EFFECT OF DRINKING NORMAL SALINE ON SWEAT OUTPUT AND VOLUNTARY WATER INTAKE

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ABSTRACT

INCREASE in sweat output as a result of drinking large volumes of water, is confirmed. The view that lowering of plasma tonicity brought about by drinking water is the chief cause of this increase in sweat output, is also confirmed. Presence of extra salt in the body has not caused any significant change in the voluntary intake of water.

INTRODUCTION

In a previous paper[1] the results of certain experiments were reported which showed that drinking large volumes of water in excess of body requirements had the effect of increasing the sweat output appreciably. It was also pointed out that apart from possible reflex effects due to the act of drinking[2], the chief cause of this increase in sweat output might be the lowering in the tonicity of the plasma brought about by drinking of water. In order to further test the validity of this, certain experiments were performed, the results of which are reported in this paper. A second object of these experiments was to find out whether the presence of sodium chloride in the body in amounts exceeding what are normally present had any effect on the voluntary intake of water. It is known that salt helps in the retention of water in the body. Drinking normal saline causes much less urine flow than drinking equal volumes of water[3]. Salt, in this manner, cuts down the loss of water through urine and it was felt that by causing in this way a saving of water which could be utilised for sweat formation, the presence of extra salt in the body might effect some economy in the water utilisation of the body.

EXPERIMENTAL

Two sets of experiments were conducted in which the test subjects were drawn from military personnel and the experimental plan was based on the Latin Square Design in order to eliminate variations arising from changes in environmental conditions. In Experiment I, three test subjects had *ad libitum* water intake till 10·00 hours at which time they emptied the bladder as completely as possible, had their body weights recorded and then sat at rest inside the laboratory wearing only cotton underwear. After half an hour which served as control period, body weights were again recorded, urine collected, and then, according to a prepared plan, one test subject—referred to as the saline group—drank one litre normal saline (9 g sodium chloride in 1 litre water) to which a few drops of lemon juice were added to improve the taste, another test subject—the water group—drank 1 litre plain water and the third test subject—the control group—had no drink. Body weights were recorded and the test subjects sat for $2\frac{1}{2}$ hours. Body surface of the test subjects who drank water or saline were visually examined for any outburst of sweat due to reflex action. One test subject on two occasions after drinking water showed such outburst of liquid sweat, mostly on the back. This response appeared about 2-3 minutes after drinking and was evidently a reflex response. An attempt was made to roughly estimate the quantity of this sweat by collecting on a weighed piece of filter paper and weighing again. It was concluded that the amount would not have exceeded about 2 grams. After every half hour, body weights were recorded, urine collected and the volume and sodium chloride concentration of the urine were determined, the later by the Volhard-Harvey method[4]. Three replicates of the experiment were completed within a period of two weeks. The D.B. and W.B. temperatures were respectively 85±2°F and 68±1°F. This set of three replicates will be referred to as Expt. I (*a*). This experiment was then repeated on a different group of three test subjects. Three replicates of this were also completed. This set will be referred to as Expt. I (*b*). The D.B. temp. and W.B. temp. during Expt. I (*b*) were respectively 88±2°F and 70±1 ° F.

In Expt. I (*b*), the following additional observations were also recorded: (*i*) Pulse rate, (*ii*) Skin temperature at two points on the trunk, one in front and one on the back recorded by thermocouples, (*iii*) Oral temperature by clinical thermometer. These readings were made four times, namely, (*i*) at the beginning of the half hour period prior to the drinking of water/saline, (*ii*) at the beginning of the first half hour period after drinking water/saline, (*iii*) at the beginning of the second half hour period after drinking water/saline and (*iv*) at the beginning of the last *i.e.* the fifth half hour period after drinking water/saline.

In Experiment II, four test subjects were divided into two equal groups—the saline group and the water group. They had *ad libitum* water intake till 11·00 hours, when, after emptying the bladder and having initial body weights recorded, the saline group drank 1 litre normal saline and the water group drank 1 litre plain water. Then they marched in the sun for 2 hours. Any urine voided was collected. At the end of marching the test subjects emptied the bladder and had the final body weights recorded at 13·00 hours. Urine voided between 13·00 hours to 16·00 hours and between 16·00 hours to 11·00 hours on the next day were also separately collected and the volume and sodium chloride concentration of the urine samples collected during these three intervals were separately determined. The test subjects were given each a mug, capacity 200 ml. and were instructed to measure their fluid intakes till 11·00 hours on the next day. They had been trained on a previous occasion in this method of keeping record of their fluid intakes. Two replicates of this experiment were done, during which the D.B. and W.B. temperatures were respectively 87±2°F and 71±1°F.

