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A Study on Alterations of Electrolytes, Osmolality, and Hormones during Graded Exercise.

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The present study examined the changes in electrolytes, osmolality, and hormones and their interactions during graded exercise to investigate mechanisms of hormones. Blood samples were drawn from eight male college volleyball players before, during, and 30 minutes after exercise on a bicycle ergometer. The results of the study are: (1) Electrolytes, osmolality, and hormones increased throughout the exercise. However, the increase up to the AT level was not significant, but the increase on and over the AT level was. Magnesium did not show increase; (2) There was a close relationship between osmolality and PRA, between osmolality and lactate, and between lactate and PRA. Both PRA and lactate increased at the work loads around the AT; level, which points to a usability of PRA to determine the AT; and (3) ANF, which controls the balance of sodium and water, can be examined to treat high blood pressure, hypertension, and heart failure.

INTRODUCTION

Hormones are secreted from the endocrinic system in response to exercise and are carried to an target organ in blood so that the target organs perform activities. Hormones are the most important messenger besides the nervous system, and control and coordinate various functions of a human body. They respond to an external stimulus, together with the nervous system, and take a major role in exercise (Geyssant et al, 1981).

There are recent reports that hormones related to body fluid and electrolytes do not change during light exercise (Convertino et al., 1983), but heavy exercise affects the endocrine response as well as the respiratory circulation and muscle activities (Freund et al., 1987). Still, there are few studies about endocrine response to maximal or graded exercise, mechanisms of recently identified ANF response to exercise, or about determination of thresholds for hormonal responses to physical activities.

The purpose of the present study was to examine the changes in electrolytes, osmolality, and hormones during graded exercise and relationships among them, and to understand mechanisms of hormonal responses to exercise.

METHOD

Subjects

The subjects of the present study were eight male volleyball players from S University, who consented to the purpose of the study and volunteered to participate in the experiment. They had no record of previous heart diseases. The average age of the subjects was 21.8 ± 2.0 years old and the average career experience was 6.5 ± 2.5 years. Table 1 presents physical characteristics of the subjects.

Table 1. Physical Characteristics of Subjects.

Subjects	Age (yr)	Height (cm)	Weight (kg)	B P (mmHg)	H Rrest (beats/min)	$\dot{V}O_3$ max (ml/kg/min)	HRmax (beats/min)	Career (yr)
C.B.H	27	185	85.0	114/64	68	64.2	188	8
J.C.G	21	190	86.8	131/66	74	62.8	184	0
K.Y.C	22	182	75.7	134/73	54	65.5	191	6
H.J.B	22	180	72.4	131/77	75	66.6	180	9
P.Y.J	21	168	67.3	133/78	70	60.7	192	3
K.J.W	21	186	75.0	141/78	61	59.1	193	8
K.C.S	21	182	72.4	126/55	58	61.3	188	7
P.S.T	20	176	64.0	135/74	73	58.2	196	2
Mean	21.8	181.1	74.8	131/71	66.6	62.3	189	6.5
± SD	± 2.0	±6.3	±7.4	± 7.4/7.7	±7.4	±2.8	± 4.8	± 2.5

Procedures

The subjects took 60 minute rest when they arrived at the laboratory for the experiment. This was to minimjize possible hormonal response to psychological factors. Afterwards, they exercised on a bicycle ergometer. Figure 1 shows the experimental protocol used in the study. The ergometer was set at 60 rpm and starting from 25 watts, the work load was intensified every four minutes by 25 watts until the subjects reached the point of exhaustion.

