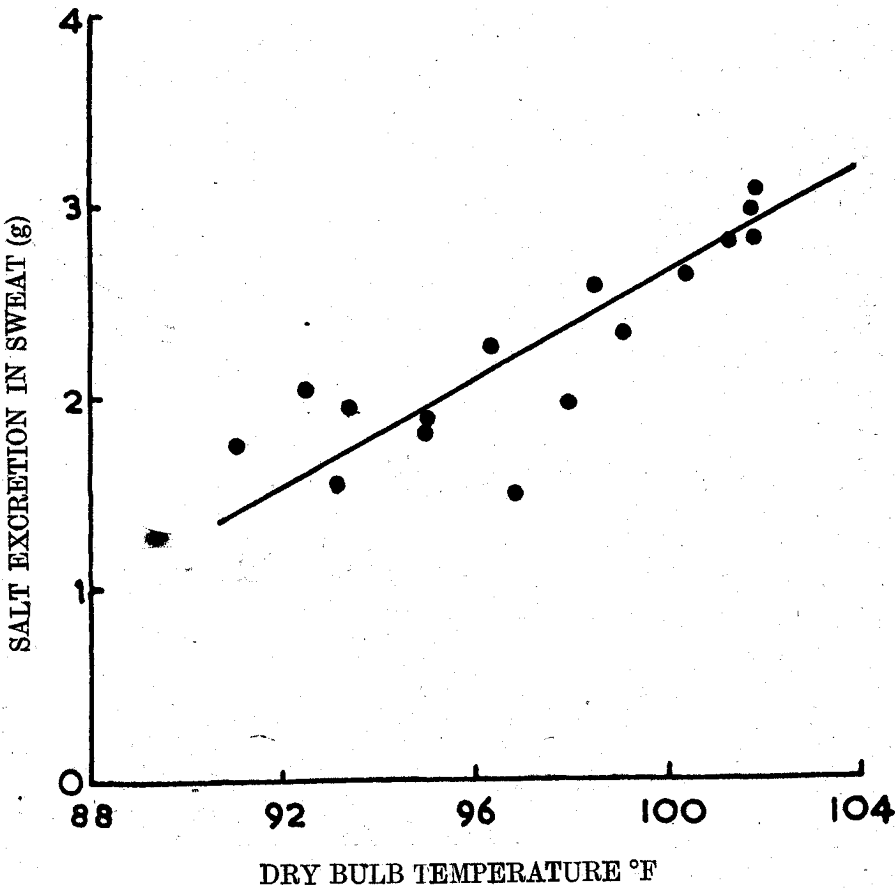

FIG. 2—Relationship between dry bulb temperature and salt losses in sweat during 2 hours exercise.

for men engaged in walking at 3·5 m.p.h. for different durations at various environmental temperatures has been calculated and is given in Fig. 3. For a person engaged in 8 hr. work in an ambient temperature of 110°F, the requirement will be 14·5 g and the sweat loss about 9 g/day. In actual practice, however, this temperature is not sustained for 8 hr. even during the hottest days of the summer

