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Changes Produced in Urinary Sodium, Potassium, and Calcium Excretion in Mice Exposed to Homogeneous Electromagnetic Stress

GARRY D. HANNEMAN, D.V.M.

Female albino mice of the Webster-Fairfield strain were exposed to a homogeneous magnetic field of 14,000 Oe. for twenty-four hours. Twenty-four hour urine samples were obtained from each mouse before, during, and after exposure. All samples were analyzed for sodium, potassium, and calcium ion concentration by the standard flame spectrophotometric technique. Control mice were handled identically except they were placed in a dummy magnet and not exposed.

Results showed the average sodium ion concentration of the urine from exposed mice increased from 2.34 mg/cc before exposure to 4.29 mg/cc following exposure. The average potassium ion concentration increased from 9.14 mg/cc to 14.59 mg/cc. The concentration of calcium ions increased from 0.083 mg/cc to 0.138 mg/cc. Only sodium and potassium showed a significant increase in concentration following exposure. Results on the control mice showed little change for all three ions.

MAN IS CONFRONTED with the problem of surviving adverse environments as he enters longer exposure to space. In order to insure survival he must be protected or shielded from the forces which he experiences during space travel. One of these forces is cosmic radiation. Recent studies have suggested that the application of high electromagnetic fields may be feasible in the future for shielding man against such radiation. Man has always lived in a weak magnetic field without knowingly experiencing any harmful effects. However, we should not overlook the possibility that such effects may be produced when this application is realized.

While studying the effects of electromagnetic stress, we are confronted with the question as to which body system would most likely be susceptible. One which plays an essential role in maintaining normal body functioning is the urinary system, particularly the kidneys, which metabolize and conserve essential inorganic ions needed by the body for maintaining the acid-base balance and the consistency of the internal environment of the body. This system may be subject to alteration by high magnetic fields, possibly through changes in electrical potential on the tubular membranes of the kidneys or by the forces exerted on certain ions during the formation of urine.

To demonstrate the effect of a magnetic field on the movement of sodium ions across a cell membrane, Gualtierotti and Capraro (1964)[1] placed a frog skin in a solution containing the isotope 24 of NaCl on one side and isotonic saline on the other. The magnetic field was produced by placing a permanent magnet on each side of the skin. The amount of radioactive sodium crossing the membrane was measured during exposure. Using this technique it was demonstrated that a field of 500 to 600 Oe. decreased the inward flux of sodium ions across the skin. Another technique, consisting of a voltage clamp and magnets, was used to determine the time course of this phenomenon. The first decrease of inward flux occurred rapidly, in about one second. An increase of the magnetic field strength resulted in further similar quantal changes in ion fluxes. The authors indicate the change appears to be proportional to the magnetic field strength and the phenomenon being altered by an induced change of polarization across the membrane. The possibility, therefore, exists that a magnetic field may somewhat inhibit the sodium pump. Some key molecules involved in the sodium transport may be, or become, magnetic dipoles and therefore be affected by the field forces. There is evidence from the results of this study that a magnetic field modifies the fundamental mechanism of sodium transport through the membrane.

The possibility of this phenomenon taking place across a cell membrane suggests that the renal tubules of the kidney may likewise be affected. The renal tubules are the site where reabsorption of ions from the glomerular filtrate takes place, with the end product being urine.

The purpose of this paper is to report the results of a study conducted on the concentration levels of sodium, potassium, and calcium ions found in the urine excreted from white mice exposed to a high homogeneous magnetic field.

MATERIALS AND METHODS

The magnet was a water-cooled Harvey-Wells L128 12-inch electromagnet with a Model HS1365 power supply, as shown in Figure 1. The pole faces are six inches in diameter, spaced 1.75 inches apart, with a four-inch homogeneous field in the center. The poles are positioned vertically, producing a horizontal field. The field strength in this study was 14,000 Oe. The magnetic field gradient was measured and found to be less than one Oe. over the central four-inch diameter at 5,000 Oe. From this the gradient at 14,000 Oe. was esti-

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From the Fort Worth Division of General Dynamics, Fort Worth, Texas.

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mated as about 50 Oe. over the four-inch diameter. The paramagnetic field strength was therefore about $.07 \times 10^6$ Oe^2/cm at 14,000 Oe.

