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Effect of Exercise on Salivary Composition and Cortisol in Serum and Saliva in Man

H. BEN-ARYEH, N. ROLL³, M. LAHAV¹, R. DLIN², N. HANNE-PAPARO², R. SZARGEL, C. SHEIN-ORR¹, and D. LAUFER

Laboratory of Oral Biology, Department of Oral and Maxillofacial Surgery, Rambam Medical Center, P.O.B. 9602, 31096 Haifa, Israel; ¹Institute of Endocrinology, Rambam Medical Center and Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel; and ²Department of Sports Medicine, Wingate Institute for Physical Education and Sport, Netanya, Israel

The effect of exercise on electrolytes and cortisol levels in serum and saliva was examined in 27 young, healthy male volunteers who performed graded submaximal cycle exercise for nine min at up to 85% of their age-predicted maximal heart rate. Seventeen men performed the Wingate anaerobic test for 30 s. A significant increase in pulse rate and systolic blood pressure and a decrease in diastolic blood pressure were found, and serum concentrations of Na⁺, K⁺, and lactate were significantly elevated immediately after exercise. A non-significant increase in saliva and serum cortisol levels was found. Significantly lowered salivary flow rate and elevated salivary K⁺, protein, and lactate concentrations were found within ten min after exercise. Salivary Mg²⁺ was significantly elevated after anaerobic exercise only.

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Introduction.

The growing interest in exercise and fitness for health reasons has resulted in a plethora of studies on their physiological effects. Many studies on the effect of exercise on muscular and hemodynamic indices and on serum composition have been published (Metivier, 1968; Lundvall, 1972; Van Beaumont *et al.*, 1972; Yoshinobu *et al.*, 1977; Greenleaf and Brock, 1980; Priest *et al.*, 1982; Dlin *et al.*, 1983). Only a few studies on the effect of exercise on salivary secretion have been done, although complaints of dry mouth after exercise are very common (Salminen and Kontinen, 1963; Shannon, 1967; Mendez *et al.*, 1976; Dawes, 1981; Bardon *et al.*, 1983). The results vary because of uncontrolled exercise schedules and different methods of saliva collection. The purpose of this study was to examine salivary flow rate and composition and cortisol levels after a well-defined ergometric exercise task.

Materials and methods.

The group studied consisted of 34 healthy, unmedicated young males, aged 22 ± 4 years (mean ± SD), who came to the Department of Sports Medicine of the Wingate Institute for stress testing. The volunteers performed two types of exercise:

Submaximal exercise (group A).—Twenty-seven men performed a graded three-stage submaximal ergometric test. The work load was increased every three min until age-predicted near-maximal heart rate was reached (approximately 85% of age-predicted maximal heart rate). The duration of the test was nine min.

Wingate anaerobic test (group B).—Seventeen volunteers (ten of whom also performed the submaximal test) performed the Wingate anaerobic test (Inbar *et al.*, 1976; Dlin *et al.*,

1983) for 30 s. In this test, the volunteer cycles on a bicycle ergometer at maximum speed, against resistance of 4.4 J/kg body weight.

Unstimulated whole saliva and venous blood were collected 90 min before and immediately following the exercise, while the subjects were in a sitting position. A standard spitting method was used. The subjects were asked to collect saliva in their mouths and to spit into a wide test tube for a period of ten min without any exogenous stimulation. The salivary and serum collections were done in the morning between 9:00 and 12:30, at least two h after consumption of a meal. Salivary volume was measured and secretion rate calculated. The salivary samples were centrifuged, and a portion of the supernatant was frozen at -20°C for cortisol measurements; the rest was kept at 4°C for chemical analysis. Concentrations of Na⁺ and K⁺ were measured by flame photometry, Ca²⁺ and Mg²⁺ by atomic absorption (Perkin-Elmer 107) (Ben-Aryeh *et al.*, 1981, 1984), and total protein by the method of Lowry *et al.* (1951). Cortisol levels in serum were measured by radio-immunoassay (Dickstein *et al.*, 1986). For determination of salivary cortisol, samples were extracted by ten vol of dichloromethane, rather than heated in the presence of methanol.