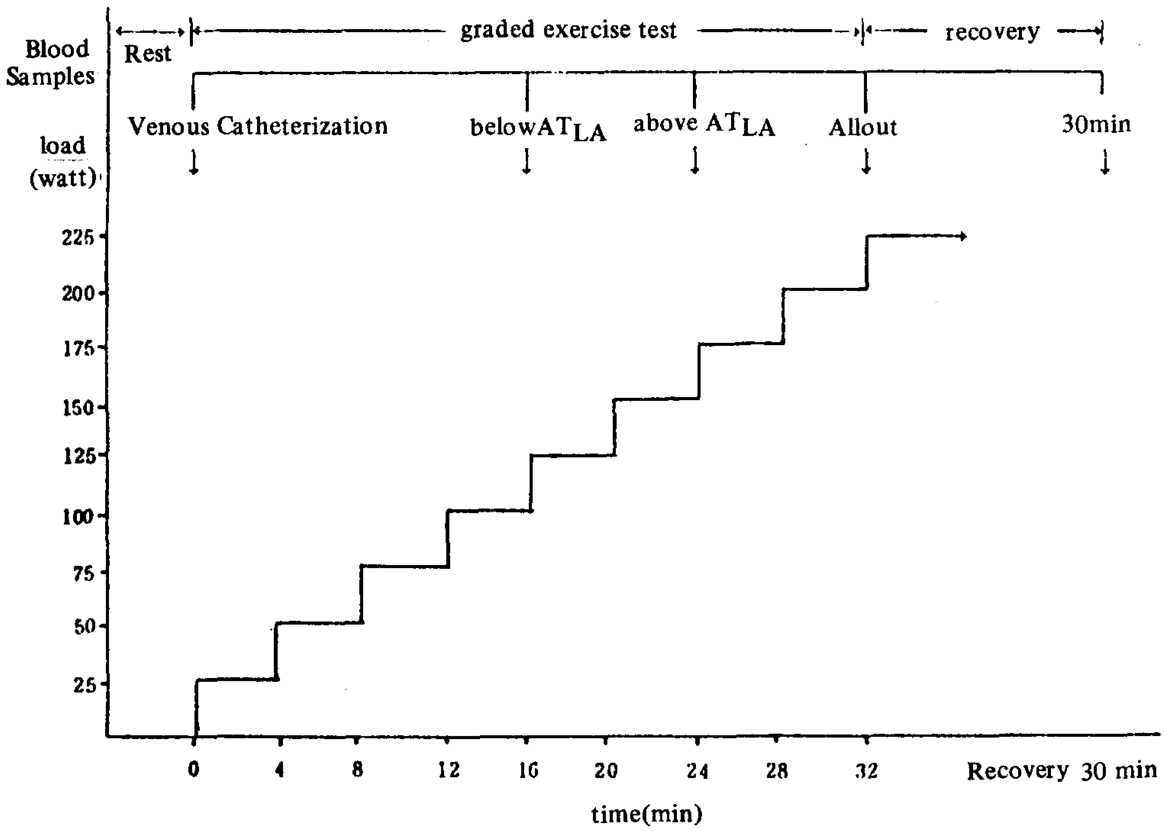

Figure 1. Experimental protocol of the study.

Analysis of Data

Respiratory gas composition was analyzed with an oxyscreen analyzer (Ergo-oxyscreen, Erich Jaeger Co., West Germany). A venous catheter with a three way stop stock (Top Surgical Man. Co., Ltd., Japen) was attached to antecubital vein during the experiment. This was to minimize uneasiness on the part of the subject when blood was collected. 10 ml of blood were sampled five times: at rest, at levels below and above lactic acid anaerobic threshold (AT-LA), at all out phase, and 30 minutes after exercise. 5 ml of the blood sample were analyzed for plasma electrolytes and osmolality in a tube containing EDTA and the rest of the sample was centrifuged and was analyzed at Green Cross Reference Laboratory. Plasma electrolytes were analyzed with STARLYTE II (Electro-Nucleonics Inc. USA), and osmolality was analyzed with FISKE Osmometer (Highland Avenue, USA). Plasma renin activity (PRA) was measured with a Gamma Coat TM [125 I) PRA Radio-immunoassay Kit, plasma aldosterone, with a Radioimmunoassay Kit (Coat-A-Count, Diagnostic Products), and plasma atrial natriuretic polypeptide, with a K-625 Radioimmunoassay Kit (Research and Diagnostic Antibodies).