It was observed in Expt. I (*a*) that in one of the test subjects, drinking of saline caused loose bowels after the end of the experimental period. This was not observed in Expt. I (*b*). Loose bowels occurred also with one of the test subjects in Experiment II. Analysis of the stool sample in the latter case showed that about 2 grams of sodium chloride were eliminated in the stool. In normal stool the amount of sodium chloride is very low[5].

RESULTS

Results of Experiment I (*a* & *b*) are presented in Tables 1, 2 and 3. The figures in Tables 1 and 2 are the means of 9 readings. From Table 1 it is seen that the sweat output for the saline and control groups in Expt. I (*a*) are not significantly different from each other, and that both are significantly lower than the sweat output for the water group, the difference between the control and water groups being just above what is required for P=0·02. Similar results are seen in Table 2 [Expt. I (*b*)]. The sweat outputs in all the three groups are slightly higher than in Expt. I (*a*) owing to the ambient temperatures being higher. There is very little difference between the control and saline groups. The difference between the control and water groups is significant at P=0·05.

In Table 3 are presented the half hourly output of sweat, urine and urinary sodium chloride for the three groups. In this table, the results of Expts. I (*a*) and I (*b*) have been combined. The figures in this table are therefore the means of 18 readings. During the first half hour during which conditions were the same for all the groups and which therefore may be considered as a control period for the whole, sweat output and urine output are substantially the same for all groups. Urinary sodium chloride was estimated only for the saline and water groups during this period, and is similar for these two groups. During the remaining 2½ hours after starting the specific experimental treatments, sweat output in the control and saline groups show a downward trend. In the water group too, after an initial rise, this downward trend is evident. The ambient temperatures on the other hand had shown a slight rise during this period. The expected response to the increase in ambient temperature is an increase in sweat output. The observed trend in sweat output is therefore the reverse of what would be expected and may indicate the increased accommodation of the body to a particular task.

Urine output in the control group also shows this downward trend. In the saline group, there is an initial increase in urine output followed by a steady fall. In the water group the urine output continues to rise, reaches a maximum after 1—1½ hours and then falls. The values at the end of 2½ hours are substantially the same in all the groups. The mechanisms, hormonal and otherwise which bring about water diuresis, therefore take about 1½ hours after drinking to exercise their maximum effect.

Half hourly determination of urinary sodium chloride was done only for the saline and water groups. In the control group, the half hourly urine samples were pooled and only the total urinary sodium chloride during the experimental period was determined. In the saline group, the elimination of sodium chloride in urine increases with time and would appear to have reached a maximum by the end of the 2½ hour period. In the water group there is an initial rise in urinary sodium chloride followed by a steady fall. This initial rise is most likely a result of the water diuresis but it may be noted that the maximum excretion of urinary sodium chloride occurs during the first half hour after drinking whereas the maximum output of urine occurs during the 1—1½ hours period.

Total output of urine during the 2½ hours experimental period (Table 3) is, as is to be expected, highest in the water group and is evidently caused by the lowering of plasma tonicity caused by the drinking of water. The urine output in the saline group also is higher than the urine output in the control group, the difference being significant. This difference cannot be due to any change in plasma tonicity since, drinking of normal saline though it would cause an increase in the volume of extracellular fluid would not cause any change in its tonicity. The reason for the increased urine flow in the saline group is not clear. It might be due to salt diuresis or due to an increase in renal circulation consequent to the increase in the volume of total circulating fluid.

Pulse

It is seen from Table 4 that drinking of plain water or saline had no effect on pulse rate. The pattern of distribution of pulse among the three groups is nearly the same before and after drinking of water/saline. A slight fall during the beginning of the half hour following drinking of water/saline occurred in all the three groups. This may be due to the fact that the test subjects were having a rest period of about half an hour before the second set of readings were recorded.

