HUMAN ECOLOGY

Circadian Rhythms of Salivary Electrolytes as an Indicator of Functional Status during Professional Activity

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Circadian rhythms of salivary sodium and potassium were studied during a week in subjects engaged in heavy physical and intellectual work. A decrease in the content of salivary sodium did not depend on the type of work but on its difficulty and intensity. The amplitude of daily fluctuations and the index of daily adaptation, which were decreased in both professional groups in comparison with the norm, were the informative parameters of rhythms for the diagnosis of functional status. By the end of the week, the rhythm of salivary sodium excretion was disordered and the strain of regulatory system increased.

Key Words: *salivary electrolytes; circadian rhythms; work; strain; fatigue*

Evaluations of the functional state of the organism during work receive little attention. It is known that chronic fatigue caused by stress factors and overworking can cause disease. In 1993 in France a number of diseases caused by fatigue at work were referred to occupational, because chronic fatigue caused by intensive work can lead to disorders in cerebral circulation, myocardial infarction, and other somatic and mental disorders [5,6].

Therefore, long strain and fatigue are regarded as a predisease. We must know the borderline of this state, which can eventuate in disease, if the strain or fatigue persists. According to D. S. Sarkisov, alteration of the rhythms of physiological processes is an important mechanism of adaptation to environmental factors and compensation of disordered functions [3]. The structure cannot be regarded without consideration for time. Professional activity is an important exogenous factor determining either synchronization or destabilization of biological rhythms, depending on its difficulty and intensity. Exogenous factors cause endogenous processes realized at an elementary level of structural and functional units [2].

We investigated the structure of circadian rhythms of salivary electrolytes, because the content of Na^+ in the saliva is inversely related to activity of the sympathoadrenal system. Measurements of salivary Na^+ during 24 h allow to evaluate the autonomic balance and relationships between ergo- and trophotropic processes during work and rest. The content of K^+ in the saliva is a potential indicator of energy production in the organism. This allows us to use salivary electrolytes as objective criteria for evaluating the functional status of the organism.

MATERIALS AND METHODS

Men aged 21-40 years, adapted to their work, were divided into 3 groups. Group 1 consisted of 19 quarry workers aged 21-25 years (hard physical labor). During examinations the workers were in a preventorium. Group 2 consisted of 35 scientists (mathematicians) aged 21-40 years, engaged in intensive intellectual work. Group 3 (control) consisted of 17 students of a military school aged 20 years; by the moment of examination they were hospitalized at medical center and had the same nutrition and sleep-wake regimen.

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TABLE 1. Circadian Rhythms of Salivary Electrolytes in the Control and Physical and Intellectual Workers during a Week (*M*±*m*)

Group	Period of the week	Mesor, mEq/liter		Amplitude, mEq/liter		Acrophase, h	
		Na^+	K^+	Na^+	K^+	Na^+	K^+
Control (*n*=17)		10.46±1.09	21.24±1.85	4.06±0.5	2.79±1.0	3.4±0.5	5.6±1.5
Hard physical labor (*n*=19)	Beginning	8.26±0.96	24.33±2.38	2.4±0.6	—	3.2±1.0	—
	Middle	8.93±1.0	26.28±2.30	2.7±0.6	1.9±1.4	3.9±1.0	3.3±3.0
	End	7.31±0.87	22.55±2.71	2.1±0.5	-	3.6±0.7	—
	Weekend	10.4±0.99	25.63±2.03	3.0±0.5	2.3±1.4	3.9±0.6	19.2±1.7
Intellectual work (*n*=35)	Beginning	9.12±1.02	22.6±1.13	1.7±0.5	1.3±0.4	5.2±1.1	14.5±1.4
	End	9.8±0.78	22.14 ± 1.10	1.6±0.6	1.2±0.5	6.8±1.0	9.8±1.8

Note. Here and in Table 2: dash: not determined.

Saliva was collected without stimulation 6 times: at 4.00, 8.00, 12.00, 16.00, 20.00, and 24.00. Simultaneously, body temperature was measured, heart beat and muscular strength (with a manual dynamometer) were evaluated. The concentrations of salivary Na^+ and K^+ ions were measured by flame photometry.

