EFFECT OF WATER INTAKE ON SWEAT OUTPUT

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ABSTRACT

The effect of drinking volumes of water in excess of normal requirement at a given time on sweat output was studied under two conditions of body activity namely marching and standing, and two conditions of exposure namely sun and shade. It was found that (1) drinking large volumes of water causes a significant and appreciable increase in sweat output, of the order of 0·8 gm/Kg/hr; and (2) this increase is very nearly the same under all the conditions studied. It is suggested that changes in tonicity of the plasma may be the main cause for this phenomenon. It is also pointed out that this increased sweat output is not a loss to the body.

Introduction

The skin is one of the important avenues of water loss from the body. The effect of water intake on the loss of water through this avenue has not been studied in detail. Information available on this subject is also rather conflicting. Gregory et al.[1] state that drinking water increases sweat output. Adolph[2] on the other hand reports that drinking water causes only a transient outburst of sweat and that this is subsequently followed by a suppression of sweating, so that the overall effect on sweat output is negligible. Eichna et al.[3] are of the same view. These studies were for the most part on men at rest drinking relatively small volumes of water, of the order of 200 ml. at a time, or on men under conditions of marked body dehydration. We were interested on the effect of large intakes of water under conditions of heavy sweat output, as for example, while working in the sun. Under such conditions it is a well recommended practice to have a full drink of water before starting the work. Any effect which such drinking has on sweat output may be expected to have a bearing on the water economy of the body.

Experimental

The test subjects were drawn from a batch of military personnel, 20-30 years of age and acclimatised to the conditions of the experiment. The study was done outdoors and lasted for about two months. In order to control the effects of variations in ambient conditions and also between test subjects, the plan of work was based on the Latin Square design.

The study was made in three parts. In the first, (Expt. 1) six test subjects were divided into three equal groups. One, "the restricted water group" was instructed to drink as little water as possible from morning till the start of the experiment (12·00 hours) and did not drink any water during the experiment. The second, "the normal water group" drank water *ad libitum* before the experiment, but did not have water during the experiment. The third, "the high water group" was given 600 ml. water 1 hour previous to, and further amounts during the experiment as detailed below. Before starting the experiment, urine was collected from all test subjects for specific gravity determination. Initial body weights were then recorded, correct to ¼ oz. with the test subjects putting on short drawers cotton only. Then they stood in the sun, putting on PT shoes and underwear for a period of 2 hrs. After every ½ hour, body weights were recorded and the subjects in the high water group were given measured volumes of water at about 80°F-85°F., so as to make up for the loss of body weight during the preceding ½ hour. It would have been more correct to give water at about body temperature, but drinking water at such temperature was not liked by the test subjects. Half hourly readings of Dry Bulb, Wet Bulb, Black Globe and Kata Thermometers were recorded. At the end of the 2 hours period, final body weights were recorded and urine collected for specific gravity determination. One replicate was completed, lasting for 6 days during which D.B. temperature was $79\pm0{\cdot}5$°F, W.B. temperature $57\pm0{\cdot}5$°F, Black Globe temperature $115\pm0{\cdot}5$°F and air velocity calculated from Kata Thermometer readings ranged from 100 to 500 ft/min. The test subjects in the high water group consumed on the average 1300 ± 30 ml. of water including the 600 ml. given 1 hour previous to the experiment.

In the second part (Expt. 2) a more strenuous task was set, namely marching in the sun at 3½ miles per hour for 2 hours with a rest period of 5 minutes after every 25 minutes marching. There were only two levels of water intake, namely the normal and high. Also, the water intake of the latter group was maintained higher than in the previous experiment by giving 1000 ml. water 1 hour prior to and 500 ml. just before the experiment, and further amounts during the experiment in the manner detailed below. Since it was to be expected that the sweat output during marching would be affected by the total weight carried by the test subject including that of his body, the following procedure was used to maintain the effective weight of each subject reasonably constant every day of the experiment during the marching. From a previous trial a suitable weight was assigned to each subject. Every day, after recording the initial body weight, the weight was adjusted at the pre-assigned value for each test subject by adjusting the load in the haversack which formed part of his marching kit. During the marching itself the body would lose weight. This was compensated for, in the normal water group by further increasing the initial weight by an amount equal to half the expected weight loss during the 2 hours marching, this having been roughly estimated from a previous trial. The test subjects in the high water group passed large volumes of colourless urine during the 5 minutes rest intervals. This urine was measured, and measured amount of drinking water was given, equal to the amount of urine passed plus the expected body weight loss during the preceding 25 minutes marching period. In this manner, while keeping the body weight in this group reasonably constant it was also assured that a high level of water was maintained in the body throughout the marching. Measurements were the same as in Experiment 1 except that body weights were not recorded during the task.

