Are diurnal changes in foot sole sensation dependent on gait activity?

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SUMMARY
Several factors affect the foot sole mechanoreceptors, such as aging, cooling and warming the foot sole as well as the use of textured insoles. It is not clear whether foot sensitivity changes during the day and how receptors respond to physiological loading. Diurnal changes of plantar receptors and the dependence of these changes on people’s step activity were investigated. Twenty-six subjects (28.6±6.71 years) participated in the study. Detection thresholds to light touch were measured in six plantar regions at 8a.m., 12p.m. and 4p.m.. Step activity was recorded for three periods. Statistical analysis showed significant decreases in detection thresholds from 8a.m. to 4p.m. (p<0.05) for the hallux, 3rd metatarsal head and the heel (Table 1). A significant correlation between a decrease of detection threshold and the number of steps was found for the heel (Figure 1) and the 3rd metatarsal head. Plantar sensation improves during the day and appears to be correlated with the number of steps and the intensity of foot loading, however, only to an unknown degree. This seems to demonstrate an “awakening” of plantar skin receptors and a progressively improving afferent signal transfer to the CNS as well as an adaptation of receptors to gait-related foot loading.

INTRODUCTION
The foot sole with its several mechanoreceptors is considered as a “dynamometric map” that is sensitive to local pressures [1]. Intrinsic and extrinsic factors that affect the mechanoreceptors in the plantar aspect of the foot, such as aging [2], cooling and warming the foot sole [3, 4] as well as the use of textured insoles [5], are known. Interindividual differences in plantar foot loading appear during a day. It is not clear whether the perception of skin mechanoreceptors of the foot sole varies during the day and how the receptors respond to physiological loading [6]. The first aim of the study was to investigate diurnal changes of plantar skin receptors. Furthermore, the goal was to find out if diurnal changes of plantar foot sensation depend on the individual level of step activity.

METHODS
Twenty-six healthy subjects – 17 women and 9 men – participated in the study. Their mean age was 28.6 ± 6.7 years. The sensory perception thresholds to light touch was measured in six regions of the foot sole with Semmes Weinstein monofilaments at 8 a.m., 12 p.m. and 4 p.m. using a 4-2-1 step algorithm [7]. Step activity was recorded between 8 a.m. and 4 p.m. using a StepWatch™ Activity Monitor (Orthocare Innovations).

RESULTS AND DISCUSSION
For the hallux (p=0.045), the 3rd metatarsal head (p<0.0001) and the heel (p=0.002) the Friedman test showed significantly decreased detection thresholds from 8 a.m. to 12 p.m.. The Wilcoxon-Test revealed significant differences of the detection thresholds between the measuring times only for the 3rd metatarsal head and the heel (Table 1). A significant correlation between a decrease of detection threshold and the number of steps was found for the heel (r=0.43, Figure 1), the 3rd metatarsal head (r=0.514), the 1st metatarsal head (r=0.530) and the medial arch (r=0.491).

According to the findings in this study there is evidence that sensory thresholds are lower in the afternoon than in the morning [8]. The measuring points of the foot sole which showed a significant improvement in sensitivity are higher loaded during gait than the ones which demonstrated no significant changes. Results of step activity measurements revealed that an increased plantar sensation appears to be associated with higher walking activity. Higher stimulation [9] as well as increased blood circulation as a consequence of pressure-induced hyperaemia [10] may be reasons for the changes in foot sole sensation.
CONCLUSIONS
The perception of tactile plantar receptors improves from the morning to the afternoon and especially to the late afternoon. This seems to demonstrate an “awakening” of plantar mechanoreceptors and a progressively improving transfer of afferent information to the central nervous system. Furthermore, the enhanced perception seems to depend on the intensity of foot loading. The more steps are performed and the higher the load of a region is the more receptors increase their sensitivity, however, only to an unknown degree. Further research should clarify whether diurnal and load depending changes in plantar sensation have any clinical relevance for neurological test protocols, e.g. “Quantitative Sensory Testing” or treatment of neurological patients.

REFERENCES

Table 1: Mean values and standard deviations (n = 26) of pressure detection thresholds at three different times of a day (*p ≤ 0.05). MTH = metatarsal head

<table>
<thead>
<tr>
<th>Detection threshold (Filament Size)</th>
<th>8 a.m.</th>
<th>12 p.m.</th>
<th>4 p.m.</th>
<th>Wilcoxon signed rank test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Hallux</td>
<td>3.84</td>
<td>0.36</td>
<td>3.84</td>
<td>0.39</td>
</tr>
<tr>
<td>MTH 1</td>
<td>4.16</td>
<td>0.61</td>
<td>4.06</td>
<td>0.49</td>
</tr>
</tbody>
</table>
| **MTH 3**                           | **4.03** | **0.54** | **3.91** | **0.44**  | **3.83** | **0.45** | **0.004*** | n.s.  | **0.001***
| MTH 5                               | 4.18   | 0.48    | 4.07   | 0.41       | 4.08   | 0.43    | n.s.   | n.s.       | n.s.          | n.s.          | n.s.          |
| Medial Arch                         | 3.65   | 0.41    | 3.63   | 0.33       | 3.6    | 0.36    | n.s.   | n.s.       | n.s.          | n.s.          | n.s.          |
| **Heel**                            | **4.09** | **0.4**  | **4.1** | **0.3**    | **3.93** | **0.37** | n.s.   | <0.0001*  | **0.023***    |               |               |
