Comparisons of Tibial Shock when walking on four different flooring surface materials used in distribution centers

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Comparisons of tibial shock when walking on four different flooring surface materials used in distribution centers

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Flooring surfaces can be made from concrete, bar grate, composite materials, or may be covered with matting material. Anecdotal data suggested that surfaces made from wood composite materials may be a more comfortable surface on which to work. The objective of this study was to quantify differences in tibial shock as 16 people walked on concrete, bar grate, a wood composite material, and a concrete surface covered with matting. An accelerometer was attached to the right shin of volunteers who were asked to walk on each surface. Significant differences across the four surfaces were observed when each participant walked at their normal walking speed (p=.041) and when they walked at a faster than normal pace (p=.023). These findings suggest that individuals working in distribution centers, where extensive walking is part of the job, would possibly experience less lower extremity discomfort on selected floor surfaces.

INTRODUCTION

Prolong standing at work has been associated with lower extremity pain (Chandrasakaran, et al., 2004; Hou and Shiao, 2006), which, in turn, is predictive of early retirement (Rice et al., 2011). Cham and Redfern (2001) showed that the level of discomfort was affected by the type of surface upon which one stands. Specifically, “softer” surfaces have been associated with less subjectively measured discomfort than harder surfaces (Redfern and Cham, 2000). Likewise, Orlando and King’s (2004) study found reduced reports of discomfort among assembly line employees when working on floor mats or using shoe insoles for a week, compared to when they stood on a woodblock floor for the same length of time.

Beyond matting and insoles, these findings suggest that workers exposed to more compliant flooring materials should also experience less discomfort. One manufacturer of a wood composite material used for mezzanine construction has anecdotal reports from their customers that are consistent with the above-referenced reports. This manufacturer was interested in identifying if there is an objective measure that can be used to substantiate these subjective reports.

Selected studies in the gait analysis literature have focused on quantifying “tibial shock” using accelerometers affixed to the lower leg (Higginson, 2009; Whittle, 1999). The signals from skin-mounted accelerometers have been shown to provide reliable measures of the initial peak acceleration at heel strike (Liikavainio et al., 2007) and have been used to document the effectiveness of cushioned insoles during running (Lake, 2000; O’Leary et al., 2008). For example, O’Leary et al. (2008) reported that the use of cushioned insoles reduced the peak tibial accelerations during the initial foot contact by an average of nearly 16 percent. These findings suggest that measurements of the peak tibial accelerations may also be sensitive to the differences in flooring material used in the construction of mezzanines.

The aims of this work were: (1) to quantify the number of steps taken in a typical day by distribution center employees, and (2) to determine if there were quantifiable differences in objective biomechanical measures that could be used to characterize different walking surfaces used in warehouse and distribution center construction. Specifically, this investigation compared the peak tibial accelerations as people walked on concrete, bargrate, matting, and a wood composite mezzanine. Our hypothesis was that peak tibial accelerations would be different across these four surfaces.

METHODS

Participants. Sixteen volunteers, 11 males and 5 females, between the ages of 18 and 52 (mean = 36 years) participated in this study. All were employed at a toy distribution facility. Mean height and weight were 1.73 m (s.d.=0.10m) and 84 kg (s.d.=23kg). BMI ranged from 20.9 to 50.2 (mean=27.7). All participants signed an IRB approved consent document. Participants were tested in this protocol in whatever footwear they were wearing at the time which for all participants was some type of athletic shoe.

Experimental Design. In the first part of the study, a pedometer was provided to each of the participants to record the number of steps taken during a typical work day. In the second part of the study, a repeated measures design was used in which participants walked on a concrete, a bar grate, a wood composite mezzanine, and mat overlaying the concrete surface. The sequence of surfaces was counterbalanced across subjects.

Instrumentation. A single axis accelerometer (Vernier, model LGA-BTA) was attached to the shin of each participant's lower leg using a self-adhesive wrap (Figure 1) and aligned with the long axis of the tibia. The sensor, sampled at 1000 Hz, was connected to a data recorder and computer. The computer was carried by one of the investigators who walked behind the participants.

Figure 1. The accelerometer position on one of the participants with self-adhesive wrap.

Walking speed is an important covariate in this study and was quantified by measuring the time required to walk the 9.1 m test distance. An auditory alarm, utilizing photo beams, was used to signal the timing process (Figure 2).