Two replicates were run, each lasting for 6 days using a different set of test subjects in each. During the first, the D.B. temperature was 74±1°F, W.B. temperature 56±0·5°F, and Black Globe temperature 98±1°F. During the second replicate these were respectively 75±1°F, 57±0·5°F, and 100±0·5°F. Wind velocity ranged from 100—500 ft/min. The test subjects in the high water group consumed on the average 3150+70 ml. water including the 1500 ml. taken prior to the marching.

In the third part (Experiment 3) three tasks were simultaneously studied, namely (*a*) marching in sun as in the previous experiment, (*b*) standing in the sun and (*c*) standing in shade, each task being studied at normal and high intakes of water. Details were the same as in Experiment 2, except that urine specific gravity was not measured. It was noted however that the test subjects in the high water group voided large volumes of colourless urine in the same manner as in Experiment 2. Two replicates were run, each lasting for six days, using the same set of six test subjects. D.B. temperature was 87±0·5°F, W.B. temperature 62±0·5°F, Black Globe temperature 119±1°F and wind velocity ranged from 100—500 ft/min. The test subjects in the high water groups consumed on the average 3070±100 ml. water including the 1500 ml. taken prior to the experiment.

Results

Sweat output (as given by loss of body weight during the task) for each test subject was expressed in terms of grams per kilogram body weight per hour. The values so obtained were subjected to Variance analysis. Results for Experiments 1, 2 and 3 are presented in Tables 1, 2 and 3 respectively. Urine specific gravities are given in Table 4.

TABLE 1

Sweat Output (gms/Kg/hr) during Standing in the Sun at three Levels of Water Intake (Expt. 1)

Group: Level of Water Intake	Sweat output (Group means)	Diff. between Group means for P.=0·05
Restricted		
Normal	8·0	0·38
High	8·4	

The values of sweat output in Table 1 (Experiment 1) are the means of 12 observations. It is seen that there is no difference in sweat output between the restricted and normal water groups. The test subjects in the former group were instructed to drink, as little water as possible before the experiment. It was thought that in this manner they would be in a condition of moderate body dehydration during the experiment. However, the urine specific gravities for the two groups were very much the same (Table 4) indicating that the degree of dilution of body fluids was the same in the restricted and normal water groups and that there was therefore no difference in the degree of body hydration between the two groups. Granting that the test subjects in the restricted water group carried out the instruction regarding drinking of water, this result would likely be due to the fact that the experiment was done during the early part of December, and that during winter months it might be difficult to create conditions of body dehydration by restricting water intake in this manner. It was therefore decided to drop out the restricted water group from further experiments in this study. In the high water group the sweat output was higher than in the other two groups; the difference of 0·4 gm/Kg/hr is significant, being above the value required for $P = \cdot 05$. The initial specific gravity of urine in this group was slightly lower than in the other two groups owing to the drinking of the 600 ml. water prior to the experiment. The final urine specific gravity was appreciably lower.

The values of sweat output in Table 2 (Experiment 2) are the means of 18 observations. It is seen that the mean sweat output of the high water group

TABLE 2

Sweat Output (gms/Kg/hr) during Marching in the Sun at two Levels of Water Intake (Expt. 2)

Replicate	Group: Level of Water Intake	Sweat output (Group means)	Diff. between Group means	Diff. between Group means for P= ·01
1	Normal	5·9	1·0	0·7
	High	6·9		
2	Normal	6·7	0·8	0·6
	High	7·5		

TABLE 3

Sweat Output (gms/Kg/hr) during three Tasks at two Levels of Water Intake (Expt. 3)

Task	Group: Levels of Water Intake	Sweat output (Group means)	Diff. between Group means	Diff. between Group means for P= ·02
Standing in Shade	Normal	2·4	0·8	0·8
	High	3·2		
Standing in Sun	Normal	5·6	0·9	
	High	6·5		
Marching in Sun	Normal	10·7	0·8	
	High	11·5		

TABLE 4

Mean Specific Gravity of Urine before and after the Task (Expts. 1 and 2)

