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**Findings Highlights:**

- **Wheelchair vibration is commonly linked to rider discomfort and low back pain**
- **Whole-body vibration may create fatigue-decreased proficiency after just one hour**
- **Wheelchair users report that vibration from bumps and cracks trigger tremors and muscle spasms**

**And...**

- **The use of Shock-Absorbing Castor Forks greatly reduces vibrations to a wheelchair, supporting the argument that as the amount of shock decreases so do the symptoms it creates.**
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**(Of course, we have ALL of the Proof.... right here!)**

**First, the bad news...**

**From study #1: Wheelchair Vibration is Detrimental for Everyday Users**

**From RESNA Study 012700 (H133E30014) June 1995.**

**LOW BACK PAIN AND WHOLE BODY VIBRATION EXPOSURE FOR WHEELCHAIR USERS**

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**ABSTRACT**

Low back pain is a common problem among people with disabilities, particularly those who use wheelchairs. The whole body vibration of vehicle operators has been linked to high rates of low-back pain complaints. This paper examines the possibility of similar occurrences in wheelchair operators by measuring actual vibration levels in a wheelchair, and comparing with the ISO 2631 standards. In certain circumstances the vibration levels are found to be too high for long-term exposure and comfort. (Red added)

**INTRODUCTION**

Low back pain is a common problem among people with disabilities, particularly those who use wheelchairs. "Ride quality" of manual and powered wheelchairs has been a topic of discussion and research for some time. The recommendations of the Wheelchair III Workshop (1) held in 1982 included a statement that, "the ride of quality of the equipment is considered to be a research item." However, at the same time it was acknowledged that ride quality was ill defined and "research and development effort is needed to provide good safety and comfort to the user." McLaurin, in the Wheelchair IV Workshop (2) in 1988 identified measurable factors of ride quality as vibration, acceleration, jerk, noise, bucking and stability. He noted the natural frequency for a person in a wheelchair in the order of 5 to 6 Hz. In the same report, Thacker identified the potential application of ISO 2631 Whole Body Vibration standards to the vibration experienced by wheelchair users. Thacker suggests the average daily exposure time for a

wheelchair user is 4-8 hours. While whole body vibration has been identified as contributing to "ride quality" for wheelchair users, no one has suggested that this vibration may be a contributing factor to low back pain experienced by wheelchair users. Numerous studies have determined that there may be some correlation between whole body vibration exposure and low back pain (3), (4), and (5). The most commonly reported effects noted in the literature are low back pain, early degeneration of the lumbar spinal system and herniated lumbar disc. However, no firm casual relationship has been established (6). Hansson and Helm (7) have indicated that whole body vibration is involved with pathophysiological aberrations in the spine. Seidel et. Al (8) suggest the possibility of fatigue failures at the endplates of the lumbar vertebrae after intense long-term exposure to whole body vibration.

It seems reasonable to assume that the vibration experienced by wheelchair users may contribute to low back pain and other associated problems. We have conducted a pilot study to determine the level of vibration experienced by a wheelchair user. An inexpensive yet robust field vibration acquisition, data analysis and dosage recording system has been developed that makes the recording and analysis of vibration data easy and efficient.

## METHODS

The prototype data acquisition system consists of a portable PC and integrated circuit accelerometers as the transducers. The vibration data are acquired and analyzed in pseudo-real-time. The data are then converted to an equivalent dosage by frequency domain conversion and comparison with ISO 2631-1 standard.

A 50 MHz 486DX laptop computer was used for this system. Power for the system is supplied by the wheelchair batteries. A custom adapter from the laptop supplies power to the accelerometer amplifiers. Three micro-machined integrated circuit accelerometers were selected for use as a triaxial transducer primarily because of performance, cost and geometry. They provide DC response, are relatively inexpensive and in surface mount configuration are very small. This was obviously a concern as the operator had to sit on the triaxial transducer pack. Simple temperature-compensated quad OP-amp amplifier circuits for accelerometers were made. Signals from the amplifiers are then passed to a PCMCIA-type data acquisition card. A sampling frequency of 250 Hz was used to satisfy Nyquist criteria for a range of frequencies from 1 to 120 Hz in accordance with ISO 2631.1. 1024 point Fast Fourier Transforms (FFTs) were used to convert the time histories to the frequency domain.

