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Acute effects of whole-body vibration

Stabilography and electrogastrography

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KJELLBERG A, WIKSTRÖM B-O. Acute effects of whole-body vibration: Stabilography and electrogastrography. *Scand J Work Environ Health* 13 (1987) 243–246. The influence of whole-body vibration on postural control and stomach motility was investigated. Fifteen subjects were exposed to two vibration signals (3 and 6 Hz random) while sitting for 1 h on a vibration simulator. A control situation, ie, sitting for 1 h without vibration, was also included. Stabilographic recordings before and 1 and 15 min after the sitting showed that exposure to these frequencies had no effect on postural control. Electrogastrographic (EGG) measurements before and during the sitting showed that, for 3 Hz, there was an initial increase in activity which decreased towards normal values. For 6 Hz there was a significant increase in activity for EGG frequencies of 0.05 and 0.13 Hz. The results imply that stomach motility can be affected by whole-body vibration in certain frequency ranges.

Key terms: postural control, stomach motility.

Stabilographic studies and other studies of postural control have unequivocally shown that the postural control system is affected by exposure to whole-body vibration provided that the vibration frequency is low enough (less than 1 Hz) or high enough (more than about 15 Hz) (3). It is also well known that the effect of the extremely low frequencies, occurring, eg, in ships, is primarily mediated by the vestibular system and that severe exposure may lead to motion sickness (12).

Studies by Martin et al (7) and Roll et al (13) using 18-Hz vibration indicate that higher frequencies act upon the extero- and proprioceptive receptors rather than on the vestibular system.

With the exception of helicopters severe whole-body vibration in occupational environments usually occurs in the 1- to 10-Hz range. Several authors have concluded that no effects on postural control appear within this frequency range (3). However, some researchers maintain that the vestibular system is affected also during exposure to vibration frequencies of 1–10 Hz, and what has been called a "latent kinetosis" is produced (14).

Studies by Bastek et al (1), Koitcheva et al (6), McKay (8), Meister et al (9), Menshov (10, 11), and Seidel et al (14) have allegedly shown stabilographic effects of exposure to vibration between 1 and 8 Hz.

However, most of the aforementioned studies are open to criticism. Some have included very few sub-

jects (1, 6, 9), at least one lacked a control condition without vibration exposure (8), and some have used no or questionable statistical test methods (6, 9, 14). For the studies by Menshov (10, 11) and Koitcheva et al (6) only incomplete descriptions of the experimental procedure are available.

The present study was conducted with the main purpose of measuring stabilographic responses before and after a 64-min exposure to stochastic vibration of either 3 or 6 Hz at levels encountered in the work environment.

The exposure period was also utilized for a minor study of the effects of whole-body vibration on surface gastrograms. Epidemiologic studies of drivers of different vehicles indicate that, apart from back trouble, gastrointestinal trouble may be one of the most common health impairments caused by whole-body vibration (3, 15). In the only study of acute effects of gastrointestinal functions (2) known to us, it was found that vibration led to an increased gastric secretion, while the rate of stomach emptying was unaffected.

The main reason for the lack of research on this subject is probably that most techniques for recording gastrointestinal activity are rather distressing for the subject and thus of limited applicability. However, surface recordings of electrical activity in the gastrointestinal tract, electrogastragrams (EGG) (4), do not present this problem. The EGG has hitherto primarily been used in studies of clinical groups, but there are investigations which indicate increased activity as a result of environmental events like noise and light (16, 17).

The aim of this part of the present study was to investigate the possibility of using the EGG to measure gastrointestinal effects of whole-body vibration and to study how possible effects vary with vibration frequency and exposure time.

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Subjects and methods

Subjects

Fifteen men volunteered to participate in the experiment. Their ages, heights and weights were 23–43 (mean 28.9) years, 167–190 (mean 180) cm, and 64–88 (mean 74.1) kg, respectively.

Vibration excitation

An electrohydraulic shaker (Fairey, stroke ± 40 mm, frequency range 1.5–50 Hz) generated vibration in the vertical direction (Z). The shaker was controlled with an acceleration signal from a frequency-modulated (FM) tape recorder (Tandberg 100). The signals had been recorded on the floor of the cabin of two industrial trucks.

The vibration was of two types. One type had a fundamental frequency of 3.1 Hz and the other a frequency of 6.3 Hz. The root-mean-square (rms) value of the fundamental frequency was 1.0 and 1.1 m/s^2 , respectively. Thus both types of vibration had random characteristics with a marked fundamental frequency. A period of 64 s with a small rms level variation was chosen from the recordings. The shaker was driven by an endless loop made out of this period. The rms value of the acceleration signal, frequency-weighted with a filter corresponding to the weighting curves in ISO standard 2631 (5), was 1.4 m/s^2 rms for the 3.1-Hz vibration and 1.6 m/s^2 rms for the 6.3-Hz vibration.

The subjects sat on a conventional driver's seat with a thin seat cushion but with no other built-in spring or damper system. They had their feet on a foot plate which also vibrated. The exposure lasted 64 min.

Stabilography

A force platform (Kistler 9281B) registering forces in three directions (X,Y,Z) was used for the stabilographic measurements. The platform had linear char-

acteristics within the frequency range 0–500 Hz. The small drift in the direct current (DC) signal which occurs in piezoelectric equipment did not affect the analysis made in the study. Signals were recorded on an FM tape recorder (Bruel & Kjaer 7003).