Means and S. D.'s of the data were obtained and compared with one way ANOVA's. When there was a difference in the means, Scheffe method of multiple comparison was applied. The significance level was set at $p = .05$.

RESULTS AND DISCUSSION

Table 2 presents plasma electrolytes, osmolality, and hormones at different points during graded exercise, and Figures 2 and 3 illustrate the observed changes in line graphs. The average exercise duration was 30.04 ± 4.20 min. and the maximal heart rate was 189 ± 4.8 beats/min.

Changes in Electrolytes and Osmolality

As can be seen in Table 2 and Figure 2, except magnesium, the electrolytes examined in the study increased linearly with increasing work load and then decreased after exercise. The increase with the work loads below the AT-LA level was not significant, but the increase at the work loads above the level was significant.

Osmolality showed a curvilinear increase during graded exercise. The increase was negligible when the work loads were below AT-LA level, but the increase was almost linear with the work loads when they were over 150 to 175 Watts until the subjects were all out. Osmolality decreased after the exercise. The

Table 2. Electrolytes, Osmolality, Hormones, and Lactate Measurement during Graded Exercise.

stages / items	rest	belowATLA	aboveATLA	all-out	recovery
Na(mEq/l)	137.9 ±3.09	141.2 ±3.39	143.7 ±2.94	147.0 ±2.16	141.5 ±2.46
K(mEq/l)	4.20 ±0.28	4.7 ±0.37	5.6 ±0.79	5.7 ±0.96	4.2 ±0.42
Cl(mEq/l)	96.8 ±3.42	101.0 ±3.59	103.3 ±2.69	105.5 ±2.95	101.8 ±2.38
Ca(mEq/l)	9.3 ±0.53	9.2 ±0.31	10.3 ±1.04	10.9 ±1.38	8.9 ±0.38
Mg(mEg/l)	1.8 ±0.23	2.0 ±0.46	1.9 ±0.33	1.8 ±0.24	1.8 ±0.23
Osm(mosm/kgH_2O)	287.5 ±3.74	287.8 ±3.69	295.7 ±4.54	308.0 ±5.73	288.1 ±7.62
PRA(ng/ml/hr)	2.6 ±1.66	3.0 ±1.34	5.9 ±2.27	10.5 ±3.79	4.2 ±2.00
ALDO(ng/ml/hr)	7.2 ±3.24	9.8 ±3.49	11.8 ±5.46	20.8 ±6.75	12.0 ±6.18
ANF(fmol/ml)	7.6 ±1.40	8.0 ±1.85	12.2 ±2.24	16.4 ±2.88	8.0 ±2.12
LA(mmol/l)	1.6 ±0.37	2.4 ±0.80	5.0 ±0.98	7.5 ±1.02	3.8 ±0.86

Mean ±SD

curvilinear change in osmolality is in agreement with Cunvertino and colleague's (1981) finding that osmolality increased as the plasma volume decreased during graded exercise.

The increase in osmolality is due to discharge of hypertonic plasma from vascular space rather than of hypotonic plasma (Van Beaument et al 1973). The increase is also due to the increase in the sodium concentration in plasma. The relative concentration of sodium and osmotic contents results from (a) the fact that water is discharged faster than sodium discharge from capillaries, and (b) hypertonic fluid discharge into vascular space from lymphatic.

