Effect of Acute Cold Exposure on Serum Potassium, and Magnesium and the Electrocardiogram in Man. (20449)

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During exposure to low environmental temperatures metabolic changes involving potassium and magnesium occur. Increases in the levels of potassium in serum have been described in animals subjected to acute cold exposure(1) and in men transferred from a warm climate to an arctic environment(2). Magnesium has been implicated as an important factor in temperature regulation primarily on the basis of animal experiments, but the data in man are scanty and controversial(3). Hypothermic rats develop increased cardiac sensitivity to injected potassium salts(4); however, the electrocardiographic changes described in hypothermia(5) were not entirely characteristic of the changes observed in either hyperkalemia(6) or hypermagnesemia(7).

The present study was undertaken to determine the extent and rapidity of any changes that might occur in the concentrations of serum potassium and magnesium during acute cold exposure. Electrolyte changes were also correlated with alteration in serial electrocardiographic patterns.

Materials and methods. Twenty-two experiments were performed on 20 young, normal men. Each subject dressed in underwear reclined for 45 minutes at an ambient temperature of 75°F, then reclined in a cold chamber maintained at 45°-50°F for 90 minutes. Venous blood was obtained without stasis at the end of the control period and at 30-minute intervals in the cold for the determination of magnesium by the method of Simonson, Westover, and Wertman(8), potassium with the Beckman flame photometer, and serum proteins by the copper sulfate specific gravity method. Ionized magnesium was estimated from the total serum magnesium and protein concentrations, using the nomogram of Willis and Sunderman(9). Rectal temperatures were obtained with clinical thermometers at the times that blood samples were drawn. Electrocardiograms were obtained on 19 subjects with a direct writing Sanborn Viso-Cardiette at the end of the control period and after 40 and 80 minutes of cold exposure. The three standard limb leads and V_2 and V_4 were employed. Tests for significance were done by paired data analyses; thus, each individual served as his own control.

Results and discussion. The data are summarized in Table I. The mean serum concentrations of proteins and potassium after 30, 60, and 90 minutes of cold exposure were all statistically significantly higher than the control values ($P < 0.05$). The absence of any correlation between the changes in proteins and potassium ($r = 0.04$, not significant) militates against the possibility that the changes in this electrolyte were due solely to hemoconcentration. There were no statistically significant changes in rectal temperature or concentration of total or ionized serum magnesium. However, any change in the concentration of magnesium may have been masked by hemoconcentration.

Analyses of the electrocardiograms failed to reveal any important changes in cardiac rate, rhythm, or conduction. Examination of the T waves in lead V_4 revealed a significant increase in amplitude after 40 and 80 minutes of cold exposure, but this small increase did not correlate significantly with the increase in concentration of serum potassium.

The mechanism responsible for the increase in the concentration of serum potassium in this study is not clear. Heightened muscle activity may have been partially responsible for this increase since shivering was a prominent feature in this experiment. Such increases have been described in rats during exercise(10) and in man during electroshock therapy(11). The results of the present report confirm the findings in animals subjected to cold exposure(1). Various mechanisms

TABLE I. Mean Values and Standard Deviations of Concentrations of Serum Potassium, and Magnesium and of Height of T Wave in Lead V_4.

Min. of cold exposure	0	30	60	90
Total serum proteins (g/100 cc)	7.24 ± .27	7.47 ± .37	7.62 ± .35	7.75 ± .31
As % of control	100	103	105	107
K (mEq/l)	4.67 ± .30	4.92 ± .30	5.11 ± .30	5.20 ± .36
As % of control	100	105	109	111
Total Mg (mEq/l)	1.55 ± .26	1.57 ± .29	1.61 ± .32	1.53 ± .33
As % of control	100	101	104	99
Ionized Mg (mEq/l)	1.1 ± .2	1.1 ± .1	1.1 ± .2	1.1 ± .2
As % of control	100	100	100	100
		40 min.	80 min.	
ECG lead V_4	8.03	9.22	9.53	
T wave height in mm	± 2.44	± 2.71	± 2.97	
As % of control	100	115	119	

have been postulated to explain the increased serum potassium in the experiments noted, but the nature of the present study does not permit analogous interpretation of the findings reported here.

Summary. Twenty healthy young men exposed to a temperature of 45°-50°F for a period of 90 minutes showed a significant elevation in the mean concentration of serum potassium, but no significant changes in the mean serum concentrations of either total or ionized magnesium. No correlation was observed between the changes in the electrocardiogram and the changes in the concentration of serum potassium.

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1. Booker, W. M., Hayes, R. L., DaCosta, F. D., Jones, W., Hill, R., and Titus, P., *Fed. Proc.*, 1952, vII, 15.

2. *Survival in the cold:* A metabolic and nutritional study of soldiers acclimatized to heat transported abruptly to a very cold climate. Med. Nutrition Lab. Chicago, Rep. No. 42, Nov. 30, 1948.

3. Hall, V. E., Grant, R. E., and Whalen, W. J., *AF Tech. Rep.* No. 6682, August, 1951.

4. Elliott, H. W., and Crimson, J. M., *Am. J. Physiol.*, 1947, v151, 366.

5. Kossman, C. E., *Bull. N. Y. Academy Med.*, 1940, v16, 317.

6. Tarail, R., *Am. J. Med.*, 1948, v5, 828.

7. Smith, P. K., Winkler, A. W., and Hoff, H., *Am. J. Physiol.*, 1939, v126, 720.

8. Simonsen, D. G., Westover, L. M., and Wertman, M., *J. Biol. Chem.*, 1947, v169, 39.

9. Willis, M. J., and Sunderman, F. W., *J. Biol. Chem.*, 1952, v197, 343.

10. Miller, H. C., and Darrow, D. C., *Am. J. Physiol.*, 1941, v132, 801.

11. Welt, L. G., Orloff, J., Kydd, D. M., and Oltman, J. E., *J. Clin. Invest.*, 1950, v29, 935.

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