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CORRELATIONS BETWEEN MECHANICAL VIBRATIONS AND HUMAN HEALTH

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ABSTRACT
The human body is made up of organ systems composed of different tissues. When it is exposed to a source of vibration, it reacts as a set of linked masses. Each tissue mass has its own natural frequency. Smaller structures tend to resonate at higher frequencies and larger masses tend to resonate at lower frequencies. Biologically the situation is by no means simpler, especially when psychological effects are included. In considering the response of man to vibrations and shocks it is necessary, however, to take into account both mechanical and psychological effects. Knowledge about comfort and fatigue-decreased proficiency is based on statistical data collected under practical and experimental conditions. Because experiments with human beings are difficult, time consuming and in extreme cases unesthetical, much of the knowledge about damaging effects has been obtained from experiments on animals. It is, of course, not always possible to "scale" results obtained from animal experiments to reactions expected from man, but nevertheless such experiments often result in valuable information. The aim of this paper is to presents some correlations between vibrations and human health.
Keywords: Vibration, Human Body, Health

1. INTRODUCTION
Vibrations can be defined as oscillations of mass about a fixed point. When the body comes in contact with a mechanical source of vibration the tissues of the body become displaced from their resting position. In the work setting there are basically three types of vibration that are significant to the worker. These include whole body vibration, segmental vibration and resonance. The most common form of whole body vibration is vehicular vibration. In this case vibration enters the body through the buttocks and the feet and to a lesser extent the hands. Segmental vibration is the result of mechanical vibration that is exposed to body parts and the effect becomes localized. This form of vibration is transferred into the hands and arms when we use power tools.
All physical systems have their own natural frequency. When tissues of the body are exposed to sources of vibration corresponding to their natural frequency these tissues go into resonance. That is, the strength or amplitude of the vibrations exceeds that of the source. When the body comes is contact with mechanical vibration there is a direct adverse physiological effect on the body. The effect interferes with work efficiency and in some situations can put the worker at risk for injury. Any factor that has the potential to impair the worker’s function is a significant issue in ergonomics and therefore must reduce to the greatest extent possible. Knowledge about comfort and fatigue-decreased proficiency is based on statistical data collected under practical and experimental conditions. Because experiments with human beings are difficult, time consuming and in extreme cases unesthetical, much of the knowledge about damaging effects has been obtained from experiments on animals. It is, of course, not always possible to "scale" results obtained from animal experiments to reactions expected from man, but such experiments often result in valuable information.

2. CHARACTERISTICS OF VIBRATION

In examination of the impact of vibration upon the human body, there are several characteristics of the vibration that must be taken into account. Direction, rotation, frequency, magnitude, point of entry, and duration are all factors which play a part in determining how vibration is transmitted throughout the body, and hence, how the body changes as a result. Direction of vibration is expressed in terms of three linear axes. These axes of vibration are fore-and–aft (x axis), lateral (y axis), and vertical (z axis). On the human body, the x axis is mapped as being from the back-to-chest, the y axis is from the right-to-left side, and the z axis is from foot-to-head in the standing or recumbent individual and buttocks-to-head in the seated individual. There are also three rotational vectors that vibration will follow - roll, pitch, and yaw, which correspond to rotation about the x, y, and z axes respectively. Rotational vectors are not usually measured in investigations of occupational vibration [1].

Frequency is usually expressed in cycles per second in Hz. Exposure to certain vibration frequencies may have profound effects on specific parts and systems of the body, particularly if the frequency of vibration corresponds to the resonant frequency of that body part or system. In such cases, vibration in that area is likely to be amplified and therefore may have more pronounced effects on that area as compared to other parts of the body. For vibrations transmitted in the z direction (e.g., for seated individuals where most vibration may be transmitted from a seat pan to the buttocks), resonance for the abdomen, including the soft organs and respiration occurs at approximately 4-8 Hz; spinal and upper torso resonances occur at 10-12 Hz; head and neck resonance occurs at around 30 Hz; and, the eyeballs are resonant at 60-90 Hz [4]. With regard to transmission of vibration throughout the body, in general, the higher the frequency of the vibration, the faster the vibration is attenuated as it moves throughout the body.

