Circadian Rhythms of Autonomic Parameters during Mental and Physical Activity

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The structure of circadian rhythms of autonomic parameters was monitored during working week in subjects occupied by physical and mental work. Differences in the rhythm structure depended on the work type and schedule, as well as on the subject age. Hard physical work was associated with biphasic changes in the autonomic nervous system functioning with dominating sympathetic and parasympathetic components in the beginning and at the end of the working week, respectively. Intensive physical work caused rhythm synchronization: the acrophases were shifted to 14.00 and the amplitude of daily oscillations was high. Mental activity with individual working schedule resulted in chronic desynchronization most pronounced in subjects over 30.

Key Words: *autonomic nervous system; biorhythms; phasic changes; mental and physical work*

Adaptive reactions of the body associated with occupational activity depend on work heaviness and psychoemotional stress and consist in intensification of biological processes and changes in their temporal organization [1,4,12,13,15]. The balance between the external and internal rhythms is an important precondition of normal body functioning during changes in work and leisure regimens. Moreover, the formation of an integral system and synchronization of biological rhythms largely depend on the working regimen [7]. Therefore, biorhythmological approach to evaluation of physiological functions allows detailed examination of the role of work in the formation of adaptive reactions and development of pathological states.

Human adaptation to occupational activity associated with stress is accompanied by functional changes in the autonomic nervous system (ANS) [8,14]. The main regularities of periodic changes in the sympathetic and parasympathetic regulation under normal conditions and during adaptation to various environmental factors were recently established. It was shown that imbalance between ANS components can promote the development of various diseases [10,14]. However, these studies are not systematic and do not consider the state of autonomic balance during human occupational activity. Of particular interest is evaluation of the relationship between dominance of sympathetic and parasympathetic nervous systems and functional states of the organism such as strain, fatigue, work capacity, and resistance.

The purpose of the present study was to examine the peculiarities of circadian rhythms of autonomic parameters during mental and physical work.

MATERIALS AND METHODS

The effect of work type and heaviness on physiological biorhythms was evaluated in 2 groups of subjects. Group I included 30 subjects (22-30 years) involved into hard physical work in the Far North (track laying in a quarry after rock explosion). Three working days (from 7.00 to 16.00) were followed by 1 free day. Work heaviness was evaluated by chronometric observations and heart rate (HR) measurement during work. Group II consisted of 35 computer workers. They were divided into 2 age subgroups: 22-30 (n=17) and 31-40 years (n=18), respectively. Both subgroups had

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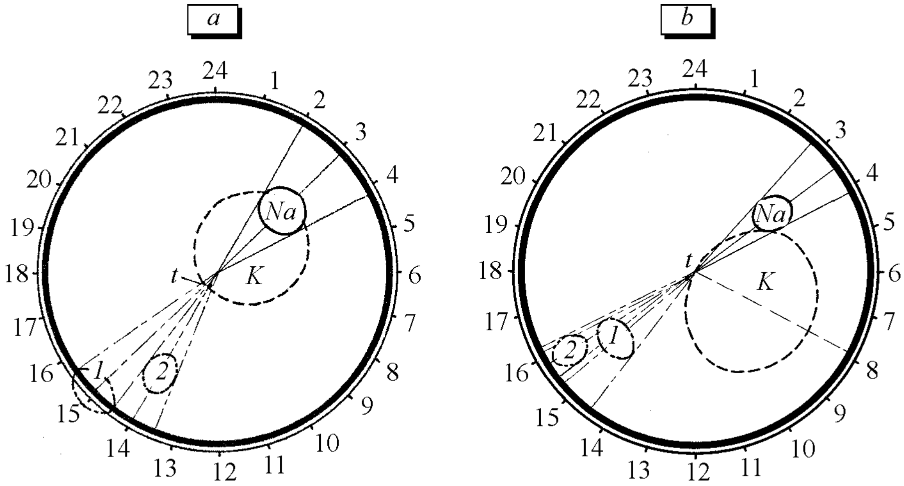

Fig. 1. Cosinor diagrams of circadian periodic changes in sodium and potassium concentrations, HR (*1*), muscular strength (*2*), and body temperature (*t*) in subjects occupied by hard physical work in the beginning (*a*) and at the end (*b*) of working week.

similar work type and regimen: individual working hours and 5-day working week.