Expt.	Level of Water Intake	Specific Gravity (Mean ± S.E.)	
		Initial	Final
1	Restricted	1·017± ·001	1·023± ·001
	Normal	1·018± ·002	1·022± ·003
	High	1·014± ·002	1·007± ·002
2	Normal	1·018± ·001	1·021± ·001
	High	1·010± ·001	1·001±0002

was higher than that of the normal group by 1·0 and 0·8 gms/Kg/hr. respectively in the two replicates and that these differences are highly significant being above the values required for $P=\cdot 01$. The initial and final specific gravities of urine for the normal group were about the same as for the corresponding group in experiment 1. For the high water group the initial value 1·01 was lower than the corresponding value in experiment 1 showing the effect of the larger intake of water prior to the beginning of the task. The final urine specific gravity for this group was 1·001, very nearly that of pure water, which shows that water elimination through the kidney was going on very rapidly. During the last half hour of the experiment, the urine voided by this group was between 450—500 ml. which is about the maximum capacity of the kidney for excretion of water[3].

From Table 3 (Experiment 3) in which each figure is the mean of 12 observations it is found that during the marching task the sweat output of the high water group exceeded that of the normal group by 0·8 gm/Kg/hr, which is about the same as the corresponding value in Experiment 2. The difference is significant at $P=0\cdot 02$. It is also seen that there was about the same difference in sweat output between the normal and high water groups in the other two tasks namely, standing in the sun and standing in the shade.

Discussion

It is seen therefore that drinking large volumes of water results in a significant increase in sweat output. This increase, in Experiment 1 was only about half as much as in Experiment 2 and 3. The only apparent cause for this difference is that the consumption of water by the high water group in Experiment 1 was only about half as much as in Experiments 2 and 3. The increase in sweat output in the latter experiments may be taken to represent maximal values for such increase, because the test subjects were drinking nearly as much water as they could, and water elimination through the kidney was going on at nearly maximum rates. The value of this increase in sweat output, 0·8 gm/Kg/hr. is equivalent to about 50 grams per hour for a person weighing 60 Kgs. It is also seen that it represents about 30% of the normal sweat output for a person standing in the shade (Table 3) and therefore cannot be considered negligible.

The mechanism of this increase in sweat output is not clear. It has been suggested that it may be due to reflex stimulation of the sweat glands due to the act of swallowing [4]. It is stated that the effect is only transitory, as is to be expected if it is really due to such a reflex, and that it is followed by suppression in sweat output so that the overall effect is negligible. It is also stated that this phenomenon is seen only in some individuals. Granting that such reflex mechanism does exist, it would appear to be inadequate to explain the results of the present study. The increase in sweat output was found to be quite appreciable, and was not transitory, but maintained till the end of the 2 hour experimental period. Also, all the test subjects showed this increase. Kuno[5] has suggested that under conditions of body dehydration the alimentary canal becomes relatively dry which may inhibit the sweat centre reflexly, and that drinking of water increase the sweat output by bringing normal conditions in the alimentary canal and abolishing the inhibition on the sweat centre. This may be true under conditions of body dehydration, but in the present study there was no evidence of body dehydration in any of the test subjects. Another possible mechanism is that the lowering of osmotic pressure of the plasma consequent to the intake of large amounts of water stimulates the sweat glands either reflexly or through the sweat centre. Experimental findings of Nishibori[6] would seem to support this view. Intravenous injection of hypotonic saline caused an immediate and large increase in sweat output. Isotonic saline had no effect, while hypertonic saline suppressed sweat output. The plausible explanation of these observations is that the introduction of the saline caused changes in the tonicity of the circulating plasma which in turn affected the sweat centre and caused the observed changes in sweat output. In the present study it is evident that there was a lowering of osmotic pressure of plasma in the high water group, since the observed increase in urine flow in this group was a direct result of such lowering of osmotic pressure. This would also explain why the increase in sweat output of the high water group was less in Experiment 1 than in Experiments 2 and 3. In the former, the intake of water by the high water group was less than in the other two experiments and the resulting lowering of osmotic pressure of plasma would also have been relatively less.

Finally, whatever might be the mechanism by which this increase in sweat output is brought about, the present study shows that it is independent of the thermal stimulus to sweating, because this increase in sweat output is found to be the same under different conditions of activity, exposure and sweating rates.

It is a sound practice to protect the body with a full drink of water before starting on a task during which the sweat loss is expected to be heavy. This initial intake of water would usually result in an increased flow of urine which represents a loss to the body so far as its evaporative needs are concerned. But the extra output of sweat caused by such drinking brings about evaporative cooling of the skin and so should not be considered as a loss to the body.

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