11TH INTERNATIONAL CONFERENCE ON HAND-ARM VIBRATION

EFFECT OF COUPLING ACTION ON TEMPORARY THRESHOLD SHIFT (TTS) OF VIBROTACTILE PERCEPTION

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Abstract

The purpose of this paper is to investigate the effect of the hand coupling actions (grip-only action and combined grip and push action) on the temporary threshold shift (TTS) of vibrotactile perception on a fingertip. Twelve subjects participated in the experiment. Six exposure treatments were used in the experiment, which are composed of two sinusoidal vibration exposure frequencies (16, 125 Hz), one control exposure condition (0 Hz), and two hand coupling actions (20 N grip-only and combined 20 N grip and 40 N push). The subjects were exposed to constant ISO-weighted acceleration of 8 m/s^2 rms of 5 minutes duration for each vibration condition. The TTS was measured before and after each subject was exposed to vibration. This study found that the TTS is affected by the coupling action at the exposure frequency of 125 Hz.

1. Introduction

The International Standard (ISO) 5349-1[1] is primarily concerned with protecting workers from incurring vibration-induced white finger (VWF) and other aspects of the so-called hand-arm vibration syndrome. The standard uses measures of frequency-weighted acceleration to quantify the severity of hand-transmitted vibration exposure in terms of the predicted number of years before finger blanching indicating vascular disorders. The standard provides the information on how the vibration magnitude associated with 10% prevalence of vascular symptoms may depend on daily and lifetime exposure to vibration.

The sensitivity of mechanoreceptors could be significantly reduced by long-term exposure to hand-transmitted vibration [2]. Probably for this reason, the measurement of finger vibration perception threshold (VPT) has been viewed as an important approach and has been widely used to diagnosis and investigate hand-arm vibration syndrome (HAVS). This method has been standardized by International Organization for Standardization (ISO 13091-1, 2001) [3]. Previous studies [4,5,6] have also shown that after a person is exposed to hand-transmitted vibration, the vibration perception threshold could be temporarily increased and it could take some time (usually greater than 10 minutes) for the VPT to come back to its normal value, which is conventionally termed as temporary VPT shift (TTS). Lidstrom et al. [7] found that the magnitude of the TTS was higher for workers exposed to long-term hand-transmitted vibration than for age-matched controls. Radzyukevich [8] suggested that the temporary threshold shift (TTS) in vibrotactile perception threshold at the end of a working day were correlated with the permanent threshold shift (PTS). Malinskaya et al [9] found that the mean TTS of workers after a day of work that included vibration exposure corresponded to the PTS of vibratory sensation that occurred in the group after 10 years of exposure. These observations suggest that the TTS after daily exposure may be used as a measure to indicate the PTS after prolonged exposure to vibration. Therefore, TTS may be used as a convenient and relevant index to investigate the effects of the vibration exposure and influencing factors on the development of finger nerve disorders.

Several studies on TTS have been reported [10,11]. These studies have provided the general understanding of the relationships among the TTS, its measurement frequency, vibration exposure frequency, vibration magnitude, and exposure duration. These studies, however, used the grip-only action in the experiment. The combined grip and push action is actually most frequently used in the operations of many power tools. It remains an issue on how the difference among coupling actions could affect the TTS. In ISO/DIS 15230: 2005 [12], it is stated that the acute effects of gripping and push or pull forces under exposure to vibration are not distinguishable. This may be because the collected experimental data could be too scattered to identify the effects of the different coupling actions. On the other hand, several studies have reported that the coupling actions could affect the biodynamic response (BR) of the hand-arm system [e.g.,13,14]. Because the BR is directly associated with the vibration-induced mechanical stimuli that could trigger the nerve reactions, any significant change in the BR may also affect the TTS. So far, however, the effect of the hand coupling action on the TTS has not been clarified.

Therefore, the specific aim of this study is to investigate the effect by comparing the TTS values for low and medium frequency exposures– 16 Hz and 125 Hz, respectively - under two coupling actions: a grip-only action and a combined grip and push action.

2. Methods

2.1 Apparatuses

The experiments were performed in two labs, one in US NIOSH and other one in Japan NIOSH. The basic configurations of the two vibration exposure test set-ups are the same as shown in figure 1. Each of them is composed of an electromechanical shaker mounted horizontally on a solid base, a closed loop controller, a power amplifier, an instrumented handle, and a data acquisition system. The same force plate (Kistler 9286AA) was used to measure the applied push force. The instrumented handles used in both labs were also of the same design. As shown in figure 2, it is composed of two parts: the base and the measuring cap. Two force sensors (KISTLER 9212) are placed between the two parts along the centerline of the handle, with which the grip force was measured and controlled in the experiment. An accelerometer (PCB 339B24) was positioned on the measuring cap at the center point of the handle to measure and control the vibration of the handle.

