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OCCUPATIONAL ASPECTS OF INFRASOUND AND WHOLE BODY VIBRATIONS

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Changes in wakefulness during exposure to infrasound and whole body vibrations were analysed by means of EEG, pulse rate and blood pressure recordings. Both infrasound at 6 Hz 115 dB(lin), and whole body vibrations at 3 Hz 110 dB, in laboratory exposures of 15—20 minutes, were correlated to significant reductions in wakefulness.

The aim of this paper is to present, briefly, some of the present-day knowledge on infrasound and low frequency vibration. Special interest will be directed to the experimental work carried out on changes in wakefulness and to the occupational aspects and consequences of possible effects of infrasound and vibrations.

INFRASOUND

Infrasound is defined as airborne sound in the frequency range below 20 Hz. Infrasound is generated at low levels by several natural phenomena such as thunder, air turbulences, volcanic activity, winds, large waterfalls, or ocean waves (1). Until the early 1960s this type of sound had been the subject of a very few studies. Today, however, the number of man made sources appears to be growing both in terms of intensity and incidence of exposure, e.g. airplanes, helicopters, cars, busses, lorries, trains, ships, air heating and cooling units, ventilation systems, compressors and transformers (2). The source of infrasound are often the same as those of audio-frequency noise, including turbulences, resonances, pulsating and reciprocating processes. The sound is propagated over great distances with a relatively little loss of energy. In some cases the sound pressure may be increased by resonances in environments far from the generating source. The infrasonic energy will not be absorbed by earmuffs. It soon became apparent that this type of noise could cause annoyance, interfere with task performance and also cause biological damage (3). General text-books on sound give the impression that the range of human hearing covers the region from 20 Hz to 20 kHz. However, the obvious discomfort of people exposed to low frequency noise indicates that human perception of infrasound is far from absent (4). In fact, a close correlation seems to exist between hearing perception and physiological effects. Recently, thresholds of hearing and changes in wakefulness due to infrasound have been examined by *Landström and co-workers* (5). Exposure to infrasound was carried out in a pressure chamber specially constructed for lower frequencies. Production of infrasound was achieved by means of eight loudspeakers placed on the walls. The thresholds of hearing at different infrasonic sinusoidal frequencies were tested according to the principle of traditional audiological tests. The results are shown in Figure 1.

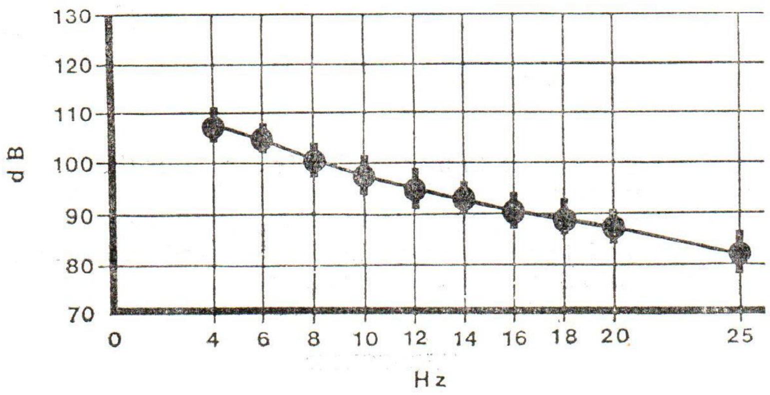

Fig. 1 — ***Mean value and standard deviation of hearing thresholds at 4—25 Hz (n = 10).***

Hearing perception of infrasonic frequencies is thought to be based on harmonics produced within the middle and inner ear. The hearing sensations are described as soft pulses or flutterings. The experimental laboratory exposures (20 minutes), at levels above the hearing threshold, were often found to be combined with weariness. The effect on wakefulness has been analysed by means of physiological tests. The reduction in wakefulness during periods of infrasonic exposure was confirmed through significant changes in EEG, (increase in theta activity), and reductions in blood pressure and heart activity (Figures 2 B, 3 B). The hypothesis that the reduction in wakefulness is based on hearing perception was confirmed by the absence of weariness among deaf subjects (Figures 2 A, 3 A).

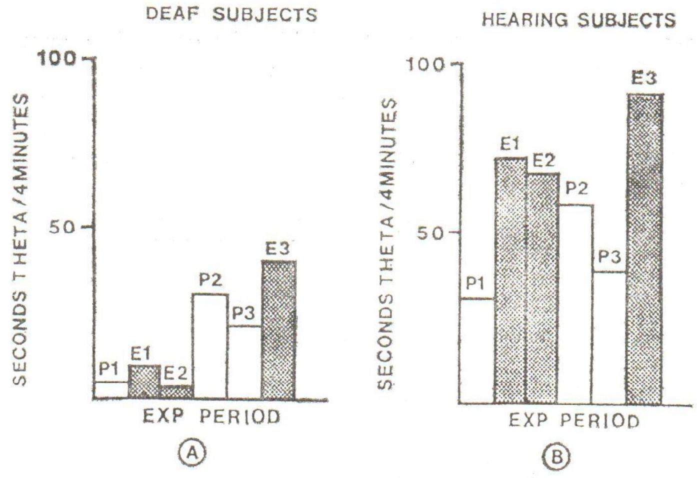

Fig. 2 — *Mean value of changes in theta activity during periods of infrasonic exposure, 6 Hz 115 dB (lin) (dark columns). Reduction in wakefulness correlated to increase in theta activity. A = deaf subjects (n = 10), B = hearing subjects (n = 10).*

