LITERATURE ON VIBRATION AND THE HUMAN BODY

A study which demonstrates of why shiatsu massage systems are better than vibration systems

Introduction to Vibration

Vibration is the oscillatory motion of various bodies. All bodies with mass elements and elasticity are capable of vibration; hence, most machines and structures including the human body experience vibration to some degree. Two different categories of vibration are distinguished in literature. Free vibration takes place when the system oscillates due to the action of internal forces only. Forced vibration is caused by the action of external forces. If the frequency of excitation coincides with the natural frequency of the system, resonance occurs. The result is large oscillations within the structure of creating potentially harmful stress. For example, the potential effect of resonance is the shattering of a crystal glass, when opera singer sings at the natural frequency of the crystal. Because of energy dissipation due to friction and other resistances, damping occurs in all structures.

The Effects of Vibration on the Human Body

Vibrations influence the human body in many different ways. The response to a vibration exposure is primarily dependent on the frequency, amplitude, and duration of exposure. Other factors may include the direction of vibration input, location and mass of different body segments, level of fatigue and the presence of external support. The human response to vibration can be both mechanical and psychological. Mechanical damage to human tissue can occur, which are caused by resonance within various organ systems. Psychological stress reactions also occur from vibrations, however, they are not necessarily frequently related.

From an exposure point of view, the low frequency range of vibration is the most interesting. Exposure to vertical vibrations in the 5-10 Hz range generally causes resonance in the thoracic-abdominal system, at 20-30 Hz in the head-neck-shoulder system, and at 60-90 Hz in the eyeball. When vibrations are attenuated in the body, its energy is absorbed by the tissue and organs. The muscles are important in this respect. Vibration leads to both voluntary and involuntary contractions of muscles, and can cause local muscle fatigue, particularly when the vibration is at the resonant-frequency level. Furthermore, it may cause reflex contractions, which will reduce motor performance capabilities.

The amount of mechanical energy transmission due to vibrations is dependent on the body position and muscle contractions. In standing subject, the first resonance occurs at the hip, shoulder, and head at about 5Hz. With subjects sitting, resonance occurs at the shoulders and to some degree at the head at 5 Hz. Furthermore, a significant resonance from shoulder to head occurs at about 30 Hz as shown in Figure 1.

Based on psychological studies, observations indicated that the general state of consciousness is influenced by vibrations. Low frequency vibrations 1-2 Hz with moderate intensities induce sleep. Unspecific psychological stress reactins have also been noted (Guignard, 1965: von Gierke, 1964), as well as degraded visual and motor effects on functional performance. Some symptoms of vibration exposure at low frequencies are given in Table 1, along with the frequency ranges at which the symptoms are most predominant.

TABLE 1

Symptoms Due to Whole-Body Vibration and the Frequency Range at which They Usually Occur (Adapted from Rasmussen, 1982).

Symptoms	Frequency (Hz)
General feeling of discomfort	4-9
Head symptoms	13-20
Lower Jaw symptoms	6-8
Influence on speech	13-20
“Lump in throat”	12-16
Chest Pains	5-7
Abdominal pains	4-10
Urge to urinate	10-18
Increased muscle tone	13-20
Influence on breathing movements	4-8
Muscle contractions	4-9

Effects of Vibration on the Spine

In recent years, considerable thought has been given to the effects of vibration on the spine. Many studies are suggesting an increased risk of low-back pain in drivers of tractors (Rosegger and Rosegger, 1960; Dupuis and Christ, 1972); of trucks (Kelsey and Hardy, 1975; Gruber, 1976; Frymoyer et al., 1980) of buses (Gruber and Ziperman, 1974; Kelsey and Hardy, 1975); and of airplanes (Fitzgerald and Crotty, 1972; Schulte-Wintrop and Knosche, 1970). These studies indicated that low-back pain occurs at an earlier age in subjects exposed to vibration. It was reported that truck driving increased the risk of disk herniation by a factor of four, while tractor driving and car commuting (greater than 20 miles/day) increased the risk by a factor of two. Also, studies of vibration exposed populations (Rosengger and Rosegger, 1960; Dupuis and Christ, 1972; Gruber, 1976) indicated that radiographic changes occur in the spines of these subjects.