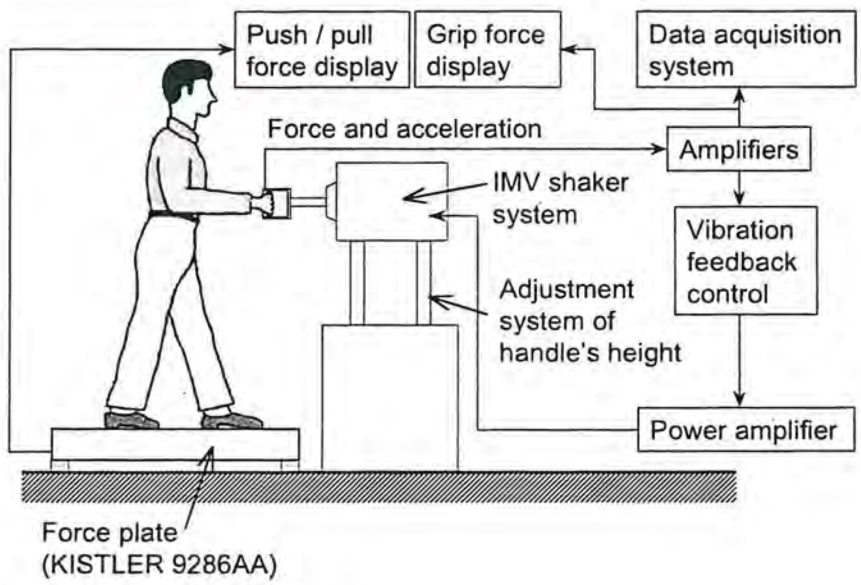

Figure 1 - Basic exposure setup and typical subject posture

However, the equipment used for measuring the TTS in each lab was different. In US lab, the apparatus made by the Institute of Sound and Vibration Research, UK, was used. In Japan lab, a RION AU-02B was used. Both devices have been used by many investigators [e.g.,16-18].

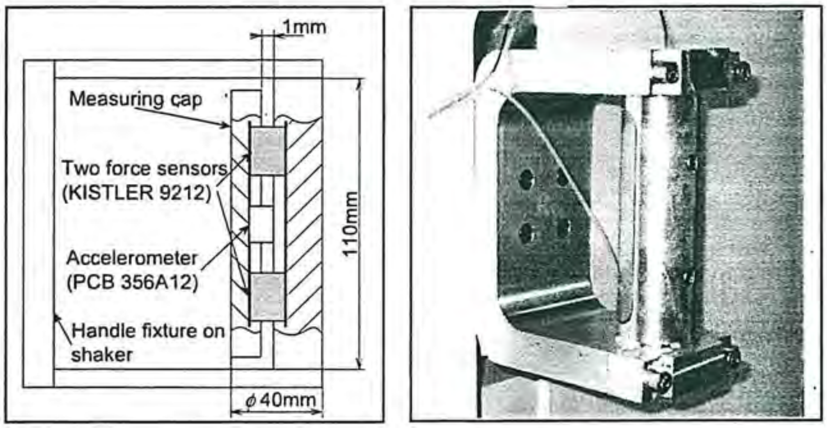

Figure 2 - Instrumented handle

2.2 Subjects

The experiments were performed with twelve healthy subjects: six American males and six Japanese males with mean ages of 24.5 and 23.5 years old, respectively. All of the subjects were non-smokers. None of the subjects have been exposed to high levels or long periods of HAV occupationally or in their leisure time activities. The experiments were approved by the Research Ethics Committee of Japan NIOSH and US NIOSH. All of the subjects underwent an explanation of the test procedure and signed their written informed consent to participate in the study.

Table 1 - Test treatment

No	*Frequency (Hz)*	*ISO 5349 Weighting RMS Values*	*Unweighted Peak Accelerations (m/s^2)*	*Hand Coupling Action*
1	0	0.0	0.0	20 N grip
2	16	8.0	12.63	20 N grip
3	125	8.0	89.07	20 N grip
4	0	0.0	0.0	20 N grip + 40 N push
5	16	8.0	12.63	20 N grip + 40 N push
6	125	8.0	89.07	20 N grip + 40 N push

2.3 Basic experimental conditions

Both labs used the same experimental conditions. The tests were performed over a two-day period. The ambient room temperature during the test was maintained between 21 and 23^{0}C. Two vibration exposure frequencies (16 or 125 Hz) were used. At each frequency, the weighted acceleration was 8 m/s^2 rms; according to ISO 5349-1 [10]. The exposure duration was 5 minutes. Two coupling actions were used, which included a 20 N grip only and a combined 20 N grip and 40 N push. A non-vibration condition was also used as the control for the comparison. The detailed test treatments are summarized in table 1. A randomised balanced design of the test order of the six exposure treatments among each group of subjects was used in this study.

