EXTRACARDIAL CHRONOTROPIC INFLUENCES ON THE HEART DURING FATIGUE

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UDC 612.176.014.32

Changes in the cardiac rhythm of 35 automobile drivers at intervals during the working day were studied by the methods of variation pulsography and auto-correlation and spectral analysis. The results showed that changes in the character of sympathetic and parasympathetic influences on the heart rate can be used as a primary index of fatigue.

Since the heart rate reflects to a certain degree the influence of work done and of the environmental conditions in which it is done [7, 12, 15, 17, 18], it was decided to study changes in the heart rate as an index of the state of cardiac regulation in automobile drivers in the course of the working day.

EXPERIMENTAL METHOD AND RESULTS

The dispersion of durations of individual cardiac cycles, as well as certain other "scatter functions" [4] may reflect intimate processes of regulation in the body. Cybernetic and mathematical methods have been used by a number of workers to study the statistical characteristics of the cardiac rhythm [5, 8, 10, 13], and this work has revealed a number of new laws governing regulation of the cardiac activity.

Methods of variation pulsometry, calculation of the auto-correlation function, and spectral analysis of dynamic series of between 120 and 150 R–R intervals of the ECG were used in this investigation [10]. The numerical values of the intervals were transferred to punched cards and analyzed on a computer. The ECG was recorded in recumbency after a rest of 3 min, in one of the standard leads, before, during and after work (3-4 times per shift) in 35 drivers working on the first and second shifts.

The investigation revealed a regular slowing of the heart rate toward the end of the working day, suggesting strengthening of the influence of the parasympathetic division of the autonomic nervous system on the heart. This hypothesis is also confirmed by the character of the variation curves, which are displaced to the right toward the 8th-9th hour of work (Fig. 1). However, on the pulse records shown, variability of the duration of the cardiac cycles is not increased, as would be expected during predominance of parasympathetic influences [3, 9, 11, 13] but, on the contrary, it is reduced, a characteristic feature of increased tone of the sympathetic system. In subject K. (Fig. 1), for instance, the coefficient of variation after work for 3 h increased from 1.3 to 2.6 and remained at this level until the 7th hour of work, but it fell to 2.1 toward the end of the shift. In addition, the blood adrenalin level of the subjects rose on the average from 13 to 15 μg %. Admittedly, as Kassil' [6] points out, the blood adrenalin level often does not correspond to the "tuning" of the autonomic nervous system.

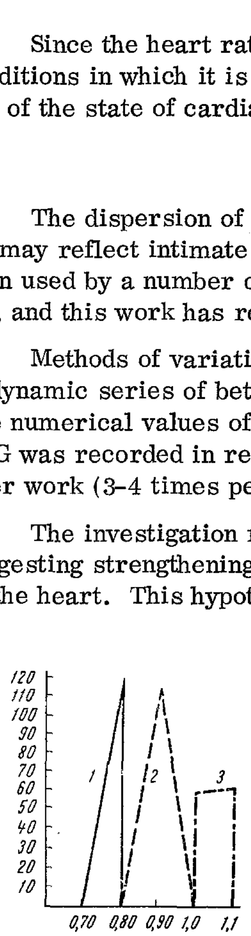

Fig. 1. Variation pulsogram of subject K. Before (1), during (2), and after (3) work. Abscissa, T_{RR} (sec); ordinate, N.

For a more detailed study of the changes in regulation of cardiac activity, the auto-correlation function was calculated. This enabled periodic components in the sequence of cardiac intervals to be distin-

Research Institute of Work Hygiene and Occupational Diseases, Gor'kii. (Presented by Academician V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 72, No. 9, pp. 13-16, September, 1971. Original article submitted November 9, 1970.

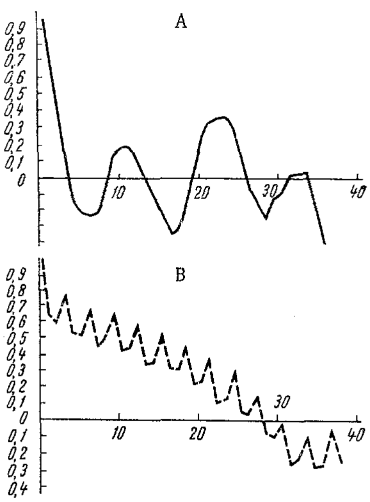

Fig. 2. Auto-correlation curve of subject V. Before (A) and after (B) work.

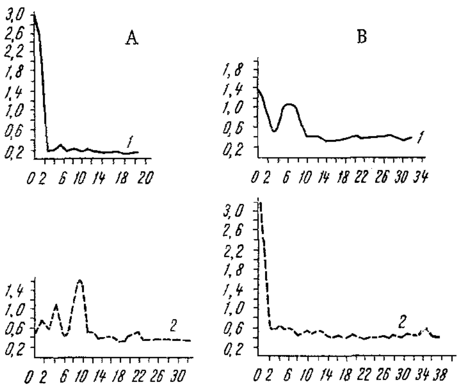

Fig. 3. Spectral curves of subjects U. and N. Before (1) and during (2) work.

guished. Respiratory arrhythmia is known to be inversely proportional to the pulse rate [6], and it can serve as an index of the influence of the parasympathetic nervous system [1, 2]. Slow waves are considered to be the result of a fluctuating change in the level of activity of the centers of the sympathetic nervous system [5], and it is claimed that the reticular formation of the brain stem participates in their formation.

The considerable variability of the auto-correlation curves obtained makes their analysis much more difficult. However, by comparing the dynamics of the indices obtained it was possible to detect a decrease in the amplitude of the respiratory waves and a simultaneous increase in the steadiness of the process toward the end of the working day (Fig. 2).

Calculation of the values of the auto-correlation function of the pulse – the magnitude of the change at which the coefficient of correlation has the value 0.3 (0.3 m) and 0 (m_0) – showed that the latter is more sensitive. It rose significantly toward the end of the working shift (m_0 by 77.2% but 0.3 m by only 22.6%), indicating an increase in the influence of the sympathetic nervous system and of all the neuroendocrine mechanisms connected with it.

Spectral analysis was used to calculate the distribution of dispersions of the cardiac intervals at different frequencies. As the results given in Fig. 3 show, toward the end of the working day there was a decrease in the respiratory fluctuations with a marked increase in the dispersion at the zero point. According to Baevskii et al. [2], the magnitude of this index reflects the influence of central regulatory mechanisms on the function of the sino-atrial node, effected through the sympathetic division of the autonomic nervous system. In these investigations dispersion at the zero point of the spectrum increased significantly toward the beginning of the 4th hour of work on the average by 17.7%, after 6 h of work by 45.6%, and after the end of work (8-9 h) by 55.7%.

The investigations thus showed that work activity of drivers causes simultaneous and prolonged activation of both the sympathetic and the parasympathetic divisions of the autonomic nervous system. Whereas activation of the parasympathetic system can be regarded as a manifestation of an asthenic response due to the performance of the complex functions associated with driving an automobile, intensification of the role of the sympathetic nervous system reflects the degree of mobilization of the body reserves in order to maintain working ability at a sufficiently high level.

Weakening of the adaptive and trophic influences of the sympathetic division facilitates the onset of changes in higher nervous activity characteristic of fatigue, as was confirmed by the results of additional investigations using methods commonly employed in work physiology (chronoreflexometry, the critical frequency of fusion of flashes, carrying capacity of the visual system, response to a moving object, and so on).

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