Statistical analysis was performed by Student's paired *t* test. Level of significance was *p* < 0.05.

Results.

Heart rate and blood pressure responses to submaximal exercise are shown in Table 1. Serum concentrations of Na⁺, K⁺, and lactate were significantly elevated following both submaximal (Table 2) and anaerobic (Table 3) exercise.

After both types of exercise, we found significantly lower

TABLE 1
BLOOD PRESSURE AND HEART RATE RESPONSE TO
SUBMAXIMAL EXERCISE

	<i>n</i>	Pre-exercise	Post-exercise	<i>p</i>
Heart Rate, beats/min	27	65.2 ± 10.8	166.2 ± 14.5	<0.001
Systolic Blood Pressure, mm Hg	27	125.0 ± 11.0	193.6 ± 19.9	<0.001
Diastolic Blood Pressure, mm Hg	27	82.0 ± 9.2	74.1 ± 9.5	<0.001

Values are means ± SD.

TABLE 2
EFFECT OF SUBMAXIMAL EXERCISE ON SERUM
CONSTITUENTS

Parameter	<i>n</i>	Pre-exercise	Post-exercise	<i>p</i>
Na, mmol/L	19	146.05 ± 3.30	149.05 ± 5.89	<0.05
K, mmol/L	18	4.44 ± 0.40	4.82 ± 0.46	<0.001
Lactate, mmol/L	21	1.62 ± 0.88	4.91 ± 1.78	<0.001
Cortisol, µg/dL	21	10.76 ± 4.04	11.60 ± 4.10	NS

Values are means ± SD.

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TABLE 3
EFFECT OF ANAEROBIC EXERCISE ON SERUM CONSTITUENTS

Parameter	n	Pre-exercise	Post-exercise	p
Na, mmol/L	11	139.20 ± 3.85	142.55 ± 3.34	<0.001
K, mmol/L	11	4.22 ± 0.32	5.42 ± 0.63	<0.001
Lactate, mmol/L	14	2.25 ± 0.84	6.89 ± 1.73	<0.001
Cortisol, µg/dL	14	9.11 ± 3.67	12.05 ± 6.12	NS

Values are means ± SD.

TABLE 4
EFFECT OF SUBMAXIMAL EXERCISE ON WHOLE SALIVA

Parameter	n	Pre-exercise	Post-exercise	p
Volume, mL/10 min	25	5.70 ± 3.22	4.56 ± 2.08	<0.05
Na, mmol/L	25	4.63 ± 4.38	4.88 ± 2.24	NS
K, mmol/L	26	20.57 ± 4.38	26.38 ± 5.69	<0.001
Ca, mmol/L	25	1.09 ± 0.52	0.96 ± 0.41	NS
Mg, mmol/L	26	0.26 ± 0.15	0.27 ± 0.13	NS
Protein, mg/dL	22	138.63 ± 86.10	192.72 ± 62.74	<0.01
Lactate, mmol/L	24	4.91 ± 3.68	12.38 ± 9.53	<0.001
Cortisol, ng/mL	26	6.54 ± 2.84	6.68 ± 2.55	NS

Values are means ± SD.