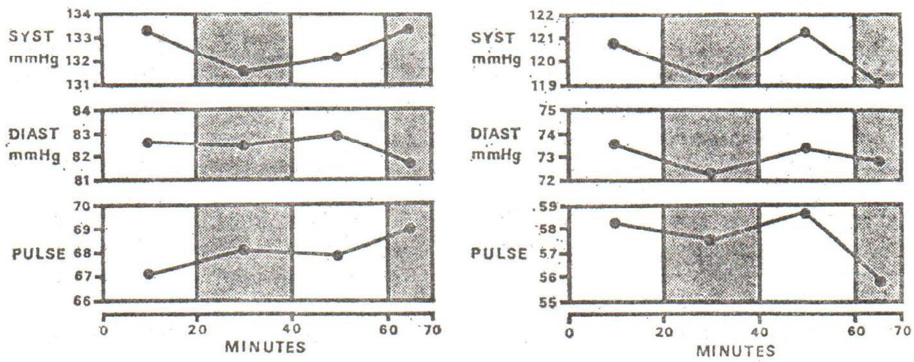

Fig. 3 — *Mean value of changes in blood pressure and heart activity during periods of infrasonic exposure, 6 Hz 115 dB (lin) (dark areas). Reduction in wakefulness correlated to reductions in blood pressure and heart acitivity. Left = deaf subjects (n = 10). Right = hearing subjects (n = 10).*

The effect is thought to be based on interactions between the cochlear system, the reticular activating formation, the cortex, the hypothalamic region and other parts within the central nervous system (Figure 4). According to this hypothesis, in cases of physiological effects the energetic level of the sound must always be high enough to allow hearing perception to occur. This is probably not only a condition necessary for appearance of weariness but also for causing annoyance.

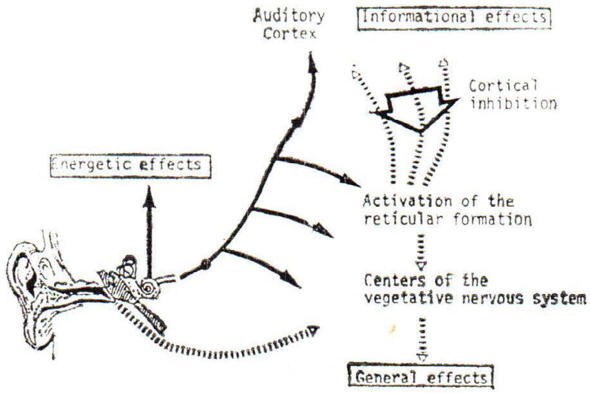

Fig. 4 — *Neural interactions between the cochlear sensory system, reticular formation, cortical regions and vegetative nervous system.*

Under these conditions, the infrasonic levels usually found in our working environments might be involved in a different kind of performance, annoyance etc.

Adverse and temporary effects on hearing, middle ear pressure, aural pain, modulation of speech, disturbances of motor performance, vestibular effects or respiratory rhythm modulations only appear at extreme levels (above 130 dB(lin)). Such levels seldom appear in normal environments (6). The hazard of infrasound is a question of the secondary consequences of weariness, annoyance and other types of CNS disturbances. At levels above the hearing threshold, infrasound might be a factor involved in accidents, performance efficiency, comfort etc. At present this might be a situation in e.g. transport, industry, offices etc.

WHOLE BODY VIBRATION

Vibration at low frequencies below 100 Hz and its effect on the human organism are closely related to infrasound. Their frequency range is similar, in both vibration and infrasound the inner ear is

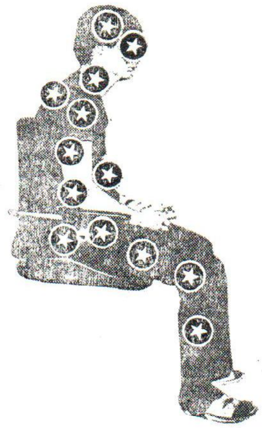

Fig. 5 — ***Localisation of sensations evoked during exposure to whole body vibration at 3 Hz, 110 dB.***

an important receptor, they both occur side by side in many environments and many of their effects, demonstrated or postulated, are comparable. Historically, however, vibration has been known as a problem for several decades. The complex of the vibration problem or of mechanically induced alternating forces, dates back to the original development and use of motor vehicles, jets, helicopters, ships, trains, tractors, earthmoving equipment etc. Exposures to these types of sources are often dominated by lower frequencies directed towards seated individuals. The vibration forces are often generated in vertical direction towards larger parts of the body. The exposure is therefore often classified as whole body vibration. The effects of vibration include a number of specific disturbances in the body, e.g. motion sickness, disturbances in vision and muscle coordination, muscle fatigue and chronic effects.

