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ENDOCRINE/METABOLIC CHANGES IN APOLLO ASTRONAUTS

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Apollo missions in the U. S. Manned Spaceflight Program have provided the opportunity for study in fluid/electrolyte and endocrine homeostasis on returning crewmen. Blood and 24 hour urine specimens were obtained 1, 2, and 4 weeks before the missions, immediately after recovery (ASAP) and 1, 2, 6 and 13 days postmission. Our results reflect changes incurred during spaceflight as well as those caused by readaptation to earth's gravity. The data suggestive of inflight changes include decrease in K_E(15%) and ASAP serum K (5%) combined with decreased urine Na(49%) and K(37%) without significant change in urinary Na/K ratio and an increased titrable acid(228%). These variables suggest that aldosterone secretion was increased during spaceflight and the resultant increased aldosterone was in part related to the measured K^+ loss. The physiological attempt to increase circulating blood volume in response to 1g was demonstrated by increased Angiotensin I (700%), aldosterone (98%), ADH (400%) with a decrease in urine volume (20%) in the first 48 hours after return to earth. These findings demonstrate endocrine/metabolic changes associated with spaceflight and are used as the data base for detailed inflight medical experiments on the future 28 and 56 day Skylab missions.

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ENDOCRINE/METABOLIC CHANGES IN APOLLO ASTRONAUTS

The United States Manned Spaceflight Program has launched 26 missions with 34 different men for flight duration from 15 min to 14 days. The flight crews have returned with no apparent lasting ill effects. However, there have been indications of biochemical changes which indicate an attempt by the endocrine system to adapt to this new environment. The biochemical response of an individual crewman to this environment becomes increasingly important when long duration space missions are flown.

The need for continued spacecraft development during Project Mercury and Gemini forced NASA to emphasize engineering technology during those programs. The medical program served as an operational safety program and in an observatory role which emphasized verification of theoretical predictions made from ground based studies by a series of increasingly comprehensive flight observations.

The operational complexities of a moon landing had to be mastered during the Apollo program. Again, this made it necessary to defer attempts at conducting elaborate and more meaningful inflight biomedical studies. However, detailed pre- and postflight observations were possible and were conducted.

It has been the concern of this laboratory to consider the profile of fluid and electrolyte changes and to relate them to the documented body weight loss which is a constant feature of spaceflight. Endocrine analysis and body compartment measurements were performed to achieve this objective.

METHODS

The same general protocol has been followed in most of the Apollo missions. Deviations from this procedure have been only due to the constraints imposed by quarantine missions (11, 12, and 14).

With crew members reclining for 30 minutes, approximately 45 ml peripheral venous blood was drawn three times before spaceflight (30, 15 and 5 days before) and four times following flight (about 2 hours after recovery, one day and two weeks following flight). All of the blood samples were drawn with the subject in a fasting state at 7:30 to 8:00 AM except the sample drawn following splashdown which is drawn regardless of crew meal status. In each instance the crew had been up and about less than one hour except after recovery when it was less than 2 hours.

Twenty-four urine samples were collected from each crewman on the same day as the blood workup. The urine is collected with no additive and immediately aliquoted, stabilized and frozen after complete collection for future analysis.

Ground control subjects have been used on each mission as a quality check on the effects of collection and transport of biological samples. These subjects were chosen from personnel involved with medical operations team.

RESULTS

Body-fluid losses in crewmen on United States and Russian manned space flights have been consistently inferred by a 2.5- to 5 percent decrease in postflight body weight. This loss averages 6 lb/crewman with over 50 percent of the weight regained within the first 24 hours after recovery in the U.S. crews. The Apollo crewmen have demonstrated a mean weight loss of 3.8 percent ± 2.3. S.D or 6 lbs.

These body weight changes have indicated significant fluid changes among all crew members exposed to weightlessness. This loss does not seem to be related to the duration of the mission. Because of this, studies were undertaken to investigate the cations and anions which serve critical roles in the homeostatic regulation of fluid volume. Serum electrolyte data from the Apollo crewmen, is summarized in Table I. It was observed that there is a 7 percent decrease in serum potassium immediately postflight with only a 0.9 percent decrease in the serum sodium without a significant decrease in serum chloride or osmolality. The twenty-four hour urine samples obtained with these serum samples exhibited significant changes when the immediate postflight samples are compared to the control samples acquired 15 days before flight. Table II gives the electrolyte analysis on the twenty-four hour urine samples. In the first 24 hours following flight, sodium and potassium are significantly decreased.

To aid in the understanding of water and electrolyte balance and renal function, renin activity was measured as angiotensin I in blood samples and the adrenal mineralcorticoid, aldosterone, was measured in the urine. Table III gives these results. The plasma Angiotensin I values show a 555 percent increase in the crewmen tested on the day of recovery. This elevation is associated with a significant increase (62%) in aldosterone also in the first day following recovery.