The results were processed by Cosinor analysis, the mean level (mesor), amplitude of fluctuations, and acrophase (time of the maximum) of the function were determined. The daily adaptation index (DAI) was calculated from the difference in the night and morning salivary samples using the following formula:

$$DAI=(C_{4.00}-C_{8.00})\times 100\%/C,$$

where C is Na^+ concentration in the saliva.

Stress and activation of the sympathoadrenal system decrease salivary Na^+ content and increase DAI. With fatigue, the level of Na^+ in the saliva increases, the difference between the content of Na^+ in the night and morning saliva is leveled, and DAI decreases [4].

RESULTS

Study of circadian structure of mineral-excretory function of salivary glands during work and in the control demonstrated circadian rhythms of salivary excretion of Na^+ in all groups at the beginning and end of the working week (Table 1). Parameters of the rhythms characterizing its circadian structure depend on the period of the working week and type of work. In workers engaged in hard physical labor and in the controls the acrophase of Na^+ content in the saliva was observed at night (3.2-3.9 h).

In intellectual workers the acrophase is shifted to the early morning: 5.2-6.8 h. The maximum excretion of Na^+ with the saliva is usually observed at night. It is explained by the predominance of parasympathetic regulatory influences on physiological processes during this period. Cholinergic regulation is known as a truly secretory for the salivary gland. Shifting of the acrophase to the morning in mathematicians can be attributed to specific features of their main sleep-wake-work rhythm and to later awakening in the morning. Interestingly, circadian rhythm of salivary Na^+ excretion is stable in workers engaged in hard physical work and the acrophase does not depend on the period of work.

Circadian structure of K^+ salivary excretion is characterized by the absence of rhythm at the beginning and end of the week in subjects engaged in hard labor. These are periods of instability: adaptation to working rhythm at the beginning of the week and fatigue at the end. The appearance of circadian rhythm of salivary K^+ is caused by metabolic changes [1]. In contrast to Na^+, K^+ excretion is characterized by migration of the acrophase: the time of the maximum K^+ content in the saliva varies within a wide range during the week (Table 1).

Changes in the amplitude were more expressed, because the amplitude reflects the magnitude of the reaction and reserve adaptation potential of the organism. In the control group, the amplitude of Na^+ rhythm was 4.06±0.5 mEq/liter, which corresponds to normal

TABLE 2. Daily Adaptation Index during a Week (*M*±*m*)

Period of the week	Group		
	control	hard physical labor	intellectual work
Beginning	49.09±3.6	46.3±7.6	39.3±5.0
Middle	—	18.7±5.2*	—
End	—	11.7±7.7*	19.8±.5.6*
Weekend	—	26.6±7.2	—

Note. **$p<0.05$ *vs.* beginning of the week.

[4]. In the workers the amplitude of Na^+ content in the saliva is significantly lower than in the control, particularly at the end of the week.

The lowest values of this parameter were observed in intellectual workers. Experimental data and measurements during adaptation to night work and athletic exercises indicate that the decrease in the amplitude of Na^+ content is caused by exhaustion of the functional reserve of the organism, which is confirmed by changes in DAI in both groups (Table 2).

Daily adaptation index gradually decreased from the beginning to the end of the week after both physical and intellectual work ($p<0.05$). This decrease was more pronounced (25%) in workers engaged in physical labor; in mathematicians this index decreased by 19%. A simultaneous decrease in the amplitude of circadian fluctuations and DAI by the end of the week indicates exhaustion of reserve potential because of fatigue. Endogenous "readiness" of the organism to work decreases by the end of the week.

The minimal body temperature and muscular strength and maximal content of Na^+ in the saliva in workers engaged in physical labor were observed at 4.00, at the period of the lowest working capacity (Fig. 1).

By the end of the week the direction of physiological changes was unchanged, but their amplitude gradually decreased, probably due to more economic energy expenditures preventing exhaustion. Recovery of energy resources requires a longer rest by the end of the week.