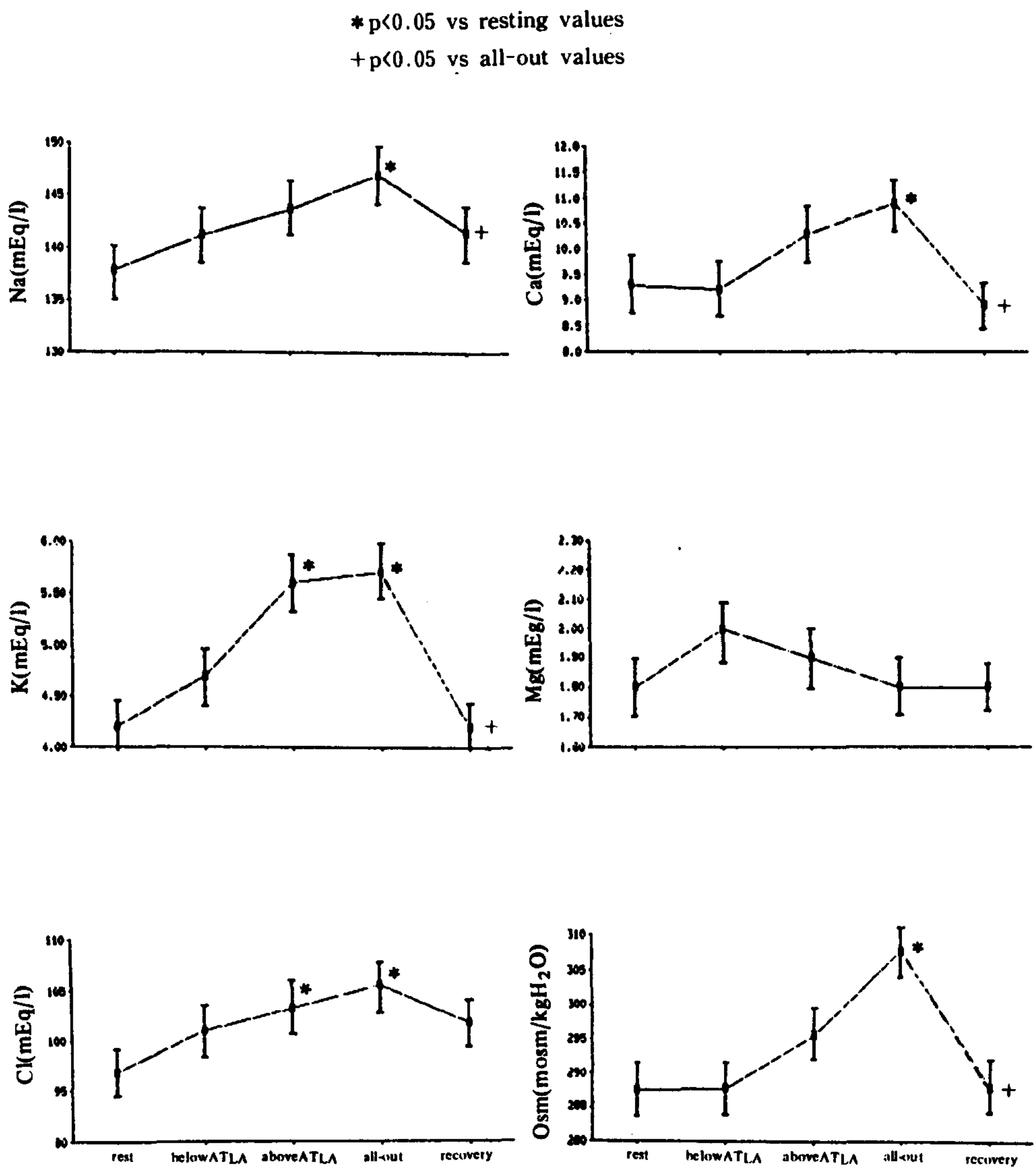

Figure 2. Responses of sodium, potassium, chloride, calcium, magnesium, and osmolality before, during, and after graded exercise.

Changes in Hormones and Lactic Acid

Table 2 and Figure 3 show the changes in hormones and lactic acid during graded exercise. Hormones and lactic acid increased in a curvilinear fashion during the exercise but decreased linearly afterwards. The increase of hormones with the work loads below the AT-LA level was slight, but with the work loads above the level, the increase was rapid.