Table IV gives the summary data on urinary volume, antidiuretic hormone (ADH) and osmolality. These results indicate a 39% decrease in urine volume post-flight with significant increases in osmolality (24%) and ADH (339%).

Plasma hydrocortisone and adrenocorticotrophin hormone (ACTH) results are given in Table V. Although no significant change was found, a mean decrease was demonstrated. These findings would seem to rule out adrenal
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responses to stress as the responsible factor in the fluid electrolyte changes post flight.

There has been a mean 5.6% decrease in plasma volume on those missions in which this measurement was made. Although these changes are less than would be predicted from bedrest studies, the decrement measured over 5 missions is statistically different from zero (p 0.005).

Examining all of these data along with the clinical conditions noted on the returning Apollo crewmen, the following hypothesis has been proposed. It is postulated that as the crewman enters the weightless environment the circulating blood volume is redistributed particularly from the lower extreminities into the abdomen and thorax. This redistribution results in a change in water balance with a net loss of water and electrolytes. The extent of the electrolyte loss could be related to electrolyte dietary intake which has been variable. It is thought the changes in water balance observed with the spaceflight crews occur within the first or second day as has been demonstrated in bedrest studies. This is the probable reason why most spaceflight crews have shown weight changes even on the shorter Mercury and Gemini Missions.

After return to earth and the one g environment, the spaceflight crews have demonstrated weight losses of which 50% is regained within the first twenty-four hours. This rapid weight gain represents endocrine mechanisms operative for water and electrolyte retention.

As much as a 20-percent postflight decrease in total body potassium has been measured, by gamma spectrometric measurement of the total body potassium-40. In the Apollo 15 mission, total body exchangeable potassium, K_E, was measured.

It was found to be decreased in this crew (ave. 13%) even though adequate dietary potassium had been ingested. The crew members of the Gemini 7 mission demonstrated positive potassium balance before and after the flight with a negative balance during the mission. These results were accompanied by increased urinary aldosterone excretion during the flight. The data from crews of the Apollo missions is indicative of elevated aldosterone, during spaceflight. This elevation could be accounted for by decreases in renal blood flow or right heart pressure. Complete explanation of the results reported here is not presently possible. These as well as other biomedical changes associated with spac flight will be the subject of in-flight experiments to be conducted during the earth-orbital Skylab missions next year.

TABLE I

SERUM ELECTROLYTES

ELECTROLYTE	N	F-15 MEAN ± SE	ASAP MEAN ± SE	% CHANGE	SIGNIFICANCE
Na (meq/l)	27	142 ± .2	140 ± .4	.9↓	$P < .025$
K (meq/l)	26	4.1 ± .06	3.8 ± .06	7 ↓	$P < .005$
Cl (meq/l)	25	104 ± .6	103 ± .6	1.2↓	$P < .10$

TABLE II

URINE ELECTROLYTES

ELECTROLYTE	N	F-15 MEAN ± SE	ASAP MEAN ± SE	% CHANGE	SIGNIFICANCE
Na (meq/vol)	20	175 ± 15	97 ±11	44↓	$P<.01$
K (meq/vol)	20	74 ± 6	46 ± 4	38↓	$P<.001$
Cl (meq/vol)	20	165 ± 15	74 ± 9	55↓	$P<.001$

TABLE III

	DETERMINATION	N.	F-15 MEAN + SE	ASAP MEAN + SE	% CHANGE	SIGNIFICANCE
PLASMA	ANGIOTENSIN I(mμg/ml/hr)	14	2.0 ± .5	13.1 ± 3.0	555↑	P<.005
	URINE ALDOSTERONE (μg/volume)	17	14.3 ± 2	23.2 ± 2	62 ↑	P<.005

TABLE IV

TEST		N	F-15 MEAN ± SE	ASAP MEAN ± SE	% CHANGE	SIGNIFICANCE
URINE VOLUME	(ml)	20	1711 ± 179	1048 ± 99	39↓	$P<.005$
OSMOLALITY	(mosmo)	20	735 ± 47	908 ± 41	24↑	$P<.005$
ADH	(m Units/volume)	16	17.3 ± 3	75.9 ± 22	339↑	$P<.025$

TABLE V

PLASMA ACTH AND HYDROCORTISONE

TEST		N	F-15 MEAN ± SE	ASAP MEAN ± SE	% CHANGE	SIGNIFICANCE
HYDROCORTISONE	(μg/100 ml)	23	14.8 ± 0.8	12.3 ± 2.0	17↓	P<.25
ACTH	(pg/ml)	6	46 ± 10	30 ± 5	35↓	P<.25