The strain of regulatory systems was evaluated by indirect parameters reflecting activity of the sympathetic and parasympathetic systems. To this end, we analyzed the structure of biological rhythms including measurements of blood pressure (BP), heart rate (HR), body temperature, and electrocardiogram (ECG) recording. The state of the cardiovascular system during various working regimens was analyzed by secondary physiological parameters: cardiac output (CO) and stroke (SV) volume.

For evaluation of the strain of regulatory systems mathematical analysis of cardiac rhythm was used and histograms and autocorrelation curve were constructed [3]. Strain index and mode amplitudes were calculated. Na^+ and K^+ contents in the saliva were measured by flame photometry [9]. All parameters were measured 6 times per day with 4-h intervals. The results were processed by Cosinor software.

RESULTS

The workers living permanently in the North and occupied by hard physical work showed significant changes in the functional body state progressing from the beginning to the end of the week. The initial working period (phase I) was characterized by activation of thermoregulatory, cardiovascular, and muscular systems indicating high activity of the sympathetic system. This group demonstrated high HR, SV, and CO, and low Na^+ and K^+ content in the saliva irrespective of the examination period (Table 1).

Maximum levels of mode amplitude and strain index associated with low variability observed in the beginning of the working week also indicated domi-

TABLE 1. Dynamics of Physiological Parameters during Hard Physical Work in the Beginning and at the End of the Working Week ($M \pm m$)

Parameter	Working week beginning		Working week end	
	7.00	16.00	7.00	16.00
Na^+ content in saliva, meqv/liter	15.5±2.3	6.3±0.5	12.0±1.9	4.8±0.8
K^+ content in saliva, meqv/liter	28.1±2.1	18.9±1.9	23.0±2.8	15.4±3.0
HR, bpm	82.4±2.9	84.4±2.2	81.0±1.8	85.5±2.0
Diastolic BP, mm Hg	75.0±1.2	70.7±1.7	70.0±1.8	77.2±1.9
SV, ml	86.5±1.0	92.7±0.9	82.6±1.2	79.9±1.1
CO, liter	7.1±0.9	7.8±0.8	7.10±0.99	6.8±0.8
Body temperature, °C	37.00±0.01	36.9±0.1	36.7±0.04	36.7±0.03
Mode, sec	0.72±0.03	0.73±0.01	0.75±0.02	0.75±0.01
Mode amplitude, %	54.0±6.8	48.0±4.2	42.3±2.7	44.2±3.8
ΔX, sec	0.21±0.02	0.22±0.01	0.24±0.01	0.26±0.01
Strain index, arb. units.	244.1±66.0	170.0±39.1	127.0±22.1	146.3±29.1

Note. ΔX: variation range.