Procedures. All participants reviewed and signed informed consent documents approved by The Ohio State University's Institutional Review Board. The accelerometer was positioned on the anterior or anterior lateral aspect of the tibia. The exact position was determined by where the investigator responsible for instrumentation believed the most rigid attachment to the bone could be attained. The type of shoes worn by each participant was noted.

Participants were instructed to walk at three different speeds on each flooring type:

1. At their normal walking pace;
2. At a slower-than-normal but comfortable pace; and
3. At a faster-than-normal pace.

Each condition was repeated twice, first walking *away* from the original starting point and then returning *to* the original starting point. Prior to collecting data on each surface, the participant did a practice walk in which they walked the full distance away from and returning to the starting point. This practice was used to familiarize the participant with the feel of the instrumentation.

Data Analysis. This approach yielded two trials in which data were obtained from each heel strike from the instrumented leg within the 9.1 m walking zone (~5 samples), for each combination of walking speed and flooring condition. At each walking speed, the high and low tibial accelerations were removed in case unusual steps were taken, and the remaining accelerations were averaged. These averaged tibial accelerations, two from each walking speed, were used to develop a regression function for each individual and flooring condition combination. The purpose of these regression functions was to obtain the tibial accelerations for a specific floor surface and walking speed for each individual participant that could be used in the overall data analysis using an ANOVA. For each participant, the average normal walking speed across the flooring conditions was calculated and then entered in these subject and surface specific regression functions to obtain the tibial accelerations values for each surface at the specified walking speed. This way the floor type comparisons of the tibial acceleration data were independent of any potential differences in the walking speed across the four surfaces.

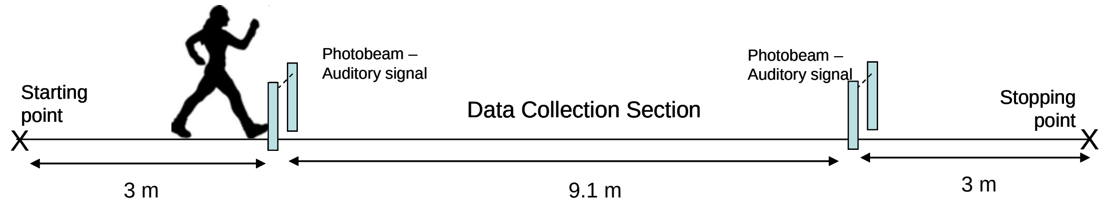

Figure 2. The data collection process had participants walk at 3 different speeds on each flooring surface.

Using the same subject and flooring condition specific regression models, the tibial acceleration values when walking 15 percent faster than the subject's average normal walking speed were obtained, to evaluate the effect of more hurried working conditions. The fifteen percent value was selected because every participant walked at least 15 percent faster when instructed to walk "faster than normal" and therefore was within the range of each subject specific regression functions relating walking speed to tibial acceleration.

The resulting data were analyzed using a within subjects analysis conducted with SPSS.

RESULTS

Figure 3 shows the number of steps taken by the participants during a typical shift. The participants were either "pickers" or "replenishers." On average these distribution center workers take 18,860 steps per day.

The means of the peak acceleration values when walking at each subject's average normal speed and when walking 15 percent faster than their normal speed are shown in Figure 4. At both walking speeds the there were significant differences in the tibial acceleration across the four floor surfaces tested. The effect was stronger with the faster walking speed. Given the exploratory nature of this work, a least-squared difference test was used to evaluate differences between flooring conditions. For both walking speeds, these post-hoc analyses indicated that the floor mat on concrete and the wood composite resulted in lower tibial shock values than when walking on bar grate.

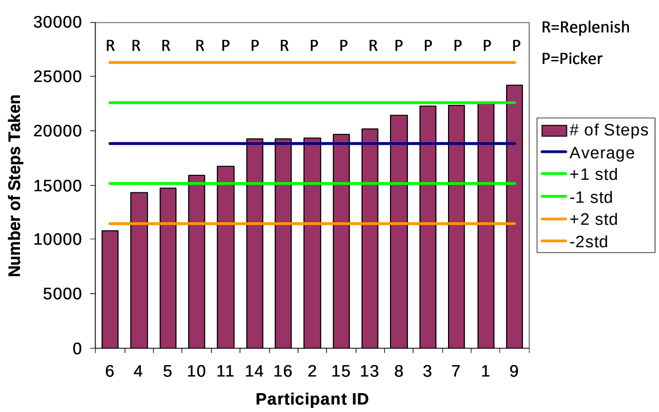

Figure 3. The number of steps taken by the 15 of the 16 participants sorted in increasing order. The "R" or "P" signifies the job title

