Whole-body Vibration

DEA350

Vestibular Apparatus

- The position and motion of the head is detected by the vestiblular apparatus. This gives us our sense of equilibrium and movement coordination.
- The vestibular apparatus comprises two sets of detection apparatus:
  - Semicircular canals
  - Vestibular sacs

Semicircular Canals

- 3 semicircular canals in each ear.
- These canals are interconnected hollow, fluid-filled doughnut-shaped tubes surrounded by bone.
- The canals are orthogonally oriented on a different plane to detect movement in that direction in space.
- They detect head movement - the position and linear velocity of the head, along with input from the vestibular sacs (utricle and saccule) and the cochlea.

Semicircular Canals

- The ampulla is a widened section that lies at the base of each canal. It contains a group of hair cells.
- Each hair cell has several hair-like structures and one larger extension called a kinocilium, which is attached to hairs.
- A gelatinous material, called the cupula, sheaths the hairs and the kinocilium. The cupula attaches to the ampulla and extends across the lumen of each duct.

Hair Cell Function

- When the hair cells bend toward the kinocilium there is a depolarization potential and an increase in vestibular nerve firing.

- When the hair cells bend away from the kinocilium the membrane hyperpolarizes, and there is an inhibition of vestibular nerve firing.

Detecting Head Position

- Head rotation is detected because the fluid in the semicircular canals moves in an opposite direction to the direction of head movement.
- When the head moves the force exerted by the fluid movement relative to the semicircular canal bends the cupula, which bends the hairs of the hair cells.

Vestibular Sacs

- Hair cells located in two connected sacs: the utricle and saccule. Detect static head position, changes in linear acceleration, and changes in head position relative to gravity. These sacs also connect with the cochlea.
- These sacs contain the macula, a special arrangement of sensory cells that have hairs that are embedded in a thick gelatinous material containing numerous otoliths (small calcium carbonate crystals).
- With head movements, the otoliths fall in the direction of gravity, which bends the hairs in that direction, producing a receptor potential which tells us which way up the head is pointing.

Whole Body Vibration

- Every object (or mass) has a resonant frequency.

- When an object is vibrated at its resonance frequency, the maximum amplitude of its vibration will be greater than the original amplitude (I.e. the vibration is amplified).
- Vibrations in the frequency range of 0.5 Hz to 80 Hz have significant effects on the human body.
- Individual body members and organs have their own resonant frequencies and do not vibrate as a single mass, with its own natural frequency. This causes amplification or attenuation of input vibrations by certain parts of the body due to their own resonant frequencies.
- The most effective resonant frequencies for vertical vibration lie between 4 and 8 Hz.
- Vibrations between 2.5 and 5 Hz generate strong resonance in the vertebra of the neck and lumbar region with amplification of up to 240%.
- Vibrations between 4 and 6 Hz set up resonances in the trunk with amplification of up to 200%.
- Vibrations between 20 and 30 Hz set up the strongest resonance between the head and shoulders with amplification of up to 350%.
- Whole body vibration may create chronic stresses and sometimes even permanent damage to the affected organs or body parts.

Whole Body Vibration

Whole Body Vibration – Exposures

- Ride quality for people movers, elevators and escalators
- Swaying buildings
- Building vibrations (highway traffic)
- Mobile workplaces (cars, buses, trains, planes, boats etc.)
- Hand-Arm and Whole-Body Vibration ANSI S3.34-1986
- ISO 2631 (International Organization for Standardization) Human Response To Whole Body Vibration standard
  - "Evaluation of human exposure to whole-body vibration -- Part 2: Continuous and shock-induced vibrations in buildings (1 to 80 Hz)" (1989)

Whole Body Vibration – ISO 2361

- ISO 2361 (parts 1,2, and 4) gives three types of exposure limits:
  - Reduced-comfort boundary
    - This is for the comfort of people traveling in airplanes, boats, and trains.
    - Exceeding these exposure limits makes it difficult for passengers to eat, read or write when traveling.
  - Fatigue-decreased proficiency boundary
    - This is a limit for time-dependent effects that impair performance. For example, fatigue impairs performance in flying, driving and operating heavy vehicles.
  - The exposure limit
    - This is used to assess the maximum possible exposure allowed for whole-body vibration.
  - Also, "severe discomfort boundaries" for 8-hour, 2-hour and 30-minute WBV exposures in the 0.1 Hz to 0.63 Hz range are given.
  - Exposure limits are given as acceleration for one third octave band frequencies and three directions of exposure:
    - longitudinal (head <-> toe)
    - transverse (back <-> chest and side <-> side).
  - The exposure limit is the lowest for frequencies between 4-8 Hz because the human body is most sensitive to WBV at these frequencies.

Whole Body Vibration – ISO 2361

Whole Body Vibration – ISO 2361

- ISO 2361 severe discomfort boundaries:

Measuring Whole Body Vibration

- Whole body vibration is measured using:
  - Hand held vibration meter (accelerometer)

Whole Body Vibration – Health Effects

- Suspected health effects of whole body vibration include:
  - Blurred vision
  - Decrease in manual coordination
  - Drowsiness (even with proper rest)
  - Low back pain/injury
  - Insomnia
  - Headaches or upset stomach