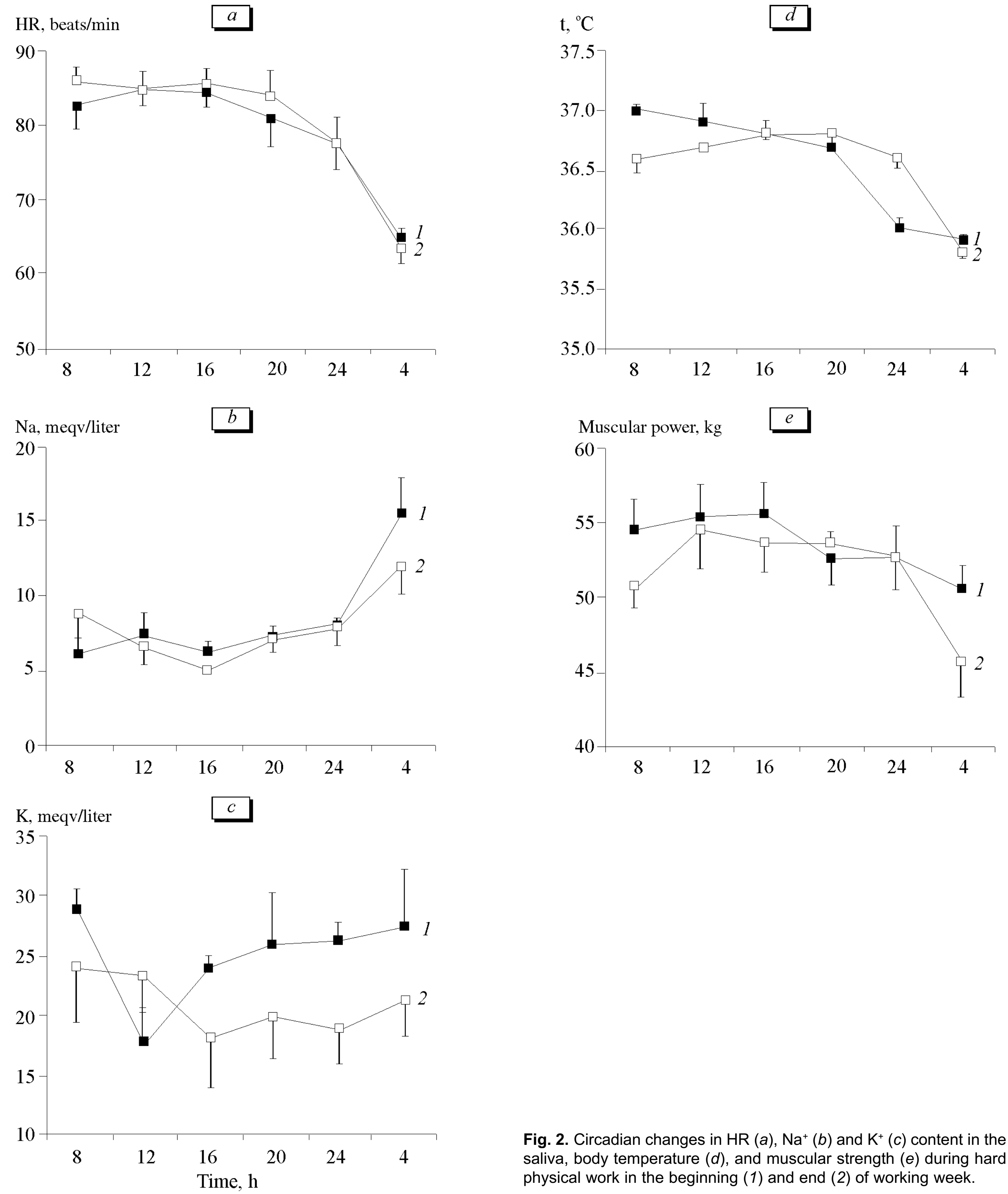

Fig. 2. Circadian changes in HR (*a*), Na$^+$ (*b*) and K$^+$ (*c*) content in the saliva, body temperature (*d*), and muscular strength (*e*) during hard physical work in the beginning (*1*) and end (*2*) of working week.

nating role of sympathetic nervous system. The decrease of Na$^+$ concentration by 32% from the initial level pointed to high activity of the peripheral component of adrenosympathetic system.

During rest hours, the parameters returned to a level corresponding to the beginning of the working day. Acrophases of most functions were recorded at about 14.00, while the peak of Na$^+$ concentration was

