REPETITIVE HEAD LOADING: ACCELERATIONS DURING CYCLIC, EVERYDAY ACTIVITIES

[1]Darrin Richards, [1,2]Irving Scher, [1]Vinod Vijayakumar, [1]Michael Carhart, [1]Robert Larson, [3]Sara Taylor, and [1]Catherine Ford Corrigan
[1]Exponent, Failure Analysis Associates, Inc.
[2]University of Southern California, Los Angeles, California
[3]University of Alabama at Birmingham, Birmingham, Alabama

INTRODUCTION

Closed head injury research has primarily focused on acceleration and force thresholds for isolated impulses, such as those experienced in motor vehicle accidents or falls. The effects of activities that result in long duration cyclic exposure have been studied for the thoracic and lumbar spine and standards for vibration dosage have been generated. The international standard ISO 2631-1 [1] provides guidance on measuring and frequency weighting vibration input. This is done for a seated occupant from the seat bottom and seatback, and for person who is standing or recumbent. Health guidance limits are defined for the vibration exposure for a seated occupant, but are mainly related to the lumbar spine and connected nervous system. Little has been done with the head.

When involved in a cyclic activity, such as running or hopping, motion of the torso and neck result in head motion. The frequency content of the accelerations experienced by the head differs from the input. Goldsmith [2] stated that the head resonance is most pronounced at 8Hz for forced harmonic resonances at whole-body frequencies. This could result in signal amplification at response frequencies near 8Hz. The purpose of this study was to investigate the frequency content of linear head accelerations during various repetitive, common activities and determine if there is significant loading at 8Hz.

METHODS

A head accelerometer apparatus was designed and constructed with linear accelerometers mounted to an adjustable lightweight headband. The sensor group had a range of ±10Gs (resolution: 0.0003Gs) along each axis. Each channel was low-pass filtered using a 100Hz anti-aliasing filter then digitally sampled at 500Hz. For testing, the headband was positioned so that the sensors were at the top of the head and its axes were coincident with the mid-sagittal plane and the coronal plane through both external auditory meati. The complete head apparatus weighed 85g.

Fifteen male and fifteen female participants voluntarily performed the activities chosen for the study: hopping (with two feet), running with an abrupt stop, jump rope, and running up and down stairs. Participants exhibited a wide range of age (from 18 to 44 years old), height (1.56 to 1.89m, mean 1.72m), and weight (51 to 106kg, mean 73kg). The subjects were asked to perform the tasks in a quick and precise manner.

The data from the sensors were filtered digitally using a 50Hz low-pass filter. The linear acceleration data were used to determine the accelerations at the approximate center of gravity (CG) of the head. The distance from the sensor to the head CG was estimated using anthropometric measurements and regression formulae given by Zatsiorsky [3].

RESULTS

All thirty participants were able to complete the tasks with no reports of injury or pain. A power spectrum density (PSD) analysis for each task across all subjects revealed that the magnitude decreased consistently by more than 30dB beyond 9Hz (see Figure 1). The largest loading was usually between 1 and 5Hz (see Figure 2). Not surprisingly, the torso and neck essentially acted as a low pass filter, not allowing the higher frequency loading to reach the head. The average number of impulses above 3Gs (a measure of dosage) was computed for each subject and each trial. On average, subjects experienced 58, 84, 24, and 4 impulses above 3Gs per minute for hopping, skipping rope, running, and stair running, respectively.

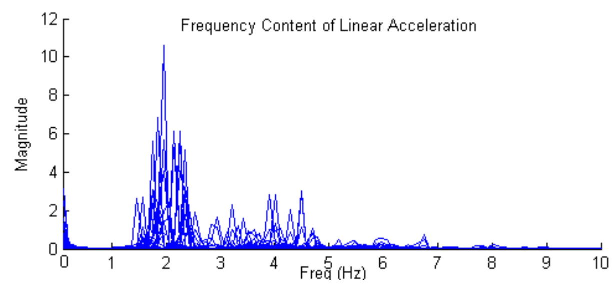

Figure 1: Compiled PSD of head acceleration while skipping rope, for all 30 subjects. The other tasks had similar plots.

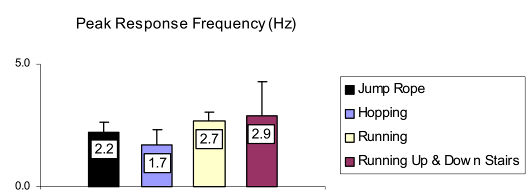

Figure 2: Peak frequency response (mean ± standard error).

DISCUSSION AND CONCLUSIONS

Previous studies have documented forced resonance values of the head, but there is limited information available describing the frequency content of head accelerations during repetitive activities. In this study, we quantified the frequency content associated with a several non-injurious repetitive activities by measuring head accelerations. The response frequency of the head was generally between 0.1 and 9Hz, with the most significant frequency falling between 1 and 5Hz.

REFERENCES

1. ISO 2631-1, Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole Body Vibration, 1997.
2. Goldsmith, W. *Critical Reviews in Biomedical Engineering*, **29(5&6)**, 441-600, 2001.
3. Zatsiorsky, V, et al. *Proceedings of the Ninth International Congress of Biomechanics*, Waterloo, Ontario, 1983.