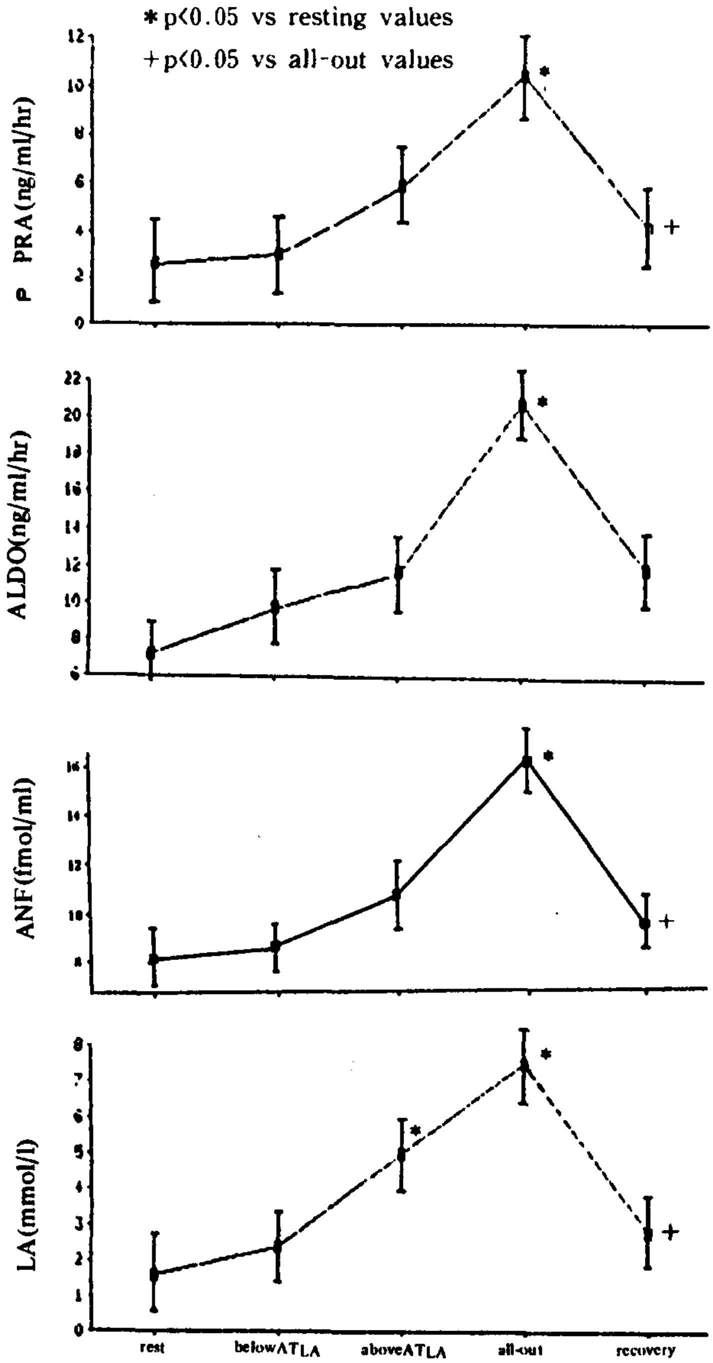

Figure 3. Responses of hormones and lactate to graded exercise.

PRA showed a curvilinear increase and the increase was significant when the work load was above the AT–LA level (70–80 % $\dot{V}o_2$ max). There is a controversy over the magnitude of rhe PRA increase due to exercise. Some found the increase to be linear (Convertino et al, 1981; Kotchen et al, 1971), while others found it to be curvilinear (Convertino et al, 1983) The discrepancy is related to training experience. Trained subjects had lower PRA levels than un–trained subjects (Melin et al, 1980; Geyssant et al, 1981). The present subjects were trained athletes, and the PRA level increased slowly until it reached the critical point, from which point on it increased rapidly.

The level of renin in response to exercise has been explained by many researchers. Bozovic and Castenfors (1976) found that ganglionic blocking agent suppresses the increase of renin. Leon, Pettinger, and Saviano (1973) reported that propranol, the beta bloking agent suppresses exercise response. Discharge from the sympathetic nervous system has a close relationship to response to exercise and was found to be associated with PRA and catecholamine during exercise (Kotchen et al, 1971). All these phenomena occur by beta stimulus to juxtaglomerular cells (Reid, Morris, and Gangong, 1978).

