Characteristics of the Integrated Electromyogram in Individuals Exposed to Long-Term Vibration

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Abstract—The functional state of the forearm muscles in individuals exposed to long-term vibration (dressers with a duration of current employment of 7–15 years, \( n = 12 \)) was assessed using turn–amplitude analysis of the integrated surface electromyogram (EMG), the nerve conduction velocity test, and the conventional motor unit action potential electromyographic test. A significant increase in the EMG amplitude and the number of turns upon graded effort, as well as a decrease in the maximal ratio of the number of turns to the average amplitude of the electromyogram from the right m. flexor carpi radialis of the dressers, was revealed, which is indicative of secondary muscular disorders connected with the specific features of the occupational movement pattern and long-term exposure to vibration.

In this connection, it is of interest to study individuals exposed to long-term vibration using turn–amplitude analysis of the EMG in combination with the conventional methods for assessing the state of the motor system, namely, the motor unit action potential (MUAP) test and the nerve conduction velocity (NCV) test.

METHODS

Twelve male workers aged 25–49 years (mean, 43.0 ± 1.5 years) operating hand-held pneumatic hammers (dressers), with a duration of current employment of 7–15 years (11.0 ± 1.1 years on average), participated in the study. At the moment of the study, all the subjects presented with muscular weakness, easy fatigability, transient pain in the arms at rest and at work, paresthesias and chilly hands in the cold, decreased sensitivity to pain and temperature, and hyperhidrosis, which corresponded to grade II vibration disease. The control group included nine neurologically healthy male volunteers aged 20–43 years (mean, 31.1 ± 2.7 years).

The EMG study was conducted with an MG440 electromyograph (Mikromed, Hungary) using the cutaneous EMG method. Bipolar tin electrodes (rectangular electrodes measuring 6 × 12 mm; round electrodes 5 mm in diameter) were coated with EG1 electrode gel and fixed 14 mm apart over the muscle belly along the course of the fibers on the preliminarily defatted skin.

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Vibration ranks high among factors leading to the development of occupational pathology. In Russia, pathology linked to long-term exposure to vibration accounts for 21.9% of occupational diseases [1] and is characteristic of heavy and transport machine-building and forestry [2].

Vibrating tools used in these industries cause powerful stimulation of the sensorimotor system. This reduces the sensitivity of mechano- and chemoreceptors and decreases the conduction velocity along the nerve trunks [2–4]. In addition, the bioelectrical activity of muscles decreases following the myasthenic reaction pattern, and muscle strength also declines [2, 3]. Under prolonged and intensive vibration, increased activity of signal motoneurons is also possible.

Electromyography (EMG) is an informative and easily performed method for assessing the function of the peripheral motor system [5]; modern tools for analyzing the interference electromyogram (EMG) include its turn–amplitude and spectral analyses, which furnish integrative parameters of the state of the neuromuscular apparatus [6]. Turn–amplitude analysis of the EMG allows the severity and type of a functional disorder of the peripheral motor system to be assessed [7], the dynamics of a pathological process and functional recovery of muscles to be monitored [8], and muscle fatigue and recovery from fatigue to be evaluated [9]. The diagnostic value of EMG turn–amplitude analysis is comparable to that of fine-wire EMG, whereby motor unit action potentials (MUAPs) or individual muscle fibers are studied; however, unlike the latter, surface EMG is noninvasive, well tolerated by patients, and free of the necessity to take into account the level of loading [10–12]. The combined use of all known EMG methods allows more accurate evaluation of the state of the peripheral motor system [13, 14].

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For EMG analysis, the most superficial muscles of the distal portion of the upper extremity, accessible for recording, whose function was first of all disturbed on exposure to local vibration, namely, the m. flexor carpi radialis and the m. flexor carpi ulnaris, were chosen. Measurements were taken on both arms in order to study the influence of the occupational movement pattern on the functional state of the muscles.
The activities of m. flexor carpi radialis and m. flexor carpi ulnaris were analyzed using a graded wrist loading test. For this purpose, the wrists of sitting subjects were statically loaded with a series of standard weights (2, 4, 6, and 8 kg) for 3–5 s with the palm held flat. The arm was bent at the elbow joint (the upper arm was along the thorax, the articular angle was 90°, the lower arm and the elbow were fixed, and the wrist could move).