From recording charts it was obvious that the largest body sway occurred in the X direction (sagittal plane). Further analyses therefore were restricted to this direction. These signals were band-pass filtered [boundary frequencies 0.01 (6 dB/octave) and 10 Hz (48 dB/octave)] and fed into a personal computer, (ABC-80) via an analogue-digital converter, with a sampling frequency of 40 Hz. The dynamic range of the tape recorder at this frequency range was 56 dB (0.04–25 N). The standard deviation of the force signal in the X direction, measured over a period of 3 min, was used as the measure of body sway in the main analysis of the data. Calculations were based on amplitude probability with a resolution of 0.05 N. In addition a frequency analysis of the data was performed using a fast fourier transform (FFT) analyzer (Hewlett Packard 3582A). In each session three stabilographic recordings were made. One was made 20 min before exposure to establish a base-line level. The others were made 1 min and 15 min after the exposure. During the measurement the subjects were instructed to stand as still as possible with their eyes closed in a relaxed Romberg position for 5 min. The differences between the two postexposure values and the preexposure value were computed and subjected to analyses of variance.

Electrogastrography

One silver-silver chloride electrode was placed on the skin approximately over the antrum, and a ground electrode was glued to the right leg slightly above the ankle. The signal was amplified and put on an FM tape recorder (Bruel & Kjaer 7003). EGG recordings were made during six 3-min periods, ie, immediately before exposure and 8, 19, 29, 42, and 61 min after the onset of exposure. The signals were frequency-analyzed in the frequency range 0–10 Hz with the use of the aforementioned FFT analyzer, and the average spectra for 3-min periods were calculated. The power spectrum density from four frequency bands (with center frequencies of 0.05, 0.09, 0.13, and 0.17 Hz) and a 0.04-Hz bandwidth were included in the further analysis of the data. The ratios between the exposure and preexposure values were subjected to analyses of variance.

Design

Each subject took part in three conditions on separate days, two of which involved a 64-min exposure to one of the recorded vibrations, whereas the third was a control condition without vibration exposure. The order of the three conditions was balanced over the subjects.

Figure 1. Mean standard deviations of the sagittal stabilogram before and 1 min and 15 min after the control and exposure conditions.

Results

Stabilography

In figure 1 the mean standard deviation of the force (Newton) in the X direction is presented. The standard deviation was, under all conditions, larger immediately after and even 15 min after the 64-min period than in the preexposure condition. This effect, however, seemed to be equally large in the control situation as in the vibration exposure. The absence of any effect of vibration exposure was confirmed by the analysis of variance which showed that there was a significant effect of time ($P < 0.05$) but no main effect of vibration or any interaction between the two factors. The frequency analysis did not reveal any further differences between the conditions.

Electrogastrography

The quality of many of the EGG recordings was too low to allow further analysis. Thus acceptable recordings in all three conditions were obtained for only nine of the 15 subjects.

As expected, the frequency spectrum had a marked peak at the lowest frequency bands analyzed (0.03–0.06 Hz). Figure 2 shows the ratio between the pre-exposure and exposure values at the five points of measurement under the three conditions. In all frequency bands an increased activity was apparent after 10 min of exposure to the 3-Hz vibration. However, after 20 min the activity had returned to the level of the control condition. This effect was confirmed by the analyses of variance, which showed that the interaction between time and exposure was significant for the 0.09-Hz ($P = 0.03$), 0.13-Hz ($P = 0.0005$), and 0.17-Hz ($P = 0.003$) bands and nearly significant ($P = 0.076$) for the 0.05-Hz band.

In separate analyses of the last four measurement points no significant interaction emerged. Thus, apart from the initial response in the 3-Hz condition, the time course of the EGG activity did not differ between the three conditions. However, these analyses also showed that the 6-Hz condition yielded a generally higher EGG activity than the 3-Hz and control conditions in the 0.05- and 0.13-Hz bands ($P = 0.046$ and 0.009 , respectively).

Figure 2. Mean electrogastrographic (EGG) activity during the control and exposure conditions expressed as the ratios between the exposure and "before exposure" values. Data from four frequency bands are presented. (Rel = relative)

Discussion

The stabilographic measurements did not reveal the slightest tendency towards an increased body sway as a result of the exposure to whole-body vibration. On the other hand, sitting for an hour obviously had this effect. Meister et al (9) also found that sitting led to increased body sway, and this effect may have been a confounding factor in some of the referred experiments purported to confirm the existence of such an effect of vibration.

It is of course possible that exposure to vibration in the 1–10 Hz range while a person is in a sitting position still might have some effect on postural control. If so, it must be of a very transient character or the critical vibration frequency for such an effect lies below 3 Hz or above 6 Hz. The EGG measurements showed that the 3-Hz vibration caused an initially raised activity in all frequency bands. An initial effect was also found by Stern (16) in his experiments on noise. However, of greater interest is the more long-lasting, increased EGG effect of the 6-Hz vibration in the 0.05- and 0.13-Hz bands.

The results of the EGG analyses must be interpreted cautiously since these analyses were not the primary purpose of the study. Thus, it was not possible to keep time of day for the experimental sessions and food intake constant. Part of the subjects went through the experiment about 1 h after lunch, whereas other sessions were carried out before lunch. However, the conditions did not differ systematically in this respect, and thus it ought not to have influenced the main tendencies of the data.

The physiological interpretation for the EGG data is not yet clear. However, signals originating from the stomach seem to come from the circular layers of smooth muscles of the corpus and antrum parts of the stomach, as these muscles contract concentrically and occlude the gastric lumen either partially or completely. These contractions move as the peristaltis (0.05 Hz) and are stimulated by the vagus nerve and by gastrin. Other motions such as segmentation and pendular motions occur at higher frequencies (8–20 contractions/min), which therefore may explain these frequencies in the EGG spectrum.

Although tentative, the results are promising enough to warrant a follow-up study with the more advanced techniques of EGG measurement (4).

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