Changes in physiological parameters by the end of the week were also observed in subjects engaged in intellectual work (Fig. 2). At the end of the week the content of Na^+ in the saliva decreased, while its daily periodicity was disturbed. Salivary excretion of

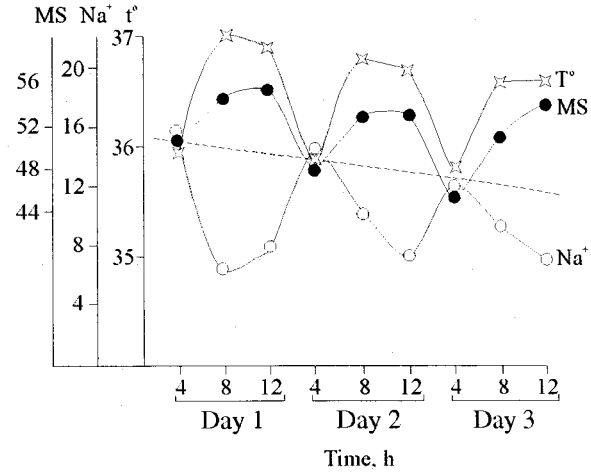

Fig. 1. Functioning of physiological systems during transition from sleep to awakening in workers engaged in physical labor during the week. MS: muscular strength.

Na^+ was no longer increased at 24.00, as was observed at the beginning of the week. The level of K^+ in the saliva was elevated and heart rate increased (Fig. 2) indicating the absence of endogenous readiness to sleep late at night. Therefore, greater strain of the regulatory systems is required for making the same work at the end of the week.

These data indicate a relationship between salivary levels of Na^+ and K^+ and the functional status: the level of Na^+ excretion decreases with increase in its strain, while that of K^+ increases. It should be emphasized that the period and mean daily level are homeostatic parameters characterizing the functioning of the organism. Acrophase and amplitude are more labile parameters reflecting the current adaptive changes.

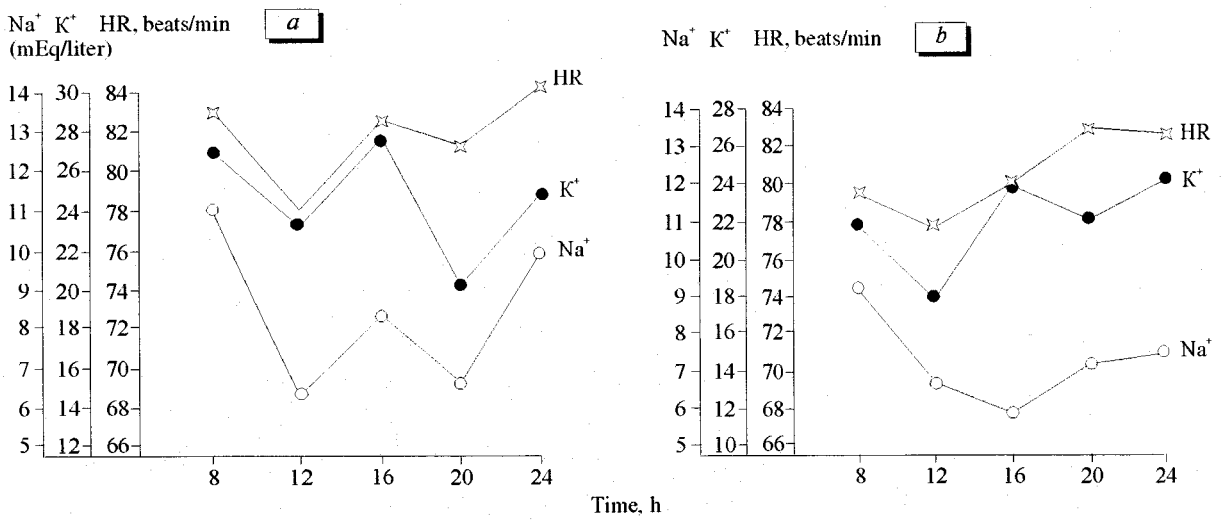

Fig. 2. Hourly changes in salivary levels of Na^+ and K^+ and heart rate (HR) in subjects engaged in intellectual work at the beginning (*a*) and end (*b*) of the week.

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