The mechanism of a human reaction to vibration stress by palmar sweating in relation to autonomic nerve tone

Abstract Objectives: To clarify the mechanism of a human reaction to vibration stress by palmar sweating in relation to the autonomic nerve tone. Methods: The autonomic nerve tone was divided into four types by using digital photoelectroplethysmography (PTG) with auditory stimuli: normal (N), hyperreactive (I and D), and hyporeactive (P) types. Palmar sweating and digital PTG were simultaneously measured on the right palm and middle finger, respectively, in 20 healthy men. The left hand gripping the handle with a grasp strength of 49 N was exposed to vibration at a frequency of 125 Hz and acceleration magnitudes of 0 m/s² (as a control), 30 m/s², or 50 m/s² for 3 min. The volume of palmar sweating was recorded before, during, and 30 min after vibration load. Three kinds of drugs related to the autonomic nervous system were orally administered to the subjects. Then 80 min after administration, the experiments were repeated. Results: Of 20 subjects, 17 showed normal autonomic nerve tone (N type), and 3 hyperreactive (I type). The palmar sweating reaction to vibration in I-type subjects was greater and lasted longer than that in N-type subjects. Vibration with an acceleration of 50 m/s² produced the greatest reaction which was about 7 times larger than that at 0 m/s² and 2.5 times that at 30 m/s² (P < 0.01). Sulpiride decreased palmar sweating during vibration, while prazosin and scopolamine inhibited it. Conclusions: The palmar sweating reaction to vibration stress was related to the background level of the autonomic nerve tone. The sweating volume was in direct proportion to the acceleration magnitude of vibration. The reaction of palmar sweating to vibration stress may be mediated through both the adrenergic and cholinergic fibers of the autonomic nervous system.

Key words Palmar sweating · Vibration stress · Autonomic nerve tone · Cholinergic and adrenergic nerve fibers

Introduction

The hand-arm vibration syndrome (HAVS) is an occupational disease due to the long-term use of vibratory tools such as chain saws and pneumatic hammers. Patients express many complaints regarding not only the peripheral but also the central nervous system (Matoba 1994, Matoba et al. 1977). Palmar hyperhidrosis is one of the symptoms encountered most often. In fact, Matoba and his collaborators (1977) reported that about 70% of the patients with HAVS suffered from palmar hyperhidrosis. In spite of this high prevalence, the mechanism of palmar hyperhidrosis in patients with HAVS is still unclear.

The three major stressors of vibration, noise, and cold environment can excite the autonomic nervous system (Matoba 1994). This suggests that the signs and symptoms in HAVS must be considered in relation to the autonomic nerve tone. The aim of this study is to clarify the physiological mechanism of the palmar sweating reaction to acute vibration stress of the hand in relation to the autonomic nerve tone. We performed two kinds of experiments. First, we observed an increase in the palmar sweating reaction to three different acceleration magnitudes of vibration. The aim of this study is to clarify the physiological mechanism of the palmar sweating reaction to acute vibration stress of the hand in relation to the autonomic nerve tone. We performed two kinds of experiments. First, we observed an increase in the palmar sweating reaction to three different acceleration magnitudes of vibration among subjects with various autonomic nerve tones. Second, the palmar sweating reaction was quantitatively evaluated under the influence of autonomic nerve-related drugs.

Subjects and methods

Subjects

The subjects were 20 healthy male volunteers whose ages ranged from 19 to 25 years. None had a history of peripheral vascular disease or injury to the neck, trunk, or upper limbs. None had...
Stimulation was recovered within 30 s after cessation of the stimulus. The amplitude of the digital PTG once reduced by the stimulation frequency of 800 Hz (Matoba et al. 1975). The recovery course of noise from the audiometer, which has an intensity of 90 dB(A) and a tone level of 600 Hz, was transmitted to the hands and arms. Three of them were smokers who were requested to refrain from smoking for at least 2 h before the test. Each subject was not allowed to make conversation, to have a nap, or to change position often during the experiment. On another day, all of the subjects were given some information about the drugs to be used. Five out of the 17 non-smokers, who were randomly selected according to the numbering, were admitted to participate in the second study with drugs. Informed consent was obtained from all of the subjects before the experiments.