The magnitude of vibration is usually expressed in terms of acceleration. The absolute threshold for perception of vertical vibration for frequencies between 1 and 100 Hz is approximately 0.01 m/s^2 [1]. Doubling of magnitude within this range will result in an approximate doubling of the sensation of discomfort. The International Organization for Standardization (ISO), has provided the following guidelines relating magnitude to comfort for passengers on public transport [2]: < 0.315 m/s2 not uncomfortable; 0.315-0.63 m/s2 a little uncomfortable; 0.5-1 m/s2 fairly uncomfortable; 0.8-1.6 m/s2 uncomfortable; 1.25-2.5 m/s2 very uncomfortable; >2 m/s2 extremely uncomfortable.

Obviously subjects' perception of comfort would also depend on their expectations (e.g., the activities they would expect to accomplish), as well as other characteristics of the vibration such as frequency and duration [2]. For example, some visual discomfort might be expected with exposure to frequencies between 60 and 90 Hz – the approximate range of resonance of the eyeballs. Average magnitude is usually expressed as a root-mean-square value (m/s^2), when examining human vibration exposure. It has been generally accepted that discomfort increases with exposure time [2], although the exact relationship is not straightforward.

3. TYPES OF VIBRATION EXPOSURE

Human exposure and response to vibration has been broadly classified as: whole-body vibration (WBV), local (segmental, hand-transmitted) vibration and motion sickness.

The distinction between whole-body vibration and other more localized forms of vibration is not precise. Both types of exposure will result in transmission of vibration throughout the whole body and whole-body exposure commonly has localized components (e.g., seated persons are often exposed to local vibration of the head, hands, and feet). Likewise, motion sickness and WBV are not easily distinguished, given that motion sickness may occur because of exposure to WBV.

Whole body vibration is transmitted to the body through the supporting surfaces such as the feet, buttocks or back. There are various sources of whole body vibration such as standing on a vibrating platform, floor surface, driving, and construction, manufacturing, and transportation vehicles.

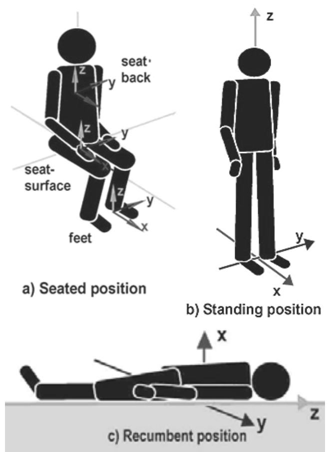

Fig. 1. Coordinate system to evaluate whole-body vibration (from ISO 2631)

The health effects of whole body vibration on drivers of heavy vehicle versus workers in a similar environment who were not exposed to whole body vibration have been compared. Research indicates back disorders are more prevalent and more severe in exposed to vibration versus no exposed workers. With short term exposure to vibration in the 2-20 Hz range at 1 m/sec2, one can feel several different symptoms: abdominal pain; general feeling of discomfort, including headaches; chest pain; nausea; loss of equilibrium (balance); muscle contractions with decreased performance in precise manipulation tasks; shortness of breath; influence on speech.

Long-term exposure can cause serious health problems, particularly with the spine: disc displacement; degenerative spinal changes; lumbar scoliosis; intervertebral disc disease; degenerative disorders of the spine; herniated discs; disorders of the gastrointestinal system; uro-genital systems.

Local vibration and segmental vibration are terms that have been used to refer to exposure when vibration is transmitted from a vibrating surface to part of the body. Often this exposure is also referred to as hand-arm, or hand-transmitted vibration, as it most commonly occurs with the use of vibrating tools, which are often hand-held. Most tools vibrate in the range of 8 to 1000 Hz. Local vibration has been associated with circulatory disorders, bone and joint disorders, neurological disorders, muscle disorders and other general disorders (e.g., central nervous system).