The animals used for this study were female albino Swiss mice of the Webster-Fairfield strain. They were approximately twenty-two weeks of age. The mice averaged 24.3 grams in weight and showed no symptoms of ill health prior to or during the study. Thirteen mice were used, six experimental and seven controls. The mice were housed individually in plexiglas cages described by Hanneman, et al (1964)[2] and shown in Figure 2. At the beginning of each experiment the experimental and control mice were placed in magnet and dummy setups, respectively. Food (Purina Laboratory Chow) and water were continuously available for both the experimental and control mice throughout the study. The mice were not removed from the metabolic cages during the study period. The urine collection funnels and centrifuge tubes were removed and replaced with clean ones at the end of each 24-hour period. The experimental and control mice were handled and housed identically except the controls were placed between two stainless steel plates, simulating the poles of the magnet, and were not exposed to the magnetic field.

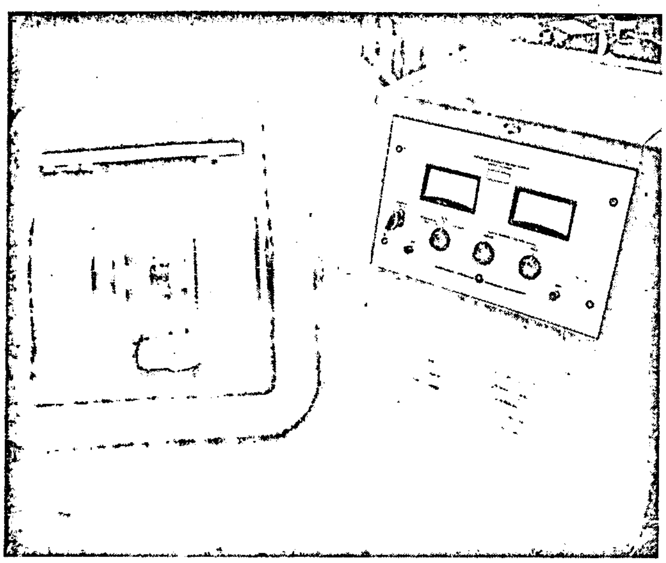

Fig. 1. View of the magnet and power supply with the metabolic cage in place during exposure.

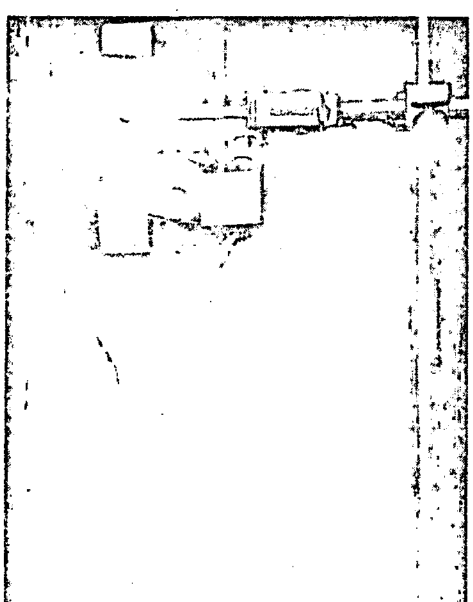

Fig. 2. Close-up view of the metabolic cage used in collecting urine from mice during exposure.

The metabolism cage as positioned between the poles of the magnet during exposure is shown in Figure 1. The urine collection tube was partially inserted into a dewar of dry ice. This kept the urine at a low temperature and prevented evaporation or decomposition during the period of collection.

Each experiment consisted of five consecutive 24-hour periods. The experimental mice were exposed during the third 24-hour period of the experiment. A total of five 24-hour samples were collected from each mouse. The urine samples were analyzed for sodium, potassium, and calcium ion concentration by the flame spectrophotometer technique. The results are expressed as milligrams per cc of urine. The average milligrams of the ions eliminated per cc of urine was determined for each day of the study. The day prior to exposure was designated as the "pre-exposure period"; the day following exposure was called the "post-exposure period." The difference between the values for the pre- and post-exposure periods constitutes the significant data.