2.4 Test procedures

Upon arrival, the subject was given 15 minutes to become acclimatized to the temperature of the laboratory. Then, the finger skin temperature of the index finger of the dominant hand was measured. The skin temperature of the test finger was above 22^{0}C before proceeding with the test. Before beginning the tests, the subjects were asked to put on a pair of earmuffs to block out the background noise and to help them to concentrate. The baseline vibration perception threshold (30 seconds) on the index finger of the dominant hand at 125 Hz was measured.

Then, the test subject was asked to stand upright facing the shaker and to grasp the handle of the shaker with his/her dominant hand (figure 1). It was required that the thumb not overlap onto the index finger. During the test the forearm of the test subject was kept horizontal, the elbow formed an angle of 90 +10 degrees, the wrist was maintained at neutral angle, and the elbow was not allowed to touch the body. Real time displays of the grip and push forces were provided via two computer monitors or two meters so that the subjects could adjust the applied forces to the desired levels.

The shaker was turned off after the 5 minutes exposure. The test subject immediately returned to the vibration perception test apparatus to get ready for the TTS testing. Beginning at the 30th second following the completion of the vibration exposure, the TTS was continuously measured for 30 seconds at 125 Hz. Following the first TTS measurement, additional same measurements were taken at 2.5, 4.5, 6.5, and 8.5 minutes after the vibration exposure, as well as 10 minutes for the Japanese. The test subjects were given a 30-minute rest period to allow for the effects of the vibration exposure to wear off.

Following the rest break, another 30-second vibration perception threshold measurement was performed, which was used as a new baseline for the next test treatment. Then, the exposure and test procedures were repeated for the measurement of the TTS for the next randomised treatment.

3. Results

Figure 3 shows the TTS results measured in both labs. The trends are similar for the results from the Japanese and US labs. However, the ranges of their TTS values are different. The data from Japan lab started at higher threshold shifts but ended at values close to the baseline values. The test frequency of 125 Hz was used for the exposure frequency of 16 Hz and 125 Hz. The TTS values of the exposure frequency of 125 Hz with both coupling conditions was higher than 16 Hz exposure frequency ($p < 0.01$).

The TTS values measured in both labs under the combined action for the vibration exposure at 125 Hz is significantly greater than those under the grip-only action ($p < 0.05$). No difference between the TTS values of the two coupling actions under the 16 Hz vibration exposure could be reliably detected.

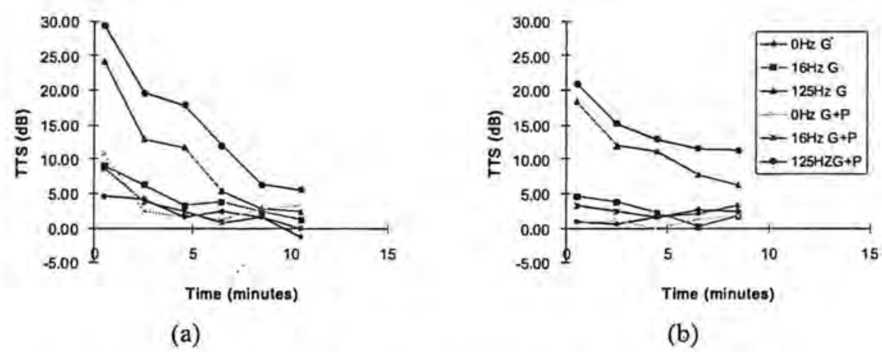

Figure 3 - TTS results measured in (a) Japan lab and (b) US lab

4. Discussion

The results of this study consistently indicate that the TTS at the test frequency of 125 Hz is affected by the coupling action. The frequency-weighted rms acceleration alone may not be sufficient to provide the risk assessment of the hand-transmitted vibration exposure. The coupling action may affect a worker's physiological response to vibration exposure and, therefore, should be taken into account in assessing the risk of the hand-transmitted vibration exposure.

The same frequency-weighted rms acceleration value was used but the TTS values under different exposure frequencies are dramatically different, as also shown in figure 3. This suggests that the ISO frequency weighting may not truly reflect the frequency dependency of the finger nerve response to the vibration exposure.

As also shown in figure 3, the ranges of TTS data measured from the two labs are different. One of the primary reasons may result from the differences between the two apparatuses or methods used in the TTS measurement. Whereas RION takes the lowest threshold magnitude, HVLab takes the average of the subject's response and release magnitudes.

5. Conclusions

This study investigated the effect of the hand coupling action on the temporal threshold shift of vibrotactile perception on the fingers. The basic trends of the TTS data measured in both the Japan and US NIOSH labs are similar, although the ranges of their TTS values are different.

The results consistently indicate that the TTS is affected by the coupling action under vibration exposure at 125 Hz.

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