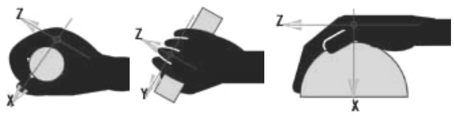

Fig. 2. Coordinate system for the measurement of hand-arm vibration (ISO 5348; 1986)

Hand-arm vibration (HAV) is the second large problem area where transmission into the human body is concerned. It is, however, rather different from whole-body vibration in the type of problems to which it gives rise. Whereas vibration transmitted into the standing or seated body normally gives rise to problems of a general nature, e.g. motion sickness, discomfort, reduced-working efficiency, etc., vibration applied to the hand-arm may, in addition, produce actual physical damage locally if the level and exposure times are sufficiently high.

The most prominent health problem associated with exposure to vibration by the use of hand tools is the vascular disorder most commonly known as vibration-induced white finger (VWF), which occurs due to damage of the small blood vessels of the fingers. This condition arises only after long-term prolonged exposure to hand-transmitted vibration (it can take 4-10 years before symptoms begin), and is characterized by blanching of fingertips (progressing to whole fingers), and reduced sensitivity, followed by a sudden return of blood (red flush) with intense pain. VWF usually occurs as a result of exposure to vibration between 25 and 250 Hz (however there is some evidence that higher frequencies might also cause vascular problems). An associated neurological condition – vibratory neuropathy, may appear prior to and during the course of VWF blanching. This represents the sensory changes due to damage of nerve endings in the fingers and can be responsible for the tingling or numbness of the fingers that occurs during an attack of blanching. Bone and joint disorders (osteoarthritis, degeneration or deformity of bones of the hands, decalcification, cysts, and vacuoles) are associated most frequently with percussive vibration between approximately 10 and 50 Hz [1].