RESULTS AND DISCUSSION

An analysis of the results from mice exposed to the magnetic field is given in Table I. The sodium ion concentration of the urine from exposed mice increased from 2.34 mg/cc to 4.29 mg/cc following exposure. The significance of this increase, as shown by the t-value, 2.457, expresses a probability level (per cent) of > 95. The potassium ion concentration increased in the exposed mice from 9.14 mg/cc to 14.59 mg/cc. The significance of this increase, based on a t-value of 2.671, is expressed at a level of > 95. The concentration of the calcium ions in the urine was found to be considerably lower than that of sodium or potassium. Calcium increased from 0.083 mg/cc to 0.138 mg/cc, which was found to be statistically non-significant, based on a t-value of 1.715, giving a level of < 90. Results on the

TABLE I. ANALYSIS OF IONS IN AVERAGE MILLIGRAMS PER CC OF URINE FROM EXPOSED MICE

	Na^+		K^+		Ca^{++}	
	Period		Period		Period	
	Pre-Exposure	Post-Exposure	Pre-Exposure	Post-Exposure	Pre-Exposure	Post-Exposure
Mean	2.34	4.29	9.14	14.59	0.083	0.138
Standard Deviation	.72	1.81	2.88	4.15	0.031	0.071
Standard Error	.25	.74	1.18	1.69	0.013	0.029
Difference	1.95		5.45		0.055	
Standard Error of Difference	.79		2.06		0.032	
Degrees of Freedom	10		10		10	
t-Value	2.457		2.671		1.715	
Probability Level (per cent)	>95		>95		<90	

TABLE II. ANALYSIS OF IONS IN AVERAGE MILLIGRAMS PER CC OF URINE FROM CONTROL MICE

	Na^+		K^+		Ca^{++}	
	Period		Period		Period	
	Pre-Exposure	Post-Exposure	Pre-Exposure	Post-Exposure	Pre-Exposure	Post-Exposure
Mean	3.01	3.69	9.01	9.99	0.082	0.099
Standard Deviation	1.72	2.17	3.26	2.64	0.088	0.050
Standard Error	.65	.82	1.23	1.00	0.036	0.019
Difference	0.68		0.98		0.017	
Standard Error of Difference	1.05		1.58		0.039	
Degrees of Freedom	12		12		11	
t-Value	0.646		0.646		0.436	
Probability Level (per cent)	<50		<50		<50	

control mice, as presented in Table II, show very little change in the sodium, potassium, or calcium ion levels during the periods corresponding to those for the exposed mice. These changes are non-significant.

Both groups of mice were given two days in which to adjust to the environment of the metabolism cage before the experiment was initiated. This element of time appears to be adequate for establishing fairly normal levels of urinary ion concentration with mice. As noted in Tables I and II, the levels of ion concentration were of similar magnitude for both groups of mice during the pre-exposure period.

The higher levels of potassium in ratio to sodium are attributed to the food which by analysis was found to contain a higher concentration of potassium than sodium.

Although the increase in the level of urinary calcium did not show a particular significance statistically, the increase may still be important. If the increased level of calcium continued to be eliminated over a period of time, an imbalance in the body might occur.

There has been relatively little research conducted regarding the effects of high magnetic fields on body fluids *in vivo*. The exact role which the magnetic field may play is not known. However, several possibilities may be considered. The presence of a high magnetic field appears to impose some kind of stress either on the entire internal environment of the body, or on certain organs. The conservation of ions needed by the body to maintain the acid-base balance and osmotic equilibrium occurs primarily in the kidneys. When the internal environment is altered the reabsorption mechanism for these ions may change. The magnetic field may effect mechanism of reabsorption by (1) causing the ions in the glomerular filtrate to spin in orbit as they pass along the renal tubules, thus preventing adequate contact with the tubule wall in the area in which reabsorption occurs; (2) creating a change in the gradient of electrical potential or chemical concentration across the tubular cell walls, altering the active reabsorption of sodium, the passive reabsorption of potassium, or the secretion of potassium; (3) altering the mechanism involved in the control of aldosterone secretion.

The adrenal hormones affect only a fraction of the filtered sodium during the reabsorption process. However, a minor reduction in sodium reabsorption can become significant if maintained over a period of several days. If an imbalance of sodium occurs, the potassium ion concentration may also be altered.

If the above possibilities did occur, they might act independently, or in combination, in producing a response such as noted in this study.

SUMMARY

The results of this study show a significant increase in the concentration levels of sodium and potassium ions excreted in the urine from white mice following exposure to a homogeneous magnetic field of 14,000 Oe. These results indicate the need for further research on the effects of electromagnetic stress on basic physiological processes in animals. Additional studies are currently being conducted to substantiate these findings.

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