VALIDITY OF ACCELEROMETERS IN PREDICTING OCCUPATIONALLY RELATED LOWER EXTREMITY EXPOSURES

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INTRODUCTION

Lower extremity musculoskeletal disorders and injuries affect a number of people in occupational settings. In many occupations, such as manual material handling jobs at distribution centers, there is exposure to prolonged standing, excessive walking on hard surfaces or uneven surfaces, stepping up or down between work surfaces, and there is vibration exposure. Quantifying these occupational exposures and their relationship to injury is necessary to determine thresholds that can be used to identify safe versus unsafe exposures levels for the lower extremities. To understand the force vectors generated at heel strike during walking, previous studies have used transient impulse forces on the tibia, also known as tibial shock [1,2].

The aim of this study was to validate the use of an accelerometer based instrumentation system that measures the transient impulse forces on the tibia, to quantify differences in material handling tasks with varying levels of lower extremity tibial shock exposure. We hypothesized that the measurement system would be able to detect variations in lower extremity tibial shock exposures across three tasks of varying exposure levels.

METHODS

Experimental Design: The study was a repeated measures design consisting of experimental conditions that simulate common types of distribution center work in which there are three different levels of tibial shock exposure as measured via the peak accelerations of the tibia.

Participants: Twenty volunteers, 11 males and 9 females between the ages of 18 and 36 years (mean = 22 years, s.d. = 5 years) participated in this study. Mean height and weight were 1.71 m (s.d. = 0.09 m) and 69 kg (s.d. = 11 kg). None of the individuals had any lower extremity symptoms or pain 6 months prior to the time of the study. All study participants signed an Institutional Review Board (IRB)-approved consent document. All participants wore some type of athletic shoe.

Instrumentation: Single-axis accelerometers (Vernier – ACC BTA) were attached to the skin on the anterior aspect of the participants' left and right tibia and secured using a self-adhesive wrap. Sensors were attached to a data logging interface (Vernier – Lab Quest Mini) and tablet computer that were placed in a backpack carried by the participant.

Procedures and Data Analysis: Participants were instructed to complete the tasks at 3 exposure levels – Low, Medium and High Exposure. The tasks are described in Table 1 below. The sequencing of the tasks was counter-balanced across subjects and each task was repeated 30 times. The peak positive tibial accelerations were extracted for each task using MATLAB. Data were normalized for individual subjects using the mean value of the peak tibial accelerations of low exposure task and computing a ratio of each peak with the mean value. The distribution of values from each task were compared by obtaining the 50^{th}, 75^{th} and 90^{th} percentile values and overall data analysis was conducted using a one-way ANOVA. Although bilateral tibial acceleration data was collected, only the leg showing the greatest tibial acceleration values was analyzed.

RESULTS AND DISCUSSION

The normalized peak tibial acceleration values for the 3 task exposure levels have been provided in Table 2. At the 50^{th} percentile, the normalized

values of peak tibial acceleration were statistically different for the Low and Medium (p=0.0021) and the Low and High Exposure Tasks (p=<.0001). The differences between the Medium and High Exposure tasks were not statistically significant. This is because the Medium and High tasks were similar apart from the stepping off and on the platform. At 75th and 90th percentile values, the peak tibial acceleration values were statistically different for the Low and Medium (p=0.0247 and p=0.0006 respectively), the Low and High Exposure Tasks (p=<.0001) and the Medium and High Exposure Tasks (p=<.0001). These differences are illustrated in Figure 1.

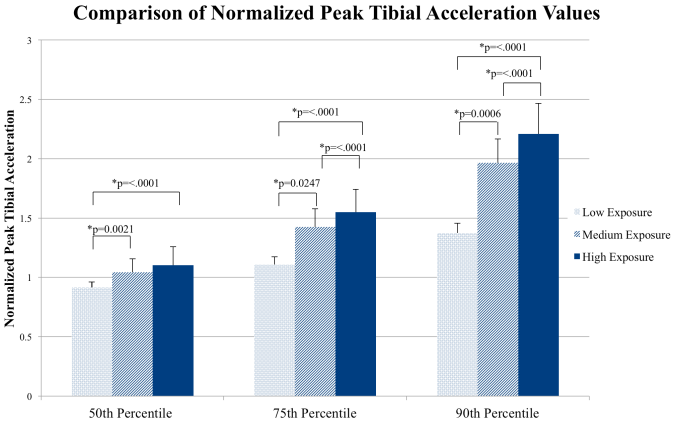

Figure 1: Comparison of Normalized Peak Tibial Acceleration Values across the 3 exposure levels

Though the differences between tasks may appear small, it is important to note that in the context of daily exposure, employees at distribution centers are often working at high speeds, involved in handling heavy cases and walking on average approximately 21000 steps/day or 10 miles/day [2]. Therefore, given the cumulative exposures in material handling occupations within distribution centers, having instrumentation and associated metrics that can differentiate between task exposures could be useful in identifying lower extremity work related musculoskeletal disorder risks.

CONCLUSIONS

The data supported the hypothesis that the instrumentation and associated peak tibial accelerations metrics could differentiate between the tasks at three exposure levels and therefore can be used to develop occupational risk models.

REFERENCES

1. Wosk J and Voloshin AS. *J. Biomech* **12**, 216-267, 1981.
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Table 1: Experimental Tasks.

Task	Description	Type of Distribution Work
Low Exposure	Slow walking, with lifting	Pick to belt operations that are self paced
Medium Exposure	Fast walking, with lifting	Pick to belt operations where productivity is continuously monitored
High Exposure	Fast Walking with lifting and stepping off and on a platform	Pick to pallet operations where workers drive pallet jacks to pick locations and productivity is continuously monitored.

Table 2: Normalized peak tibial accelerations measured for tasks at 3 exposure levels.

	50th Percentile		75th Percentile		90th Percentile	
Task	**mean**	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**
Low Exposure	0.9151	0.0465	1.1082	0.064	1.3743	0.0827
Medium Exposure	1.0443	0.1131	1.4254	0.1533	1.9655	0.2018
High Exposure	1.1021	0.1558	1.5505	0.1926	2.2083	0.2566