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ORIGINAL ARTICLE

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Effect of cold ambient temperature on palmar sweating response to vibration stress

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Abstract We investigated the effect of cold ambient temperature on the palmar sweating response to vibration stress. Ten healthy, male subjects were exposed to eight ambient temperatures (5, 7, 10, 14, 18, 22, 24 and 28°C). At each ambient temperature, each subject gripped the handle of a vibration generator with his left hand with a grasp strength of 49 N. This hand was then exposed to a 125-Hz sinusoidal vibration with an acceleration of 50 m/s^2 (rms) for 3 min at each ambient temperature. Palmar sweating and skin temperature were measured simultaneously on the palm and the fourth finger, respectively, of the subjects' right palm. The palmar sweating response showed a significant change among eight ambient temperatures. The palmar sweating measured at an ambient temperature of 5°C was found to be significantly larger than those measured at 10, 14, 18, 22, 24 and 28°C. Vibration exposure caused a significant increase in the palmar sweating response. Our results suggest that a cold environment plays a significant role in the palmar sweating response to vibration stress.

Keywords Palmar sweating · Cold ambient temperature · Vibration

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Introduction

Workers using vibratory tools such as jack hammers and chainsaws are generally exposed to three major risk factors of vibration, noise and a cold environment. Palmar hyperhidrosis is one of the signs often encountered among patients with hand-arm vibration syndrome, which is an occupational disease that results from the long-term use of vibratory tools (Matoba et al. 1977). It has been shown that vibration or noise stimuli make palmar sweating increase (Ando et al. 2000; Sakakibara et al. 1989). The combined effects of vibration and noise on palmar sweating have also been observed among healthy subjects (Sakakibara et al. 1989). To date, however, little research has been carried out regarding the relationship between the palmar sweating response to vibration stress and a cold environment. In the study presented here, we evaluated quantitatively the palmar sweating response to vibration stress transmitted to the hands and arms at various ambient temperatures in order to elucidate the role of a cold ambient temperature on palmar sweating during exposure to hand-arm vibration.

Methods

Subjects

Ten healthy male volunteers, 20–27 years of age, participated in the study, having neither a history of excessive palmar sweating nor experience of any significant exposure to hand-arm transmitted vibration. One of them was a smoker but refrained from smoking for at least 4 h before the test. Each subject wore a vest, underpants, a shirt, trousers and a pair of socks throughout the series of experiments. The estimated resistance of clothing against dry heat loss (the clo value) varied from 0.7 to 0.8. All subjects provided their written informed consent to participate.

Measurements

Palmar sweating volume was measured using a ventilated capsule method (Hidrograph, AMU-100), as described in our previous paper (Ando et al. 2000). A capsule of 1 cm^2 in size was mounted on the right palm, through which dry N_2 gas flowed. Dry N_2 gas flowed into the capsule at a rate of 0.3 l/min from one side and exited from the other side after being moistened by the sweat. The sweating volume was calculated from the change of humidity inside the capsule. Throughout the experiments, the skin temperature was measured on the right fourth fingertip by means of a thermistor.

Information regarding thermal sense and comfort, numbness and pain in the fingers and hands were obtained from each subject.

Experimental procedure

A soundproofed artificial weather room was used throughout the experiments. Relative humidity was constant at 60% and air velocity in the operating zone of the hand was around 0.13–0.20 m/s. Each subject was exposed to one of eight ambient temperatures (5, 7, 10, 14, 18, 22, 24 and 28°C), presented randomly, with or without vibration. The subjects were unaware of the actual ambient temperature in the room throughout the experimental series, which continued over 8 consecutive days. In order to exclude adverse reactions to vibration, the subjects experienced the vibration stress before the experiment several times.

Before starting the experiments, each subject stayed calm in a waiting room that was maintained at 24°C for 15 min, and then he entered into the experimental room, where he remained for at least 60 min at the room temperature in a relaxed position on a chair with his palms open and down on his knees. Palmar sweating volume was recorded for at least 5 min after confirming its stability. Then the subject was asked to grasp the handle of a vibration generator with his left hand. Visual feedback through an analogue dynamometer allowed the subject to maintain a constant grip strength of 49 N. A 125-Hz sinusoidal vibration was given with an acceleration of 50 m/s^2 (rms) for 3 min. Vibration was produced in the vertical direction by an electrodynamic vibrator (Akashi ASE-12). The vibrator generated a noise level of 60 dB. A preliminary study has proven that this intensity did not significantly increase palmar sweating of the subjects. After terminating the vibration, observation was continued until palmar sweating volume returned to the prestimulation level. Figure 1 shows the experimental set-up. The study was performed during winter in December, January and February.

Data analysis

The volumes of palmar sweating before and during vibration were analysed quantitatively. The mean value before vibration exposure was obtained using the data of the last 3 min out of 5-min control periods. Repeated-measures analysis of variance (ANOVA) was applied to evaluate the difference in palmar sweating among the eight ambient temperatures studied. When it indicated a significant difference among the responses, a multiple-comparison test (the Newman-Keuls test) was used to compare different conditions. A "P" value of 0.05 was set as the limit of statistical significance.