The vibration characteristics of a commonly used powered wheelchair were determined using a commercially available vibration assessment system and compared to ISO 2631/1 standards (9). The ISO standard defines and presents numerical values for limits of exposure for vibrations transmitted from solid surfaces to the human body in the frequency range 1 to 80 Hz. Criteria for preserving comfort, working efficiency, and safety and health are named "reduced comfort boundary," "fatigue-decreased proficiency boundary," and "exposure limit" respectively. These limits are defined for the different purposes for which the standards may be used. For example, the "fatigue-decreased proficiency" limit would be used in relation to maintaining the efficiency of a vehicle or equipment operator while the "reduced comfort" limit might be used to define the vibration exposure to assure passenger comfort in transportation systems. The ISO standards do not specifically address the potential biomechanical and pathophysiological effects of vibration on the spine. The "fatigue-decreased proficiency boundary" specifies "a limit beyond which exposure to vibration can be regarded as carrying a significant risk of impaired working efficiency in many kinds of tasks, particularly those in which time-dependent effects (fatigue) are known to worsen performance as, for example, in vehicle driving." The maximum safe exposure, or "exposure limit," is determined for any condition of frequency, duration and direction, by doubling the values allowed for the criterion of fatigue-decreased proficiency. The "reduced comfort boundary," derive from various studies conducted for the transport industries, is approximately one-third of the corresponding levels of the fatigue-decreased proficiency boundary.

## PROTOCOL

Using a commonly-available powered wheelchair, data were collected under a variety of conditions for a single user. The wheelchair control system was set up using the manufacturer's standard values for such parameters as speed, acceleration, sensitivity and braking. Conditions tested included high (H) and low (L) speeds, sling (G) and solid (D) seat, and indoor (I) and outdoor (O). The sling seat was the seat provided by the manufacturer. The solid seat consisted of a ¾" plywood fit between the seat rails. No wheelchair cushion was used. The indoor condition consisted of a clinic hallway carpeted with low pile industrial carpeting. The outdoor condition consisted of a gravel parking lot. A test run was also made on a typical concrete sidewalk at high speed using the sling seat (Sidewalk). Data were collected for a total of 5 minutes for each condition. The vertical acceleration level averaged over the measurement time was compared to the ISO standard.

## RESULTS

Representative samples of raw data in the time and frequency domain are shown below. Table 1 illustrates the results of the pilot testing. Results are reported as time limits as defined by the ISO 2631 standard.

Cond.	Avg. Accel. (m/s <sup>2</sup> )	Red. Conf. Lim. (h)	Fatigue Dec. Pro. (h)	Expo-sure Lim. (h)
I-L-G	0.181	2.5	16	24
I-H-G	0.354	1	4	16
I-L-D	0.247	2.5	8	24
I-H-D	0.366	1	4	16
O-L-G	0.528	25min	4	8
O-H-G	0.868	1min	1	4
O-L-D	0.536	25min	4	8
O-H-D	0.832	1min	1	4
Sidewalk	1.26	<1min	25min	2.5

## DISCUSSION

Whole body vibration has been identified as a contributing factor to the “ride quality” of wheelchair mobility. Ride quality in this context generally refers to the comfort of the wheelchair user. **The results of this pilot study demonstrate that a typical powered wheelchair exposes the user to discomfort after 2.5 hours for the “best” conditions and in less than one minute for the “worst” condition of riding over a sidewalk. It is conceivable that the whole body vibration a wheelchair user is exposed to may create a condition of fatigue-decreased proficiency after only one hour when outdoors.** For the most severe conditions, an exposure limit of 2.5 hours is conceivable.

It is made clear in the ISO standard that it “is applicable only to situations involving people in normal health: this is, persons who are considered fit to carry out normal living routines.” **The fact that wheelchair users often have decreased trunk muscle function and other postural and stability insufficiencies implies the different limits established by the ISO standard may be higher than can be tolerated by typical wheelchair users. Further research is needed to better characterize the vibration response of wheelchair and accessories, i.e. cushions.** The new vibration data collection and analysis system described will make performing this research easier and more efficient.