The perception of whole body vibration is based on sensations transmitted from different types of receptors. Vibrations are sensed by Pacinian corpusles in deeper parts of the body, muscle spindles, Golgi tendon organ, joint organs, mechanoreceptors in the skin, the non-auditory labyrinth and by vision. Perception of vibration is an important factor in the case of discomfort which is a subjective sensation of physiological and psychological displeasure. Subjects usually express discomfort as disturbing, unpleasant, uncomfortable, annoying, alarming, objectionable and fatiguing. Discomfort is one occupational aspect of whole body vibration, comfort is another. In some cases whole body vibration will be sensed as pleasant, comfortable and is sometimes deliberately used for putting us to sleep (the rocking chair, the hammock, the cradle). The occupational aspects of an unintentional weariness are well understood in cases where alertness is demanded.

The reduction in wakefulness due to whole body vibration has recently been verified by *Landström and co-workers (7)*. The subjects were exposed to a frequency of 3 Hz and 110 dB (common exposure in tractors, trains and road vehicles). Exposure to this frequency and level was described as movement of the whole body activating a large number of receptors within the nervous system (the labyrinth, proprioreceptors, vision, mechanoreceptors etc). The repetitive stimulations are directed to the reticular formation and the central nervous system through the sensory nervous paths (Figure 5).

A significant weariness after a 15-minute exposure was confirmed through EEG recordings (increased theta activity), and reductions in heart activity (Figure 6).

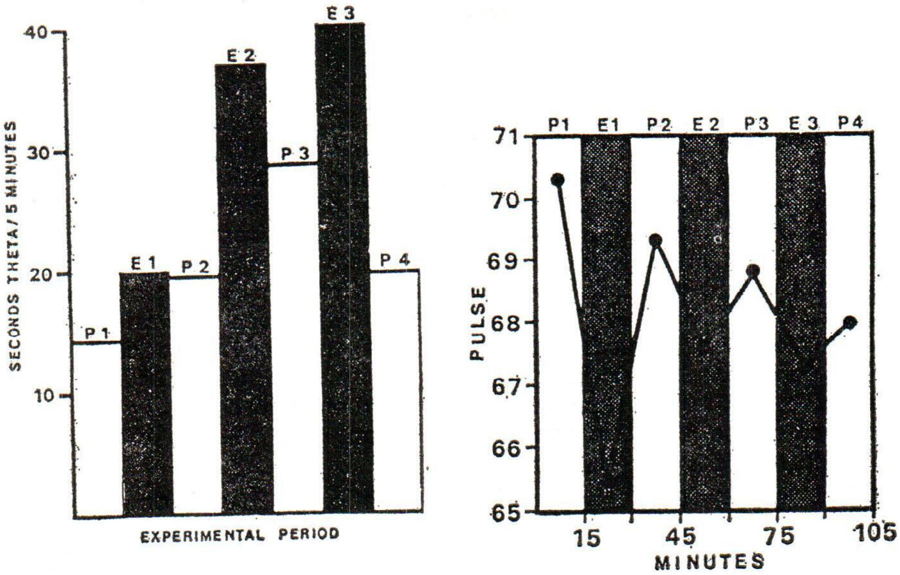

Fig. 6 — *Mean value of changes in theta activity and pulse during exposure to whole body vibration, 3 Hz 110 dB (dark areas). Reduction in wakefulness correlated to increase in theta activity and reduction of pulse rate (n = 15).*

CONCLUSION

The effect of whole body vibration (»a cradle for the body«) is comparable to the effect of infrasound. Both exposures are in some cases correlated to reductions in wakefulness. This circumstance is of course alarming since they often occur in the same type of environment and at times when alertness is important (road vehicles, trains, helicopters, ships etc). Measures should be directed at eliminating low frequency vibrations and the infrasonic source. The measures might also include changes of the working environment in favour of increased wakefulness (light, temperature, routines, working-hours etc).

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Sažetak

ULTRAZVUK I VIBRACIJE SA STANOVIŠTA PROFESIONALNOG OŠTEĆENJA

Opisuju se današnje spoznaje o štetnim učincima ultrazvuka i niskofrekventnih vibracija. Istraživanja su provedena na nekoliko parametara i posebice s obzirom na budnost. U ispitanika koji su bili izvrgnuti ultrazvuku od 6 Hz i 115 dB i vibraciji cijelog tijela od 3 Hz i 110 dB tijekom 15—20 minuta mjeren je ritam pulsa, krvni tlak i sniman je EEG. Utvrđeno je da postoji značajna korelacija između stupnja ekspozicije i smanjenja budnosti. Ova zapažanja upućuju na to da niskofrekventne vibracije i ultrazvuk, što se javljaju na nekim radnim mjestima (kamioni, vlakovi, brodovi, helikopteri i sl.) mogu štetno utjecati na budnost osoba u kojih je visoki stupanj budnosti bitan za rad. U takvim prilikama bilo bi korisno uvoditi promjene u okolini (temperatura, svjetlo, radno vrijeme itd.) čime bi se povećao stupanj budnosti, ukoliko se ne mogu ukloniti izvori vibracija i ultrazvuka.

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