INFLUENCE OF FLOORING ON OBJECTIVE STANDING FATIGUE MEASURES

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INTRODUCTION

Standing for long periods of time has been directly associated with lower extremity discomfort, pain and fatigue and low back pain (Redfern and Chaffin, 1995). These problems are particularly prevalent among workers who stand for long periods of time in restricted areas, such as checkout supermarket workers, assembly and quality control inspection workers.

Flooring may play a role in standing fatigue, however previous studies of flooring on subjective and objective measures thought to be related to fatigue/discomfort, have had mixed results. The majority of the differences in the reported results are probably due to differences in procedures and analysis methods, particularly variations in testing duration and exposure time. The impact of flooring on discomfort/pain is still largely unknown.

The first aim of this study was to examine the effect of different floors on subjective measures of fatigue and discomfort, and some related objective measures, using a longer testing session. The second aim was to investigate the relationship between these measures and material properties of the mats. This paper reports the objective measures recorded during the experiments. Tiredness/discomfort ratings findings are reported elsewhere (Cham and Redfern, 1999).

PROCEDURES

The flooring conditions included a hard vinyl tile floor and 6 floor mats placed over a force plate. During a 4-hour testing interval, subjects stood on the force plate and performed 12 series of computer tasks. Center of pressure (COP) position and electromyographic recordings (EMG’s from soleus, tibialis anterior and erector spinae) were collected for 10 minutes and 1 minute every 20 minutes at a sampling rate of 20 Hz and 1 kHz, respectively. Skin temperature over a number of leg muscles and elbow (control) was recorded every 15-17 minutes. Every 30 minutes, subjects were allowed to walk back and forth on a runway (covered with the same floor they stood on) for 2 minutes. Leg volume was measured pre and post standing. All subjects wore the same brand of shoes and socks.

RESULTS AND DISCUSSION

Of the 4 measures collected (COP, EMG, skin temperature and leg volume), only COP and skin temperature showed statistically significant differences among flooring and times. During the 4th hour of the experiment, the change in the normalized (to the elbow control temperature) skin temperature (over the soleus, tibialis anterior, quadriceps and hamstrings) was significantly (p<0.05) affected by floor conditions. The greatest changes in the normalized temperature were recorded over the soleus when standing on the hard floor (Table 1). Post-hoc analyses revealed not only significant differences between a number of mats and the hard floor, but also significant differences among several mats. COP measurements were used to compute the number of lateral weight shifts as subjects stood on the floors. The hypothesis
was that a greater amount of weight shifting may indicate an attempt to reduce increasing body stress and fatigue. ANOVA showed that, in the 4th hour, the number of weight shifts was significantly different (p<0.05) among floors. Again, the hard surface had the greatest number of shifts (Table 1).

EMG’s showed no statistically significant spectral change differences. Changes in lower leg volume were found not to be statistically significant among flooring conditions. However, interesting trends showed that leg swelling was greatest for the hard floor.

Comparisons of floor material properties to the objectives measures were performed. Floor properties were evaluated through specific measurements including stress-strain tests and a drop test. The stress-strain tests yielded the stiffness, work-lost and load-decay measures, while the drop test yielded the drop-max-g accelerations. (see Cham and Redfern, 1999 for details of material tests.) Increased stiffness and drop-max-g and decreased work lost (Table 1) were found to be associated with significant decreases in COP weight-shift and reduced changes in the normalized skin temperature, both of which can be used as an indication of a good floor performance.

Table 1: Material properties, skin temperature and center of pressure findings (4th hour)

<table>
<thead>
<tr>
<th>Floor</th>
<th>Stiffness (N/mm)</th>
<th>Worklost (N.mm)</th>
<th>Drop-Max-G acceleration (g)</th>
<th>Load decay (N)</th>
<th>Normalized skin temperature changes over soleus (°C)</th>
<th>Normalized number of weight shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (hard floor)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1.01</td>
<td>175.56</td>
</tr>
<tr>
<td>B</td>
<td>6732.8</td>
<td>1408</td>
<td>6.66</td>
<td>269</td>
<td>0.09</td>
<td>166.19</td>
</tr>
<tr>
<td>C</td>
<td>4463.1</td>
<td>303</td>
<td>8.49</td>
<td>437</td>
<td>0.55</td>
<td>174.85</td>
</tr>
<tr>
<td>D</td>
<td>3040.0</td>
<td>992</td>
<td>5.98</td>
<td>462</td>
<td>0.28</td>
<td>170.50</td>
</tr>
<tr>
<td>E</td>
<td>2443.6</td>
<td>3348</td>
<td>4.72</td>
<td>982</td>
<td>0.35</td>
<td>173.87</td>
</tr>
<tr>
<td>F</td>
<td>2252.4</td>
<td>3392</td>
<td>3.06</td>
<td>686</td>
<td>0.79</td>
<td>186.41</td>
</tr>
<tr>
<td>G</td>
<td>1814.0</td>
<td>1600</td>
<td>4.88</td>
<td>468</td>
<td>0.53</td>
<td>174.80</td>
</tr>
</tbody>
</table>

i Stiffness modulus evaluated at a load level of 4000 N.
ii Worklost is the area enclosed in the load/unload-deformation hysteresis curve.
iii Drop-Max-g is the maximum deceleration of a 10 pound weight dropped on the mat from a 0.124 inch height.
iv Load-decay required to maintain a given displacement (corresponding to a load level of 2000 N) for 2 minutes.

### SUMMARY

This 4-hour experiment indicated a significant flooring effect on skin temperature changes and lateral COP weight shifts. The hard floor and floor mat F consistently yielded worse performance. The relationships between the mat material properties and fatigue measures suggest that floor performance increased with greater elasticity and stiffness, and lower energy absorption. This study suggests that 1) floor materials can affect objective parameters, 2) these parameters may be useful in evaluating floors and 3) a minimum of 4-hour testing period should be used in future laboratory studies.

### REFERENCES

Cham R., Redfern M.S. (1999); The influence of flooring on standing comfort and fatigue; to be published in *Human Factors Proceedings*.