Skin temperature

From Table 4 it is seen that in all the three groups the skin temperatures recorded a fall at the beginning of the half hour following the drinking of water/saline. This may be due to the same reason mentioned for the fall in pulse rate, namely, due to rest. No effect attributable to drinking of water/saline was observed.

Oral temperature

From table 4 it is seen that mean oral temperature was very nearly constant during the experiment in the control group. In the water and saline groups, the mean oral temperature fell, following the drinking. The chief cause would appear to be the temporary cooling of the mouth due to the drinking of large volumes of fluid whose temperature was lower than that of the body. In both groups, the mean oral temperatures rose to nearly the initial levels and remained so, during the rest of the experiment, as shown by the third and fourth row of observations in Table 4. The results indicate that the increased sweat output consequent to drinking plain water is not reflected in changes in skin and deep body temperatures as measured in these experiments.

Results of Experiment II are given in Tables 5 and 6. The figures in these tables are means of 16 readings. Sweat output in the water group is significantly higher than in the saline group, the difference being higher than that needed for P=0·01. The difference moreover is of the same order as in Experiment I. In table 5, output of urine and urinary sodium chloride are given for three periods of the 24 hour day. The urine output for the water group during marching was 390 ml. which is less than the urine output for the water group during sitting (Experiment 1) for a corresponding 2 hour period. This is evidently owing to the increased sweat loss during marching. The urine output for the saline group during marching is, as is to be expected, less than for the water group, but during the third period (16·00 hours to 11·00 hours on the next day) the urine output of the former exceeds that of the water group, the difference between the two being significant. This is evidently an instance of salt diuresis : more urine being excreted to get rid of the excess salt in the saline group. The total output of urine during the 24 hour day is about the same for both saline and water groups. It is also seen that the 24 hour urinary output of sodium chloride of the saline group exceeds that of the normal group by about 6 grams. The excess salt intake of the saline group was 9 grams of which, it may therefore be concluded, roughly about 60 per cent gets eliminated in the urine during the first 24 hours.

The total voluntary consumption of water during 24 hours for the saline group was slightly less than for the water group (Table 6), but the difference is not significant.

DISCUSSION

These experiments confirm that drinking large volumes of water causes a significant increase in sweat output. These also show that reflex effects due to the act of drinking is not an important cause for this increase because such reflex, if any, should have occurred in the saline group to the same extent as in the water group and should have caused an increase in sweat output in both, whereas no increase (over the Control) has occurred in the saline group. On the other hand these experiments confirm the view that the chief factor concerned in this increase in sweat output is the lowering of plasma tonicity consequent to the drinking of water. Drinking normal saline, even though it brings about an increase in the volume of extracellular fluid, causes no change in the tonicity which remains substantially the same as in the normal. This would explain why there is no significant difference in sweat output in the saline and control groups. In the water groups, lowering of plasma tonicity and consequent increase in sweat output occurs. The reverse effect, namely, reduction in sweat output owing to body dehydration has also been reported[6] and may be attributed to an increase in the tonicity of plasma due to dehydration. Body-dehydration caused by salt depletion, on the other hand, is not accompanied by such reduction in sweat output[7]. In this case the dehydration apparently does not bring about any increase in plasma tonicity.

The response of the sweating apparatus to changes in tonicity of body fluids is thus seen to be analogous to the response of the kidney to such changes. It is well established that this response of the kidney is mediated by the anti-diuretic hormone of the pituitary. It has been suggested that sweat glands too are under the partial control of this hormone[8], which would explain the similarity of the two responses. The kidney is the most important organ for maintaining the fluid balance of the body. These experiments would suggest that the sweat glands too may have this function, though much less important than that of the kidney. The sweat glands, although they are primarily secretary organs, may therefore possess secondary excretory functions. For instance, such a secondary function has been assigned to them with respect to sodium chloride and it has been suggested that this is mediated by the adrenocortical harmones in the same manner as the latter controls the secretion of sodium chloride by the kidney[9].