## ACKNOWLEDGMENTS

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**Now here's the GREAT NEWS!**

## **From study #2: Vibration Reduction With Shock-Absorbing Front Castor Forks**

### **WHEELCHAIR VIBRATIONS USING SHOCK-ABSORBING FRONT CASTOR FORKS—JUNE, 1998**

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## INTRODUCTION

According to Cooper (1995), more than 20 million people worldwide rely on wheelchairs as their primary source of mobility. Despite the growing acceptance and push to accommodate people in wheelchairs, these individuals still deal with obstacles and inconveniences on a daily basis. They can be as minor as small cracks on a sidewalk, or as great as un-cut curbs or extremely rough terrain. According to Gaal et al. (1997), many improvements could be made to wheelchair design, thus decreasing the number of incidents that occur. Gaal reported that 42 percent of incidents were tips and falls, a number of which required medical attention. **In addition, many wheelchair users report that the repeated vibrations from bumps and cracks are at least partly responsible for their tremors and muscle spasms. The purpose of the study was to compare the shock-absorbing characteristics of a standard wheelchair caster with a new shock-absorbing caster. (Red added)**

## METHODS

Three subjects (75.30+-11.34 kg) volunteered to participate in the study. Two different sets of front wheel casters were attached to a Quicke wheelchair. The first set was a standard rigid caster (STC) while the second set was a new shock absorbing caster (FLC) manufactured by Frog Legs (Vinton, IA). The wheelchair was instrumented with accelerometers (FA and BA) attached near the front and the back axles. A third accelerometer (HA) was attached over the frontal bone of the head. All three accelerometers were sampled at 5000 Hz using a 12-bit analog to digital converter. Each subject took part in two experiments. The first experiment consisted of the subjects sitting in the wheelchair with the right front and back wheels sitting on a treadmill bed equipped with a 2 mm bump at 1.53 m/s. Each subject had ten impacts recorded while using each caster. Peak accelerations were identified from the front wheel impact (FWI) and the back wheel impact (BWI). The second experiment

consisted of the subjects rolling down a ramp with a 3 cm drop at the end. The subjects were traveling at approximately 2.0 m/s just prior to the impact. Each subject had five of these impacts recorded while using each caster.

## RESULTS

Tables 1 and 2 show the mean and standard deviations (s.d.) for the treadmill and ramp experiments respectively. **These results suggest a definite decrease in the vibrations with the FLC, particularly in the ramp experiment where the peak accelerations are much higher.** FWI clearly elicits a much greater peak acceleration than BWI. A very minimal difference in vibrations exists at the head in both experiments when comparing the two caster systems.

**Table 1. Treadmill Experiment**

Peak accelerations (g) from FWI				
Accelerometer	STC	s.d	FLC	s.d
FH	33.18	15.60	16.81	6.50
HA	0.10	0.03	0.16	0.03

**Table 2. Ramp Experiment**

Peak accelerations (g) from FWI				
Accelerometer	STC	s.d.	FLC	s.d.
FA	209.62	130.50	68.00	32.20
HA	0.78	0.22	0.42	0.08

**Peak accelerations (g) from BWI**

Accelerometer	STC	s.d	FLC	s.d
BA	0.74	0.08	0.68	0.13
HA	0.13	0.03	0.13	0.04

**Peak accelerations (g) from BWI**

Accelerometer	STC	s.d.	FLC	s.d.
BA	36.70	2.60	22.40	8.60
HA	1.87	0.61	1.45	0.45

## DISCUSSION

Vibrations that are left underattenuated by the wheelchair and casters may be absorbed by tissues of the body. These tissues include skin, muscle and vessels in parts of the body in contact with the chair; bone, ligaments and intervertebral discs in the spinal column and finally any active muscle tissue used to maintain head and trunk posture. Remaining vibrations could disrupt the visual and vestibular systems as they gather environmental information. This would support the argument that as the amount of shock decreases, so should the incidence of injury to these tissues. More research is needed to determine how these vibrations affect those who use a wheelchair as their primary method of mobility.

## REFERENCES

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**By using these TWO studies, the conclusion is CLEAR...  
Frog Legs Shock Absorbers are a proven benefit to your  
clients who use wheelchairs!**

Use of Frog Legs Shock Absorbers have been known to reduce back and neck pain, spasms and fatigue. And now they're paid for! HCPCS Codes E1015 & E1016. Make them a part of every prescription for a new wheelchair and order them to retrofit to each user's current chair!