Aldosterone (ALDO) increased during graded exercise. The increase up around the AT–LA level was not significant, but the increase at all–out phase was significant when compared with at rest.

ALDO is secreted from liver and kidney (Coppage et al, 1962; Laragh et al, 1966; Melby, 1973; Morris, 1981). Aldo decreases during exercise due to decrease of liver and kidney blood flow (Rowell, 1974). Aldo level does not return to the rest level immediately after exercise, but about six hours after exercise, it resumes its level at rest as blood flow returns to its normal state.

Some studies found that exercise do not affect Aldo level. Knochel et al (1972) found that Aldo did not change after three day training in soldiers. The mechanism concerning alteration of Aldo is not fully investigated.

ANF increased at all out but soon returned to the level at rest after 30 minutes of recovery. ANF was assumed to be circulation hormone by some (Gutkowska et al, 1985; Hasler et al, 1986; Shenker et al, 1986; Weidmann et al, 1986). High level of ANF was reported in the patients with temporary heart constriction (Gutkowsak et al, 1985) and other heart diseases (Tikkamen et al, 1985). Shifrim et al (1985) found high ANT with the patients with temporacy heart diseases.

ANF is thought to be related to balancing the water and electrolytes and short and long term control of blood pressure.
Thus, ANF takes a physiological role of balancing water and sodium, and is related to high blood pressure, hypertension, and heart failure.

As can be seen in Figure 4, there was a high correlation between PRA and lactate level during graded exercise. They showed an almost parallel increase. PRA increased after $\dot{V}o_2$ max reached about 70 %, revealing that AT is closely related to increase of sympathetic nerve activity. The result shows that sympathetic nerve activity and blood energentics at AT is an important factor in determining exercise work load and in designing experiment protocol. The level of PRA can be to indicate is a key factor in determining AT during graded exercise.

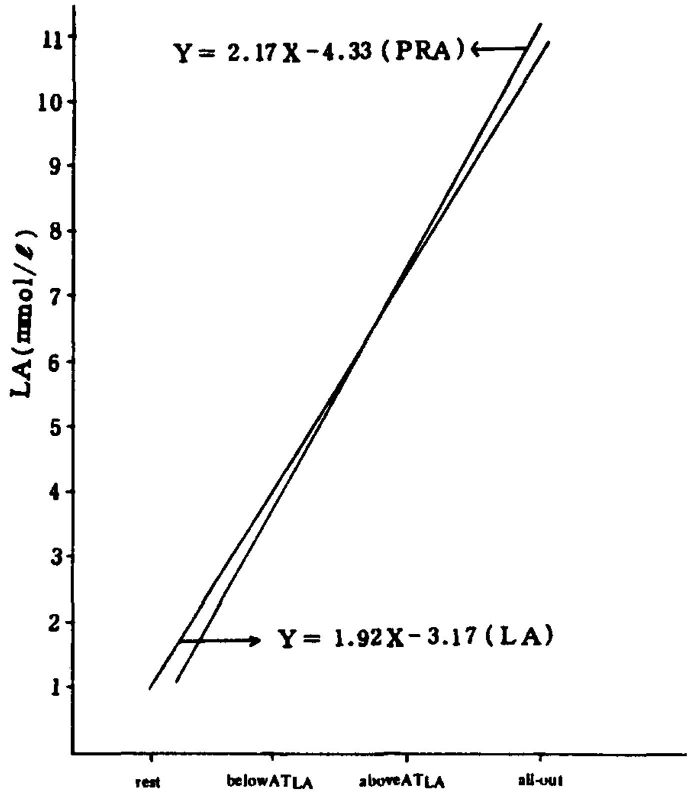

Figure 4. Linear regression of PRA and LA during graded exercise.

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