Examination of the autonomic nerve tone

The activity level of the autonomic nerve tone was estimated by digital photoelectroplethysmography (PTG) with auditory stimuli (Matoba et al. 1975, 1981). After resting in a relaxed state on a bed for 20 min, the examinations were commenced. First, the subject was kept in a sound-proof room with his fingers situated at the level of his heart in a supine position. The probe was put on the tip of his right middle finger. Second, after confirming that the amplitude of the digital PTG had been stabilized, auditory stimulation was given to the subject through a headphone for 10 s. The signal was white noise from the audiometer, which has an intensity of 90 dB(A) and a frequency of 800 Hz (Matoba et al. 1975). The recovery course of the amplitude of the digital PTG once reduced by the stimulation was observed for 60 s. The pattern of the recovery process was classified into four types as shown in Fig. 1 (Matoba et al. 1975).

With the normal (N) type, the amplitude recovered the amplitude induced by the noise stimuli within 30 min. Intermediate (I) type recovers within 60 min, while delayed (D) type does not revert to the prestimulation level within 60 min. Poor (P) type does not respond to the noise stimuli. [Cited in Matoba et al. (1975)]

Fig. 1 Criteria for the classification of the activity level of the autonomic nerve by digital photoelectroplethysmography (PTG) with auditory stimuli. The activity level is classified by the recovery time course. Normal (N) type recovers the amplitude induced by the noise stimuli within 30 min. Intermediate (I) type recovers within 60 min, while delayed (D) type does not revert to the prestimulation level within 60 min. Poor (P) type does not respond to the noise stimuli. [Cited in Matoba et al. (1975)]

Previously experienced any significant exposure to vibration transmitted to the hands and arms. Three of them were smokers who were requested to refrain from smoking for at least 2 h before the test. Each subject was not allowed to make conversation, to have a nap, or to change position often during the experiment. On another day, all of the subjects were given some information about the drugs to be used. Five out of the 17 non-smokers, who were randomly selected according to the numbering, were admitted to participate in the second study with drugs. Informed consent was obtained from all of the subjects before the experiments.

Experimental protocol

The experiments were performed in a sound-proof room at an ambient temperature of 24 °C and a relative humidity of 60%. The subjects wore light clothing and sat on a chair in a relaxed position. In order to exclude adverse reactions, the subjects experienced the vibration exposure before the experiment. After examining the activity level of the autonomic nerve tone at rest, all the subjects were asked to grasp the handle with their left hand for 3 min at a constant grasp strength of 49 N. Visual feedback through an analogue meter allowed the subjects to keep the strength constant. Then, half of the subjects chosen at random grasped the handle generating sinusoidal vibration of 30 m/s² at 125 Hz for 3 min. Sinusoidal vibration was produced in the vertical direction by an electrodynamic vibrator (Akashi ASE-12). A rest period was inserted to ensure that the subject had no tingling in his fingers, then the third experiment was started. The procedure was the same as in the second experiment except for an increase of the acceleration magnitude to 50 m/s². The other half of the subjects were administered a vibration of 50 m/s² before that of 30 m/s². Before starting each experiment, we confirmed the stability of the level of palmar sweating and digital PTG, which showed almost the same volume of sweating in each subject.

On another day, we performed another study involving the oral administration of three kinds of drugs: 100 mg of sulpiride, 1 mg of prazosin hydrochloride, and 10 mg of scopolamine butylbromide. Five men participated in the study. Each subject took one of the three kinds of drugs at random on one day, and the study was performed consecutively for 3 days. Before receiving a drug, the subject was asked to perform the same experiment as described above at an acceleration magnitude of 50 m/s². Then 80 min after administration, the subject was exposed to vibration. During the experiments, palmar sweating and digital PTG were simultaneously recorded before, during, and after at least a 30-min period.

Data analysis

The volume of palmar sweating during stimulation was analyzed quantitatively compared with the prestimulation level. In the first study, the Friedman test and Mann-Whitney’s U-test were applied to evaluate the increase in palmar sweating volume in response to the vibration stress at different acceleration magnitudes and with different autonomic nerve tones, respectively. In the second study,