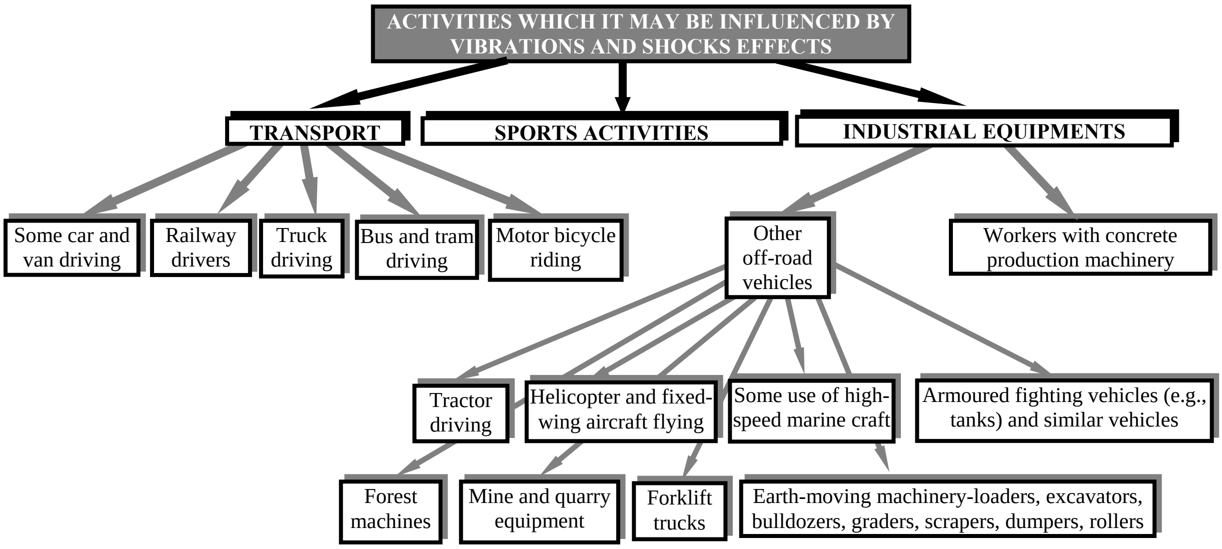

Figure 3. Activities which it may be influenced by vibrations and shocks effects

Motion sickness results from exposure to frequencies below 1 Hz, more particularly those below 0.5 Hz. Symptoms are many and varied, but may include vomiting, nausea, sweating, spatial unease, drowsiness, and dizziness. While motion sickness is most common in children, and many fail to show signs of susceptibility in adulthood, it has been demonstrated that everyone may be made sick if the appropriate stimulus is used. Symptoms are most frequently observed in moving vehicles but there are a number of other environments where motion sickness may be initiated (e.g., fairground devices, simulators, microfiche readers, swimming) [1]. The frequency-dependent effects of vibration on humans are summarized in figure 4.

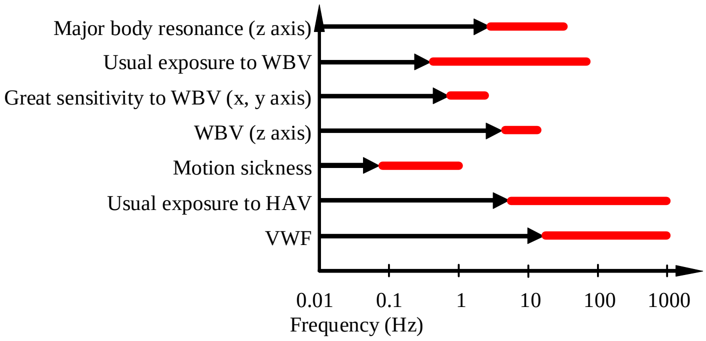

Fig. 4. Frequency-dependent effects of vibration on human body

4. CONCLUSIONS

Occupational exposures to whole-body vibration mainly occur in transport but also in association with some industrial processes. Land, sea and air transport can all produce vibration that can cause discomfort, interfere with activities or cause injury. The most common exposure to severe vibration and shocks may occur on off-road vehicles, including earth moving machinery, industrial trucks and agricultural tractors.

Hand power tools tend to vibrate at relatively high frequencies so they would set up resonance frequencies at the point of contact at the fingers and the vibrations would become dampened (by reducing the amplitude) as they travel up the arm. In fact, any frequencies over 30 Hz become significantly dampened as they travel from the fingers into the larger tissues of the body. When the muscles of the body are exposed to vibration, they react by exhibiting a protective reflex. The reflex causes the muscles to contract and shorten resulting in an increase in energy consumption. These sustained static muscle contractions result in a rapid fatiguing of the muscle. Fatigued muscles are much more susceptible to injury. The most significant effect is the contraction of the muscles that line the walls of the small blood vessels. These muscles serve to regulate blood flow by constricting and dilating the vessel size. Blood flow is cut off to the affected body part resulting in numbness and tingling. The worker consequently looses sensation and motor control. This condition is known as vibration syndrome or white finger syndrome. Susceptibility is particularly increased when coupled with cold working conditions, eliciting a condition known as Raynaud’s disease. It is known that there are measurable effects on visual acuity with vibrations of the eyes beyond 4 Hz and especially in the range of 10-30 Hz. Images in the visual field becomes blurred and visual acuity is sharply reduced.

It can conclude that the heavy equipment operators and drivers are particularly at risk for accidents and injury due to the above factors. In addition, studies involving strong vibrations such as those seen in resonance frequencies, the brain’s ability to process information and the performance of skilled motor tasks become impaired. In the case of jack-hammers and chain saws, where the vibrations are lower than 40 Hz there is the risk of losing bone mass in the arms along with developing osteoarthritis and tendonitis in the wrist and elbow.

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