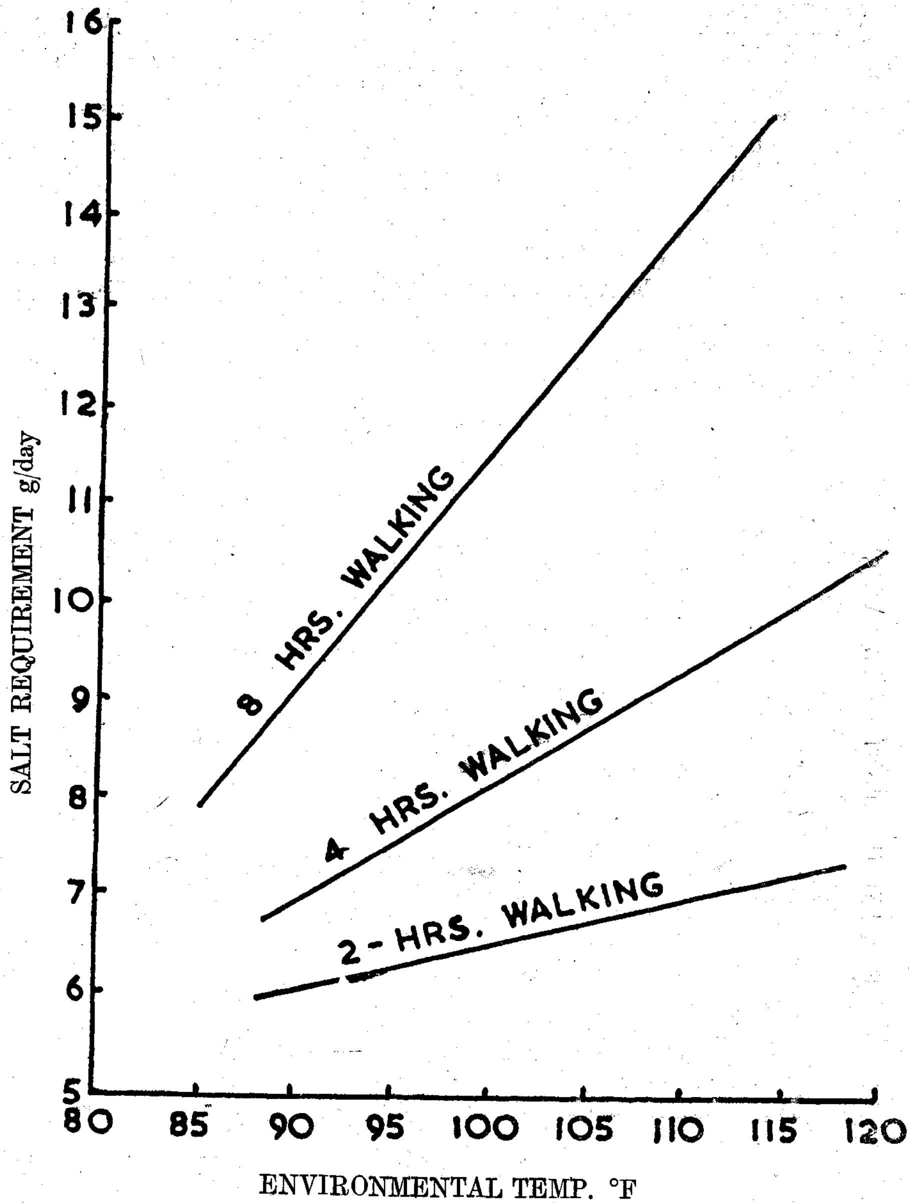

FIG. 3—Relationship between salt requirement and air temperature for different duration of walking at a speed of 3·5 m. p. h.

in tropics. Therefore, it can be said that the normal salt content of the Armed Forces ration supplying 16 g of salt is quite enough during ordinary Indian summer. If, however, the summer is extraordinarily hot or some severe type of work is done, the requirements will be higher and extra salt will be necessary for these days. Further work is intended to be done on this aspect of the problem.

The laboratory work has been supported by studies on 23 I. N. ratings working in the galleys and hot machinery spaces of I.N. ships, where the globe temperature ranged from 105 to 119° F and the subjects were made to work for 4 hr. during the day and 4 hr during the night. They were given 14·5 g of salt daily in their diet[5]. No case of salt deficiency was noticed in 2 weeks as judged by their urine chloride concentration, which varied from 0·86 to 1·33 g/100 ml. of urine. Further, during the period of study there was no complaint by any subject pointing to salt deficiency.

Studies on workers in Textile Industry in India[6] have also shown that there is no salt depletion in them after working for 8 hours in an environmental temperature of 86°F E.T. The men consumed only that amount of salt which was required to satisfy their palate.

The Salt content of Indian dietary varies from 14 to 24 g per day[7], the highest values are for Southern India, where the climate is hot and humid throughout the year and the lower values are for Northern India. The reason why such wide variations exist in the salt content of different dietaries is due to difference in taste. It was found by the author and his colloborators[8] that the physiological requirement of salt is less than that needed for balancing the taste in food. If enough salt is taken to satisfy the palate there is no likelihood of any salt deficiency occurring in the body. This finding supports the views of Richter[9], who believes that ingestion of salt is regulated by varying the threshold of salt taste in taste buds.

The symptoms of salt deficiency observed in our studies on subjects consuming 3·1 g of salt per day were headache, giddiness, lassitude, weakness, anorexia, lack of concentration and memory. In the earlier stages there was a feeling of sitting idle and disinclination to do any physical or mental work. Headache and giddiness were experienced more on standing than on sitting or lying down. By the 4th day, other symptoms like nausea, vomiting, constipation, lack of thirst and insomnia were noticed in some of the subject.