No significant difference has been observed between the 24 hour voluntary water intakes in the water and saline groups. This shows that under conditions of this experiment presence of extra sodium chloride in the body has no effect in lowering the water needs of the body. However, the following considerations would appear to indicate that under certain conditions such effect may be expected. Even when the body is dehydrated, drinking of water results in an initial increase in the output of urine[8, 10], this increase representing a loss to the body, of water which could have been used for evaporative purposes. The presence of extra sodium chloride in the body reduces this loss of water as urine. Such sparing effect may be expected to become appreciable under conditions, as for example long marches in the desert in summer when repeated drinking of water becomes necessary. It is proposed to carry out these tests during the summer.

TABLE. 1

SWEAT OUTPUT (GM/KGM/HR) FOR SALINE, WATER AND CONTROL GROUPS DURING SITTING

[Experiment I (a)]

Group	Sweat output (Group means)	Difference between group means for P=0·02
Saline	2·00	
Water	2·40	0·3
Control	2·05	

TABLE 2

SWEAT OUTPUT (GM/KGM/HR) FOR SALINE, WATER AND CONTROL GROUPS DURING SITTING

[Experiment I (b)]

Group	Sweat output (group means)	Difference between group means for P=0·05
Saline	2·40	
Water	2·75	0·3
Control	2·35	

TABLE 3

HALF HOURLY OUTPUT OF SWEAT (GM/KGM), URINE (ml) AND URINARY SODIUM CHLORIDE (gm) FOR THE SALINE, WATER AND CONTROL GROUPS DURING SITTING

[Experiment I (*a* & *b*)]

*Period	Sweat			Urine			Urinary Nacl.		
	Saline	Water	Control	Saline	Water	Control	Saline	Water	Control
1	1·36	1·36	1·30	38	40	38	·272	·274	
2	1·19	1·54	1·23	45	105	34	·263	·309	
3	1·11	1·36	1·20	32	220	30	·324	·293	
4	1·11	1·25	1·04	29	215	21	·382	·250	
5	1·03	1·15	1·04	30	115	23	·417	·204	
6	1·00	1·19	0·99	23	27	20	·419	·176	
2 to 6	5·44	6·49	5·59	159	682	128	1·805	1·232	1·020

* Period 1 : Half hour period prior to drinking water/saline.
2 : First half hour after drinking water/saline.
3 : Second hour after drinking water/saline.
4 : Third half hour after drinking water/saline.
5 : Fourth half hour after drinking water/saline.
6 : Fifth half hour after drinking water/saline.

TABLE 4

MEAN PULSE, SKIN TEMPERATURE AND ORAL TEMPERATURE FOR SALINE, WATER AND CONTROL GROUPS

[Experiment I (*b*)]

*Period	Pulse/min.			Skin temp. °F.			Oral temp.°F.		
	Saline	Water	Control	Saline	Water	Control	Saline	Water	Control
1	68	65	66	94·9	94·8	94·7	98·4	98·4	98·3
2	65	63	65	94·6	94·6	94·4	98·0	98·0	98·3
3	66	63	64	94·7	94·6	94·4	98·3	98·2	98·2
6	64	63	63	94·7	94·7	94·5	98·3	98·3	98·2

* The figures given in the column for Period have the same meaning as in Table 3. The observations were recorded during the beginning of each period.

TABLE 5

SWEAT OUTPUT (GM/KGM/HR) FOR SALINE AND WATER GROUPS DURING MARCHING IN THE SUN

Experiment II

Group	Sweat output (Group means)	Difference between group means for P=01
Saline	10·8	0·34
Water	10·4	

TABLE 6

INTAKE OF WATER (ml) AND OUTPUT OF URINE (ml) AND OF URINARY SODIUM CHLORIDE (gm) FOR SALINE AND WATER GROUPS DURING THREE PERIODS IN 24 HOURS

Experiment II

Group	Period, Hours	Urine output	Urinary Nacl. output	Water intake
Saline ..	11·00—13·00 (marching)	140	1·676	4260±260
	13·00—16·00 (Sedentary)	162	2·478	
	16·00—11·00 next day (Sedentary, rest)	969	11·400	
	Total for 24 hrs.	1271	15·554	
Water ..	11·00—13·00 (marching)	390	1·440	4380±310
	13·00—16·00 (Sedentary)	165	1·737	
	16·00—11·00 next day (Sedentary, rest)	665	6·460	
	Total for 24 hrs	1220	9·637	

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