Results

Figure 2 shows palmar sweating responses before and during vibration exposure at eight ambient temperatures. Palmar sweating, both with and without vibration exposure, increased in relation to a drop in ambient temperature. Repeated-measures ANOVA indicated that palmar sweating changed significantly among the eight ambient temperatures ($F=2.81$, $P=0.01$). The mean value of palmar sweating at 5°C was significantly larger than values measured at temperatures at 10, 14, 18, 22, 24 and 28°C ($P<0.05$). Vibration exposure caused an increase in the palmar sweating responses at all eight ambient temperatures ($F=33.94$, $P<0.01$).

Finger skin temperature did not change significantly between before and during vibration exposure at the eight ambient temperatures studied.

Discussion

In the present study, we evaluated palmar sweating volume at eight ambient temperatures. A marked palmar sweating response was observed in the cold ambient temperature. Palmar sweating at 5°C was significantly larger than that measured at 10, 14, 18, 22, 24 and 28°C.

Fig. 1. Experimental set-up. While sitting upright in a chair, the subject's left hand was subjected to a 125-Hz sinusoidal vibration of 50 m/s^2 (rms) for 3 min. Measurements were made of palmar sweating and skin temperature of the palm and fourth fingertip, respectively, of the subject's right hand

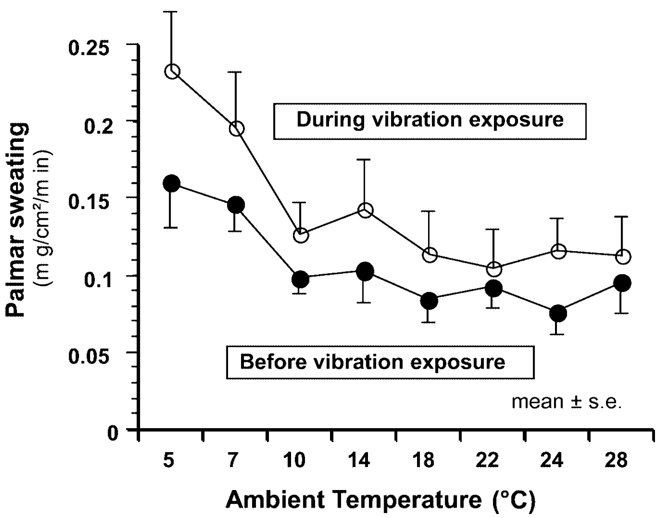

Fig. 2. Palmar sweating response before (*closed circles*) and during vibration (*open circles*) at eight different ambient temperatures. Values are presented as the mean ± SEM

It is suggested that palmar sweating depends in part on thermal characteristics. Whole-body exposure to cold air at 7 ± 1.5°C has been observed to increase plasma noradrenaline and to serve as the main activator of the sympathetic nervous system (Nakamoto 1990). We have indicated that the palmar sweating response to vibration stress is dependent upon the background level of autonomic nerve tone (Ando et al. 2000). The marked response of palmar sweating observed at 5°C may be attributed to activation of the sympathetic nervous system by the cold environment. On lowering the ambient temperature, Okamoto et al. (1994) observed, using the simultaneous microneurographic technique, an activated sudomotor component in the tibial nerve. Our results are compatible with the findings of that neurological study. Sweat glands are, from an anatomical point of view, innervated by adrenergic as well as cholinergic fibres(Uno and Montagna 1975). This fact suggests that the palmar sweating observed in the present study at a cold ambient temperature is of stress origin and is controlled by the adrenergic system.

Vibration exposure augmented the palmar sweating response to ambient temperatures. Vibration as a stressor may excite the higher centres of the sympathetic nervous system in the hypothalamus (Matoba et al. 1985). In addition, vibration stress is thought to induce palmar sweating through the somatosympathetic reflex (Sato and Schmidt 1973). These two mechanisms may be responsible for the palmar sweating response observed during vibration. When repeated-measures ANOVA was applied to those values obtained at 5°C (cold), 22°C (neutral) and 28°C (warm), an interaction was found in those palmar sweating responses between two factors of vibration and ambient temperature ($F=4.16$, $P=0.03$). This finding suggests the possibility of synergistic effects of the cold and vibration on palmar sweating.

Every subject performed a series of experiments for 8 consecutive days. Palmar sweating is categorized as a mental sweating and occurs during mental, emotional or noxious stress (Kuno 1956). Palmar sweating, in other words, is easily influenced by the subject's mental condition. This means that the different palmar sweating baselines observed before vibration exposure would be due to the subject's mental condition rather than the ambient temperature. Although the intra-individual comparison of palmar sweating was not assessed before starting a series of eight experiments, seven out of ten subjects showed a tendency for palmar sweating to increase with the drop in ambient temperature.

Some researchers have described the ambient temperature of 5°C as being moderate cold (Enander et al. 1979, 1980). In outdoor work environments, the ambient temperature can be as low as below zero. In this respect, further studies are needed under colder ambient temperatures to provide more information on the palmar sweating response to vibration of workers who use vibratory tools.

In conclusion, the palmar sweating response is significantly increased with vibration exposure, especially at cold ambient temperatures. The findings of the present study suggest that a cold environment plays an important role in the mechanism underlying palmar hyperhidrosis in workers using vibratory tools.

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