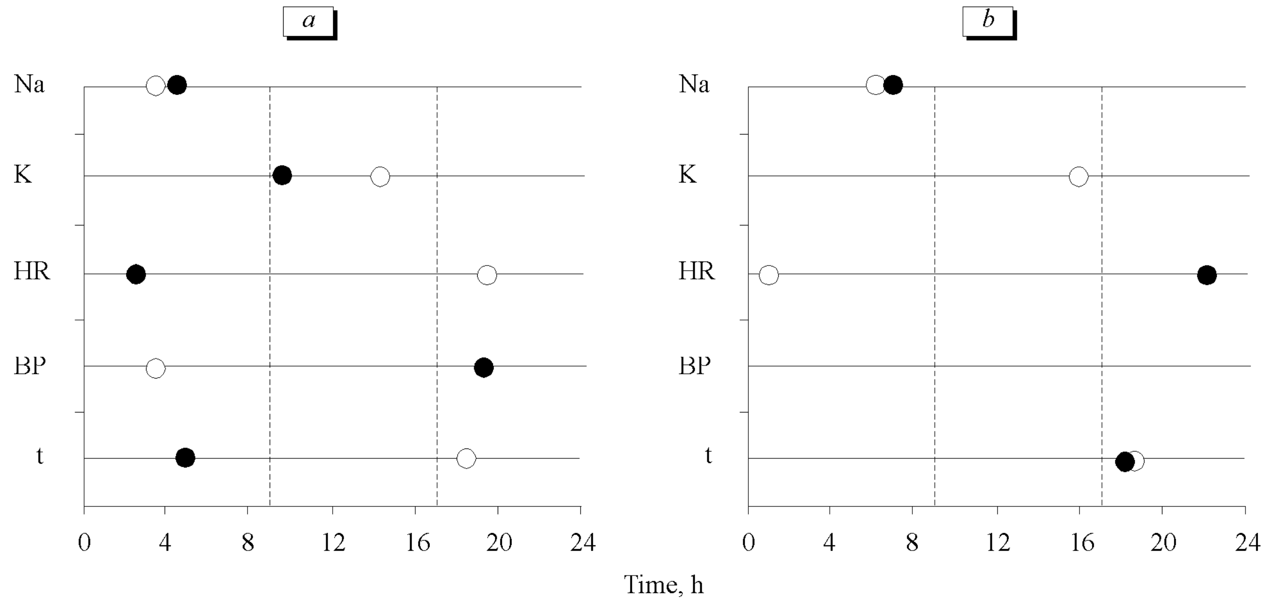

Fig. 3. Acrophases of circadian rhythms in physiological functions and Na^+ and K^+ content in saliva in the subjects occupied by mental work in the beginning (open circles) and at the end (filled circles) of working week. Absence of circles — no rhythm was revealed. *a*) subgroup I, *b*) subgroup II; BP: blood pressure.

in antiphase (Fig. 1). In the middle of the working week (phase II) the direction of parameters gradually changed indicating the decreasing role of sympathetic effects on regulatory processes.

The analysis of circadian rhythms showed that in contrast to week beginning, homeostasis was not completely restored during rest hours at the end of the working week (Fig. 2). These changes can be regarded as internal desynchronization and fatigue, which is confirmed by correlation analysis and supported by previous data [2,4,6].

The obtained data show that functional body state during hard physical work is characterized by biphasic changes in the autonomic homeostasis manifested as predominance of sympathetic and parasympathetic regulation in the beginning and at the end of the working week, respectively.

In group II subjects, no synchronous mobilization of the autonomic systems was revealed. Amplitude and phase characteristics of individual parameters were uncoupled, while function acrophases were time-dispersed and showed the phenomenon of floating acrophases (Fig. 3) typical of fatigue or transitional period caused by adaptation to new conditions. All subjects demonstrated low level of autonomic parameters in the beginning of the day (from 8.00 to 12.00) and its increase by night (20.00-24.00) typical of the persons occupied by intensive mental work.

Only one parameter, K^+ concentration in the saliva, reached a maximum during traditional working hours (8.00-17.00), while other acrophases were shifted to later hours. This pattern of functional activity probably depended on work organization in these subjects (evening work). Intensive mental work in the evening and night hours conflicts with biological capacities of the organism. Activation of mental work during this period can be provided only by functional strain. This deviation of phase and amplitude characteristics from the standard values can be classifies as desynchronization [2,11].

Despite similar tendencies of the examined regularities, phase changes in autonomic parameters showed age-dependent differences. In subjects over 30, the increase in CO was associated with HR acceleration, while in young subjects with SV increase. This can be explained by age-dependent decrease in myocardium contractile function [5]. However, the same mental work caused different effects: the price for adaptation was higher in the elder group.

Judging from the strain of regulatory systems at the end of the week, intensive mental work in the elder group is comparable with hard physical work.

Thus, during hard physical work, circadian rhythms of physiological functions demonstrate pronounced synchronization and high daily amplitudes persisting during the working week. Mental work causes divergencies of the acrophases of individual functional parameters and decreases the amplitude of circadian changes pointing to chronic desynchronization.

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