Water requirements

As evaporation of sweat is practically the only mechanism by which body can dissipate heat in the tropics, quite a lot of water is lost in this way. The maximum sweat loss that we have obtained in our studies is about 3 *l.*/day during resting in shade[10] and about 8—9 g./day[11] while marching in the sun. If water loss in urine, faeces, respiration and insensible sweating etc. is combined with sweat loss during marching in sun, about 10-11 litres of water are required for a soldier daily during summer. This is quite a difficult problem in the field, as a soldier can carry only about a little of water in his water bottle. Special arrangements are, therefore, necessary to provide sufficient drinking water during operations. We have also confirmed the findings of Adolph and associates[12] that in the tropics, even when water is provided *ad libitum* one does not drink enough to make up the total water loss, because during work in summer, thirst is not a sufficient guide for water requirements of the body[13]. Even after drinking enough to satisfy thirst, some water deficit is left which increases with increase in the ambient temperature of the working places. This deficiency is made up during hours of rest and meals, when a lot of water is drunk leaving very little space for food. To make the soldiers drink sufficient water during work in the tropics, they should be trained to drink every hour whether they feel thirsty or not, provided of course, the water supply is adequate. It can be achieved in practice by providing an abundant supply of cool and palatable water. This will reduce the chances of their going into water deficiency during work and at the same time will not impair appetite during meal hours.

It has been further seen that there is wide variation between individuals regarding their physiological responses to heat stress[5]. For different trades requiring work in extreme heat e.g., stokers, cooks, tank drivers etc., only those persons who can tolerate heat better should be selected. Changes in the pulse rate and body temperature are found to be quite simple and reliable measures of heat tolerance[14].

Conclusions

(1) Salt content of service rations is quite enough for the troops engaged in normal peace time duties in ordinary Indian Summer. Extra salt may be taken on the day when the summer is very hot or a severe type of work is done for a prolonged period.

(2) If enough salt is taken to satisfy the taste, there is no likelihood of any salt deficiency occurring in the body.

(3) Further work is necessary to determine the salt requirements, under trying service conditions.

(4) During work in heat, thirst is not a sufficient guide for water requirements of the body. To keep the body in fluid balance water should be taken every hour.

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Discussion

Dr. M. S. Ayyar (Sardar Vallabh Bhai Patel Chest Institute) said that physiology and psychology have all round importance in the application of science. It is indeed nice to see that due emphasis has now been put on both of these factors as is evident from the paper read. He posed the question whether the effect of age, nature of food and weight of individuals have been considered in working out the salt and water requirements.

The Chairman replied that since the experiments have been carried out on the soliders, the age group is necessarily restricted to 25 to 30 years. Very young and very old people do not come into the picture. As regards food, standard service rations were supplied to all the subjects, and the salt content of food-stuffs was taken into consideration.

Capt. Batra, I.N., Director of Personnel, Indian Navy, posed the question whether the necessity of giving lime juice to the ratings in the ships in the summer is valid or not in the light of the conclusions put forward by Lt. Cdr. Malhotra. He said that as far as he thought lime juice was being given as a vehicle for extra salt. Surg. Lt. Cdr. M. S. Malhotra replied that lime juice was originally started as a source of supply of vitamin C to prevent scurvy in the sailors who could not get fresh rations for very long period. This necessity is no longer there now. But lime juice is definitely of great use to make ratings drink more fluids at sea. It had been observed that while working in heat, thirst was not a sufficient guide to water requirements. If cool and palatable drinks are supplied extra fluids are taken which are very useful to reduce heat stress. According to his opinion lime juice should continue as a vehicle for extra water intake by the ratings.

Surg. Capt. B. L. Taneja, DMS (Navy) suggested that the laboratory findings on salt requirements should be validated by extensive field trials. Taste alone cannot be universally accepted as a suitable criterion for determining the salt needs of the body. For the present, provision of some extra salt during summer need not be discouraged as it is not likely to be a load on heart, blood-pressure, or kidneys in normal healthy persons.

Lt. Col. K. K. Nayak, Adviser in Medicine, Western Command, MH Delhi Cantt. said that aldosterone, one of the adrenal hormones, is concerned with the control of salt in the human body. The output of this hormone varies in different individuals and hence some may need more and others less of salt to maintain the salt equilibrium. Further, it is possible that thirst and taste for salt varying in individuals could be dependent on the corresponding hormonal output. He concluded that in his experience extra salt was not needed.

Major G. C. Mookerjee, Armed Forces Medical College, Poona, said that extensive work on this subject has been done in UK and USA but he pointed out that as far as information goes, conflicting views still exist on this subject.

The Chairman while concluding the discussions agreed with the speaker that the laboratory studies are not enough to settle the need of issue of extra salt and that validation of laboratory data in the field under more realistic test situations is very important and also essential. He further pointed out that it is necessary to know first the total body sodium as the base line before drawing conclusions from serum concentrations. It is hoped that in near future isotope dilution technique with radioactive sodium would be utilized to get the complete picture.