It is well known that the spine fractures (in compression) when subjected to strong vertical acceleration. Vibration at lower acceleration levels have been suggested to cause fatigue failures of different component structures of the spine; these vibrations also interfere with the nutrition of the disc, predisposing it to degenerative changes (Sandover, 1981 and 1985). Wilder et al. (1982); Punjabi et al. (1986); Pope et al. (1987) Hagnea et al. (1986) and Broman et al. (1989) measured the response of the trunk to whole-body vibrations. Their results indicated that the resonance frequency is between 4-5 Hz. Trunk muscle activities during vibration have also been measured (Seroussi et al. 1987) a cyctic muscle activity occurs for experimental seated subjects. Significantly higher EMG activities were observed for vibration as compared to static moment loads only.

Vibration Syndrome

The upper extremities of the human being can be considered a unique body segment. As with whole body vibration, the response to segmental vibration depends on frequency, amplitude, etc. Segmental vibration causes a symptom complex usually referred to as vibration syndrome. The symptom originates from injuries to the blood vessels, nerves, bones, joints and muscles. Injuries can occur after exposure times from months to decades, and are usually, at first, reversible. The most well known of these symptoms is Reynaud's Syndrome or Traumatic Vasopastic Disease (TVD) (Taylor, 1974). In industry is called the white finger disease/syndrome. The syndrome can be described as a sudden block in the blood circulation to the fingers, which become white, pale, cold and sometimes painful. Tactile sensitivity is reduced, preventing precision work. TVD is caused by smooth muscle constriction in the blood vessels of the fingers. Other vibration-induced symptoms come from the peripheral nerves and consist of paresthesias and tingling sensations. A decreased nerve action-potential conduction velocity has been found, and a decrease in the ability to perform precise motor movement of the fingers.

Transmission of Vibration in the Upper Extremity

Most hand held tools generates random vibration over a wide frequency range (typically 2 2000 Hz) Low-frequency vibrations can be transmitted to the trunk and head. It may cause unspecific symptoms such as headache, vertigo, nausea, and psychological stress reactions. Attenuation occurs with 3dB/octave in the frequency range of 20 – 100Hz. The attenuation of the elbow and upper part of the arm increases by about 10dB/octave between 100 & 630 Hz, and the wrist by about 6 dB/octave. Iwata (1972) found that the vibration at the wrist was two to three times higher at 20 Hz that the input vibration; that is, resonance had occurred.

The transmission of vibrations in the upper extremity is linear. When the vibration of hand-held tool increases by 10 dB. The hand grip force is important to the transfer function. When increased from 20 N to 40 N 912dB), the hand vibration increases only by 3 to 5 dB. It appears that the transmitted vibration is proportional to the cube root of the hand grip force (Pyykko et al., 1976). Several factors influencing the transmissions of vibrations to the hand are listed in Table 2.

Concluding Remarks

- The automotive industries strive to reduce vehicle vibration, in particular its transmission to the seats. It has been shown that vibration increases discomfort and reduces operator performance.
- Excellent massage systems should be able to enhance the comfort of truck muscles, but not increasing discomfort (Seroussi et al., 1987 indicated that vibration significantly increases truck muscular activities when compared to static loading using EMG techniques.
- Resonance frequency must be avoided; in particular, frequencies in the range of 5Hz. It may not be easy to avoid these frequencies when a massage system based on the concept of vibration is integrated to automobile seats. Combined vibrations from various systems may generate undesirable resonance frequencies, which are unacceptable to the human body.

TABLE 2

Factors Known or Believed to Influence the severity of Occupational Exposure of the Hand to Vibration (Bramer and Taylor, 1982)

Physical:

Dominant vibration frequencies entering the hand
Years of employment involving vibration exposure
Total duration of exposure each work day
Temporal pattern of exposure each work day
Dominant vibration direction relative to the hand
Nonoccupational exposure to vibration

Biodynamic

Hand grip forces
Surface area, location and mass of parts of the hand in contact with the source of vibration
Posture (position of the hand and arm relative to the body)
Other factors influencing the coupling of vibration into the hand (e.g.., texture of handle)

Individual:

Factors influencing source intensity and exposure duration (e.g., tool maintenance,
Work rate, skill, and productivity)
Biological susceptibility to vibration.
Vasoconstrictive agents affect the peripheral circulation (e.g., smoking, drugs)
Predisposing disease or prior injury to the fingers or hands (trauma, lacerations, etc.)
Hand size and weight
Epidemiological factors (age, etc.)

FIGURE 1

Transmissibility of Vertical Vibration From Table to Various Parts of the Body of a Sitting human subject as a function of Frequency (Adapted from Rasmussen, 1982).