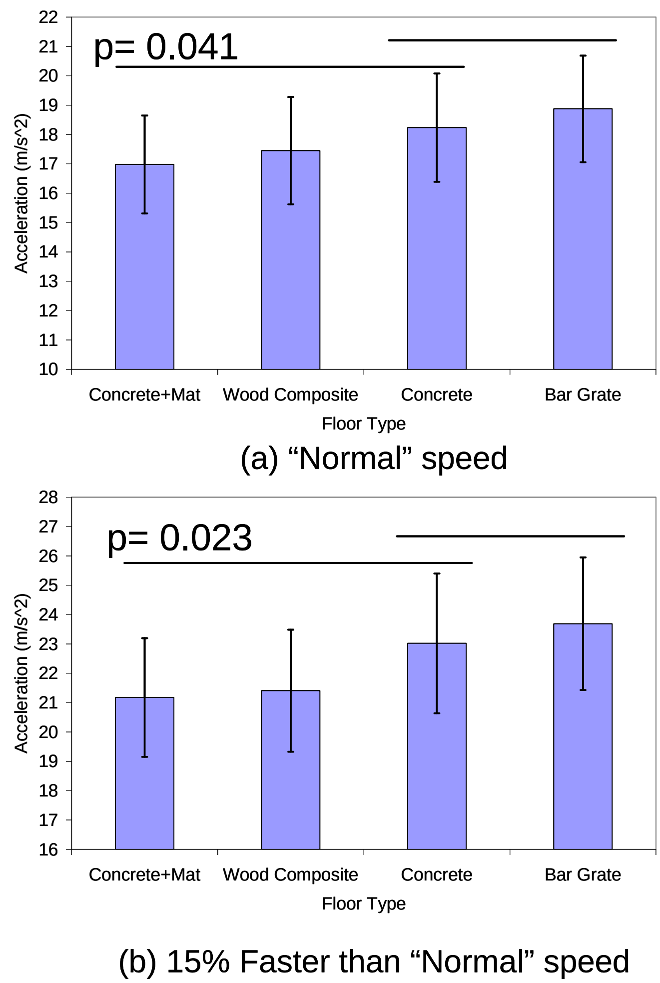

Figure 4. The mean of the peak tibial accelerations (tibial shock values) across subjects when the subjects walked at their normal walking speed (a) and when they walked 15% faster than normal. The horizontal lines above the bars indicate conditions that were not statistically different using Least Squared Difference test.

DISCUSSION

The tibial acceleration findings presented here suggest there are differences in tibial shock across different flooring surfaces used in distribution centers. The magnitude of the significant differences with this limited sample size was between 7 and 10 percent, with the differences becoming slightly larger at the faster walking speed. In distribution center environments people often move a hurried pace as their work output is often continuously monitored by the warehouse management system.

One also needs to consider these results in the context of daily exposure. Even with a modest .6 m stride length this translates in to more than 11 km traveled. If we focus on the product selectors who take more steps than the replenishers, the mean number of steps jumps to 21,000 steps per day, the distance increases to 12.6 km, again assuming a modest .6 m stride length. The small reduction in tibial shock with this quantity of steps could represent a significant reduction in cumulative lower extremity load exposures. These data suggest that designers of mezzanine surfaces should consider the use wood composite materials over using bar grate or concrete surfaces. Likewise, there is a trend that supports the use of mats on concrete ground level surfaces. However, epidemiologic investigations will be required to determine if these results correlate with differences in lower extremity discomfort and pain associated with extended walking during the workday.

We also expected that the compliant soles of the athletic shoes would potentially mask differences across floor types. But even with these compliant shoes we still see small effects. We had no way to assess the status of these athletic shoes as to their level of wear. Given people work in these athletic shoes on a daily basis, the effectiveness of the cushioning may be reduced relative to when the shoes were new, therein making flooring compliance more important.

CONCLUSIONS

Overall these data supported our hypothesis in that the peak tibial accelerations differed across flooring surfaces on which distribution center employees typically work. These findings suggest there is the potential for reduced cumulative loading of the lower extremities when working on wood composite mezzanine surfaces or matted surfaces, particularly if one works at a hurried pace. Further study is needed to determine if these findings translate to reduced lower extremity discomfort and ailments.

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