PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN HEAT ACCLIMATION FOR SUBJECTS WITH A CONTROLLED DIET

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INTRODUCTION

As a consequence of becoming acclimated, a person is able to work in a hot environment under less physiological strain and continue working for a considerably longer time than when not acclimated (1). It has been well documented that sweat sodium (Na^+) concentration decreases with acclimation (1,2) and that it increases with rate of sweating (2,3). Although rate of sweating also increases during acclimation, few studies have noted the extent to which observed changes in Na+ concentration have been influenced by changes in sweat rate (2), and in this case, diet was not controlled. The effects of high and low Na^+ diets on acclimation have been studied (4), but less so for moderate Na^+ diets. The aim of this paper was to quantify changes in physiological parameters and sweat electrolytes while acclimating subjects whose diets contained a moderate amount of Na^+ before and during heat exposure.

METHOD

Subjects. Four male subjects, who were unacclimatized to heat, yet physically trained, participated in the study. The subjects had a mean (± SD) age of 20 2 years, height of 1.78 ± .05 m, weight of 82.3 ± 6.9 kg and percent body fat of 16.9 ± 4.7% (Harpenden skinfold calipers using the 4-point method).

Experimental design. Subjects participated in the study on 5 consecutive days, exercising in a hot-dry environment (45.2 ± 0.5°C dry bulb, 39.6 ± 1.6% RH). Each heat/exercise exposure lasted 90 min each day. Within this time, subjects completed a 15 min cycle on a cycle ergometer (approximately 125 $W \cdot m^{-2}$), followed by 4 sets of a 10-min standardized stepping task. Subjects stepped onto a 22.5 cm block at a rate of 15 steps/min (approximately 216 $W \cdot m^{-2}$) in time to an electronic metronome. Subjects were not permitted any water to drink during the experiment. Subjects consumed a strictly controlled "moderate" (4 $g \cdot d^{-1}$) sodium diet for 2 days prior to the experiment and every day during the experiment. They also consumed at least 4 liters of water each day.

Measurements. The following measures were taken during the heat exposure: aural temperature (Tau); 4-point mean skin temperature ($\bar{T}_{sk}$); heart rate (HR); sweat rate; sweat sodium (Sw_{Na^+}); and sweat potassium (Sw_{K^+}). T_{au}, $\bar{T}_{sk}$ (thermistors) and HR were recorded continuously throughout the experiment. Sweat rate was determined by weighing subjects before and after the exercise on the cycle and before and after each of the 4 sets of stepping and dividing by the duration of each activity. Sweat collection patches were attached at 8 sites over the body. Sweat was absorbed on squares of filter paper held in place by

patches made of polythene and Transpore tape. A set of 8 filter papers were inserted and removed from the patches before and after each set of stepping. The sweat-soaked filter papers were analyzed for sodium and potassium using flame photometry.

RESULTS

Table 1: Change in aural temperature during acclimation[1].

Day	Start T_{au} (°C)	End T_{au} (°C)	Difference over 1 day (°C) E-S	Difference over 5 days (°C) E5-E1
1	36.78f0.10	38.83 ± 0.46	2.05 ± 0.50	
2	36.60f0.22	38.70 ± 0.41	2.10 ± 0.28	
3	36.53 ± 0.28	38.55 ± 0.41	2.03 ± 0.26	
4	36.33 ± 0.29	38.50 ± 0.37	2.18 ± 0.38	
5	36.35 ± 0.31	38.33 ± 0.22	1.98 ± 0.26	-0.5 ± 0.28*

[1] Values shown are means ± SD
* Significant difference, $P < .05$

Table 2: Change in mean skin temperature during acclimation[1].

Day	Start $\bar{T}_{sk}$ (°C)	End $\bar{T}_{sk}$ (°C)	Difference over 1 day (°C) E-S	Difference over 5 days (°C) E5-E1
1	32.35 ± 1.22	38.52 ± 0.78	6.18 ± 0.59	
2	32.83 ± 1.93	39.00 ± 0.43	6.17 ± 1.60	
3	31.76 ± 1.96	38.50 ± 0.15	6.75 f2.00	
4	31.86 ± 1.34	38.37 ± 0.45	6.51 ± 1.58	
5	31.73 ± 1.28	38.34 ± 0.60	6.62 ± 0.70	-0.18 ± 1.35

[1] Values shown are means ± SD

Table 3 Change in heart rate during acclimation[1].

Day	Start HR (bpm)	End HR (bpm)	Difference over 1 day (bpm) E-S	Difference over 5 days (bpm) E5-E1
1	81 ± 15	154 ± 13	73 ± 14	
2	84 ± 6	152 ± 11	68+ 6	
3	70 ± 13	146 ± 8	77 ± 14	
4	72+ 16	143 ± 16	71 ± 19	
5	75 ± 16	145 ± 4	70 ± 18	-10 ± 10

[1] Values shown are means ± SD

T_{au}, T_{sk} and HR. Between Day 1 and Day 5, there were decreases in mean T_{au}, $\bar{T}_{sk}$ and HR, although only T_{au} was significant ($P < .05$) (Tables 1-3).