The MBN-Neiromiograf software (Moscow, Russia) was used to analyze the EMG. The EMG amplitude (root-mean-square value (RMS), µV) and the number of EMG turns per second (turns are fluctuations in the EMG potential with amplitudes exceeding 100 µV) were studied [5, 6].

The EMG analysis was performed as described previously [7, 8, 14]. Based on the individual data for establishing the type of functional relationship between the EMG parameters and the load applied, regression analysis with the linear regression model was used: the coefficients were calculated, and the regression curves were constructed.

We also studied how the ratio of the number of EMG turns to the average EMG amplitude over 1 s varied with the loading weights. The average 1-s EMG amplitude increases as a function of loading, since these two values are in direct proportion to each other, while the number of EMG turns increases in proportion to the effort only until the latter reaches 40% of its maximal value, which corresponds to the EMG “saturation” state, and remains relatively constant with a further increase in loading [6]. Therefore, the plot of the number of EMG turns versus the average EMG amplitude over 1 s shows a maximum, whose position is of diagnostic value in revealing neuromuscular diseases [6, 7]. This method is known in the literature as revealing the increment in the EMG parameters and showed the graph slope relative to the x axis. For m. flexor carpi radialis, these coefficients ranged between 5.7 and 18.5 (mean 13.8 ± 3.3) for the EMG amplitude and between 13.6 and 26.9 (mean 19.4 ± 2.1) for the number of EMG turns (Fig. 1); for m. flexor carpi ulnaris, the range was between 2.5 and 9.5 (mean 5.04 ± 0.83) for the EMG amplitude and between 19.4 and 34.5 (mean 26.5 ± 2.2) for the number of EMG turns.

Analysis of the EMG parameters without consideration of the load revealed that the maximal value of the ratio of the number of EMG turns to the average EMG amplitude over 1 s (the peak ratio) in healthy subjects is observed at an amplitude of 255.46 ± 27.13 µV for m. flexor carpi radialis and 208.38 ± 11.17 µV for m. flexor carpi ulnaris, constituting, on average, 0.76 ± 0.03 and 0.95 ± 0.1, respectively (Table 4; Fig. 2).

The characteristics of the total EMG in the group of subjects exposed to long-term vibration differed from the values obtained in the control group. As a rule, the subjects had a dense, high-frequency, and low-amplitude electromyogram. More marked changes in the quantitative EMG characteristics were revealed in the right arm muscles, especially in m. flexor carpi radialis, which is likely to be linked to the specific occupational movement pattern and to the distribution of the negative effect of vibration. Thus, in the dressers, the EMG

RESULTS AND DISCUSSION

The results of the study of the motor and sensory NCV parameters for the median and ulnar nerves in the dressers and in the control group are shown in Tables 1 and 2. It is noteworthy that the M-response amplitude decreases, thus indicating a decrease in the number of motor fibers innervating the nerve (an axonopathy type of disorder). The NCV along the motor fibers of the median nerve tended to decrease by 2–4 m/s as compared to in the control group, although, on the whole, the velocity values were within the normal range (Table 1). In the subjects exposed to long-term vibration, the nerve action potential amplitude was significantly decreased (by two- or threefold), as was the NCV along the sensory fibers of both nerves (by 6–8 m/s) (Table 2). In some of the subjects (n = 3), no nerve action potential was recorded, which evidences a substantial reduction in the number of sensory fibers. No differences in the values of the NCV along the motor and sensory nerves, the M response, and the nerve action potential parameters between the right and left arms were revealed.

The study of the EMG characteristics in the control group revealed a significant increase in the EMG amplitude (RMS) and the number of EMG turns for m. flexor carpi radialis and m. flexor carpi ulnaris with increasing loads. The relationship between the EMG parameters and loading was expressed in the form of linear equations, where the coefficients of regression reflected the increment in the EMG parameters and showed the graph slope relative to the x axis. For m. flexor carpi radialis, these coefficients ranged between 5.7 and 18.5 (mean 13.8 ± 3.3) for the EMG amplitude and between 13.6 and 26.9 (mean 19.4 ± 2.1) for the number of EMG turns (Fig. 1); for m. flexor carpi ulnaris, the range was between 2.5 and 9.5 (mean 5.04 ± 0.83) for the EMG amplitude and between 19.4 and 34.5 (mean 26.5 ± 2.2) for the number of EMG turns.