TABLE 5
EFFECT OF ANAEROBIC EXERCISE ON WHOLE SALIVA

Parameter	n	Pre-exercise	Post-exercise	p
Volume, mL/10 min	17	5.47 ± 3.91	2.96 ± 2.70	<0.001
Na, mmol/L	14	4.97 ± 2.19	5.58 ± 2.95	NS
K, mmol/L	14	20.84 ± 5.36	25.54 ± 6.96	<0.01
Ca, mmol/L	13	1.10 ± 0.35	1.41 ± 0.62	NS
Mg, mmol/L	13	0.25 ± 0.12	0.37 ± 0.18	<0.01
Protein, mg/dL	13	138.53 ± 72.33	224.61 ± 121.18	<0.05
Lactate, mmol/L	8	3.63 ± 1.33	8.74 ± 3.79	<0.01
Cortisol, ng/mL	12	6.55 ± 1.75	8.32 ± 3.51	NS

Values are means ± SD.

salivary flow rates and elevated salivary concentrations of potassium, lactate, and protein (Tables 4 and 5). Magnesium concentration in saliva was significantly higher only after anaerobic exercise (Table 5). The cortisol levels in serum and saliva were elevated; however, the increase was non-significant (Tables 2-5).

Discussion.

Many of the effects of exercise observed in this study can probably be attributed to an increase in catecholamine secretion from the adrenal medulla and from sympathetic nerves. One example is the well-known increase in heart rate and systolic blood pressure (Shephard, 1982). The elevation in serum Na⁺ and K⁺ (Tables 2 and 3) may be ascribed to the catecholamine-induced shift of water from the circulation (Felig *et al.*, 1982). These changes were more pronounced after anaerobic exercise (Table 3).

We analyzed salivary samples collected within ten min after exercise; thus, a dilution of very short effects is probable.

The effects of exercise in lowering salivary secretion rate and elevating K⁺, protein, and lactate concentrations are given in Tables 4 and 5. The lowered salivary secretion rate could be a result of a decrease in blood flow in the salivary glands, which in turn is a result of exercise-induced increase in catecholamine secretion. Also, dehydration and mouth-breathing caused by vigorous exercise could contribute to the decrease in measured salivary flow. These significantly lower resting

secretion rates are in accord with the well-known complaint of dry mouth after exercise (Dawes, 1981). However, this condition could also be caused by the change in consistency of saliva and its high viscosity (caused by the increase in protein secretion), since many of the salivary proteins are glycoproteins (Ellison, 1967). The significantly elevated K⁺ concentrations could also have resulted from sympathetic activation by exercise (Garrett *et al.*, 1977). The considerably elevated Mg²⁺ concentration found after anaerobic exercise may also indicate the involvement of sympathetic nerves in Mg²⁺ secretion. The concentrations of Ca²⁺ and Na⁺ were unaltered by exercise, suggesting a different secretory mechanism for the various electrolytes in saliva.

Salminen and Kontinen (1963) examined whole saliva after long mild exercise; thus, not surprisingly, their results differ from ours. They found elevated Na⁺ and no change in K⁺, while we found an increase in K⁺ concentration. Bardon *et al.* (1983) examined whole saliva after aerobic and anaerobic exercise. The only change that they reported after aerobic exercise was a slight increase in ribonuclease activity. Their results after anaerobic exercise were similar to ours; however, in contrast to our results, the effect on K⁺ was not significant.

In agreement with this study, significantly elevated lactate concentrations were found by Mendez *et al.* (1976) in both serum and whole saliva after a running exercise. Significantly higher protein concentrations were reported by Salminen and Kontinen (1963) and Bardon *et al.* (1983) in whole saliva, and by Dawes (1981) in parotid saliva. Protein is secreted into saliva after sympathetic activation (Speirs *et al.*, 1974). In our volunteers, an increase in viscosity of the saliva was observed concomitant with the elevation in protein concentration; thus, further investigation into the types of proteins elevated by exercise would be of interest.

We observed an increase in cortisol levels in both serum and saliva after exercise; however, the increase was non-significant (Tables 2-5). The results of studies by other investigators vary (Few, 1974; Davies and Few, 1978; Kindermann *et al.*, 1982), depending on the type and duration of exercise and the timing of sample collection. We collected the samples immediately after short exercise; it is possible that a later collection of samples would have revealed significant alterations in cortisol levels.

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