Sweat rate. Daily sweat rate increased significantly ($P < .01$) between Days 1 and 5, and also between each consecutive day ($P < .05$), except the change

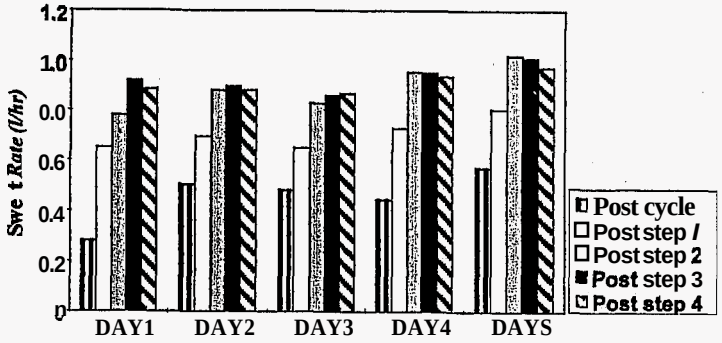

Figure **1.** Change in sweat rate within and between sessions.

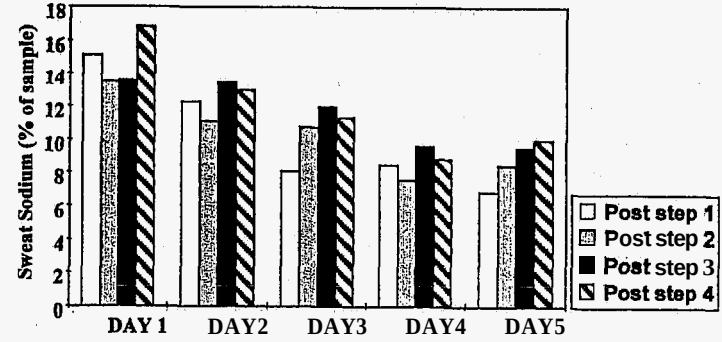

Figure **2.** Change in sweat sodium within and between sessions.

between Days 1 and 2 (Figure 1). There was a mean increase in sweating response of 25% over the 5-day acclimation period. This demonstrates that a degree of heat acclimation was achieved in each subject, although other studies have found substantially higher increases in sweat rate of 70% (2) and 100% ***(5).*** Sweat rate also increased significantly ($P < .05$, except for Day 1) within each day (Figure 1).

Sweat sodium and potassium. Daily Sw_{Na^+} concentration decreased significantly ($P < .01$) between Days 1 and **5**, and also between each consecutive day ($P < .05$), except the change between Days 4 and 5 (Figure 2). Sw_{Na^+} did increase within each day, although not significantly. Overall, daily Sw_{K^+} concentration decreased significantly ($P < .01$) between Days 1 and 5, although the level fluctuated during that time. There were no significant changes within days for Sw_{K^+}.

Relationship between sweat rate and sweat sodium. Sweat rate was plotted against sweat sodium for Days 1 (unacclimated) and **5** (acclimated), to assess the effects of both increased sweat rate and acclimation on sweat sodium. Although the regression lines were not significant, there was a clear trend of increased Sw_{Na^+} with increased sweat rates and lower Sw_{Na^+} content after acclimation. The same graph was plotted for Sw_{K^+}, which showed an increase in Sw_{K^+} with increased sweat rates and a decrease in Sw_{K^+} after acclimation, the difference being larger at higher sweat rates. However, there are large inter-indi-

vidual differences in sweat rate, Sw_{Na^+} and Sw_{K^+}, and there are insufficient data to draw firm conclusions.

DISCUSSION

The small number of subjects in this experiment does not allow strong conclusions to be drawn, but it may be regarded as a case study. It appears that it is possible, to an extent, to acclimate subjects who consume a controlled, moderate sodium diet, during 5 days heat exposure. Many previous studies have not controlled diet, and therefore any reported changes in sweat sodium/potassium must be used with caution. It has been reported that a low sodium diet during heat exposure may increase the risk of circulatory incompetence/heat illness, particularly due to low stimulus for water intake (4). This experiment demonstrated that acclimation can be achieved with a moderate sodium diet and that a high sodium diet may not be necessary. Since it has been shown that sweat sodium and potassium concentration increase with sweat rate and decrease with acclimation, it is important that changes in sweat sodium and potassium are related to sweat rates so that the acclimation reduction in sweat electrolytes is not underestimated due to the sweat rate increase in acclimation. Previous studies that have produced greater increases in the sweating response (2,5) through acclimation used different techniques and longer periods of acclimation. Although the ideal sweat collection technique may have been a body washdown, the method used took samples fiom eight sites over the body. The sweat collection patches were considered to be regularly aerated, although not to the normal extent, and this method allowed a comparison of change in sweat electrolytes throughout each session, as well as over the five days.

CONCLUSIONS

Heat acclimation is possible while exercising in the heat for five days and consuming a controlled, moderate sodium diet prior to and during heat exposure. Under these conditions, sweat sodium and potassium concentration increased with sweat rate and decreased with acclimation.

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