Can Insole For Obesity Maintain The Arch Of The Foot Against Repeated Hyper Loading?

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Disclosures:

Introduction: Obesity is a serious public health problem in the 21st century. Increasing obesity population, adult acquired flatfoot deformity (AAFD) has notably risen in recent years. The AAFD is marked by arch collapse and increase heel valgus and is related to posterior tibial tendon dysfunction (PTTD) which cause pain/swelling behind medial malleolus and along medial longitudinal arch (1). At the end of the stage of the PTTD, serious foot deformities and loss of gait ability are occurred. Meanwhile posterior tibial muscle plays an important role as a dynamic support to the arch (2), the muscle function is not able to maintain the arch structure in a state of obesity (3). Although the use of insole for AAFD in normal weight has effects in clinical practice, it is still unknown that the insole protects the foot structure of obesity against repeated hyper loading during ADL. The purpose of this study was to investigate time-dependent change of arch structure when insole applies to cadaveric foot during repeated hyper loading as simulated obesity.

Methods: 20 cadaveric feet from 3 female and 17 male were studied. Mean age was 83 years (range, 59-93yrs). 15 specimens were left foot and 5 were right. The specimens had no evidence of previous injury, operations, or severe deformity by visual inspection. Each specimen was cut at the proximal third of the leg. Figure 1 shows the diagram of the experimental system. Tibia and fibula were fixed with Kirschner wires and embedded in polymethyl methacrylate with 5-cm-diameter acrylic tube. The foot was set on force plate and fixed by custom jig. Tibial shaft was set a perpendicular to the force plate. Specimens were assigned to three groups: normal group (n=7), obese group (n=7) and obesity with insole group (n=6). The insole (arch support, Nakamura Brace Co., Shimane, Japan) utilized in this study was made from silicone rubber. The insole was designed to support the medial longitudinal arch and the transverse metatarsal arch of the foot. An appropriate size of insole was chosen from three sizes. The top of medial arch support was inserted in the beneath the navicular bone. Time-dependent change of arch height was monitored with 2-dimentional analyzer, which was consisted of light emitting diode (LED) and charge-coupled device (CCD) camera. A 1.6 × 0.8 mm rectangular red light emitting diode (LED) was attached to the medial aspect of the navicular with minimum disruption. The displacement of the LED light was monitored via a CCD camera connected to a personal computer. The image was converted to the coordinate system. The y-axis was located along the tibial shaft and the x-axis was parallel to the horizontal plane of the force plate. The program's translational accuracy was 0.06 mm (0.2% full scale). The data of arch height sampled at the point of maximal weight bearing during 10,000 cycle loads. To simulate the mid-stage phase of gait, loads applied to proximal end of specimen by material testing machine (AG-I, Shimadzu, Kyoto, Japan). The load set 500N as normal weight, and 1,000N as simulated obesity, and that was monitored by four load cells (FC22, Measurement Specialties Inc, Hampton, VA, USA; capacity 45kgf, nonlinearity ±1%FS) under the force plate. The frequency of the axial loading was approximately 1 Hz. 32N traction force was applied to the posterior tibial tendon with the weight bearing condition during cyclic loading.

We evaluated the arch structure using the bony arch index (BAI). The BAI was calculated from the navicular height (h) divided by the foot length (l) (BAI=h/l). Foot length (l) was measured from the heel to the first metatarsophalangeal joint. The navicular height (h) was measured from the coordinate y-axis. A low arch was defined as a BAI less than 0.21 with weight bearing, a normal arch had a BAI between 0.21 and 0.27. The BAI was calculated each 1,000 cycles. Results were expressed as a mean ± standard deviation (SD). Repeated measurement two-way analysis of variance with post-hoc Tukey comparisons was used for the BAI data analysis. Statistical testing was performed using SPSS 17.0 software (SPSS Inc., Chicago, IL).All significance levels were set as α=0.05. This study was approved by our institutional review board (IRB).

Results: Table 1 and Figure 2 shows the time-dependent change of BAI in the weight bearing condition in each group. The initial BAI of the insole, obese, and normal group was 0.251±0.005, 0.234±0.012, and 0.239±0.009, respectively (Table1). The initial BAI of insole was significantly higher than that of obese group (p<0.05)(Figure 2). In the cyclic load from 1,000 to 3,000, the BAI of the insole and normal group were higher than that of obesity group (p<0.05)(Figure 2). The BAI at the 3000 cyclic loading was 0.209±0.010(insole group), 0.193±0.012(obese group), and 0.213±0.013(normal group). The BAI of the obesity group was significantly decreased compared to normal group from 3,000 to 10,000 cycles (p<0.05), however, the BAI between insole and
obesity group was not different significantly (Figure 2). At the 10000 cyclic loading, the BAI was 0.190±0.014 (insole group), 0.180±0.023 (obese group), and 0.213±0.011 (normal group). There was no difference between insole and normal group during whole cycles (Figure 2).

**Discussion:** We demonstrated that time-dependent change of arch structure when the insole was applied to the obesity condition. In the weight bearing condition, the insole maintained the BAI even in the state of obesity until 3,000 cycles. After 3,000 cycles, however, the BAI of insole group was less than 0.21, which reached the diagnostic criterion for a low arch. In addition, the difference between the insole and the obesity group was not found after 4,000 cycles. These results suggested that the insole for obesity might maintain the arch structure in the early period of time, but it might be corrupted by repeated hyper loading with duration despite a dynamic support by posterior tibial muscle.

**Significance:** Insole for obesity did not maintain the arch height by repeated hyper loading, suggesting that the effect of insole for obesity might be counteracted gradually in repeated gait. Although insole is easily available, the positive effects of insole might not be expected to the foot of obesity in their ADL.

**Acknowledgments:** The authors would like to thank Minoru Nakagawara, PhD, for his technical support to produce this experimental system.


![Material Testing Machine](image1)

**Figure 1. Diagram of the experimental system.** Displacement of LED was monitored via a CCD camera during 10,000 cycles loading. The image converted to the coordinate system. Repeated axial loadings were applied to the proximal end (Normal 500N, Obesity and insole 1,000N ). Posterior Tibial Tendon was pulled proximally by a servomotor with the weight bearing condition during cyclic loading (32N).
Table 1. BAs of three groups in the weight bearing condition (mean±SD).

<table>
<thead>
<tr>
<th>Cycles Group</th>
<th>0</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
<th>6000</th>
<th>7000</th>
<th>8000</th>
<th>9000</th>
<th>10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.239 (0.009)</td>
<td>0.218 (0.009)</td>
<td>0.214 (0.011)</td>
<td>0.213 (0.013)</td>
<td>0.212 (0.012)</td>
<td>0.214 (0.011)</td>
<td>0.211 (0.010)</td>
<td>0.214 (0.011)</td>
<td>0.215 (0.013)</td>
<td>0.210 (0.012)</td>
<td>0.213 (0.011)</td>
</tr>
<tr>
<td>Obesity</td>
<td>0.234 (0.012)</td>
<td>0.205 (0.010)</td>
<td>0.196 (0.012)</td>
<td>0.193 (0.012)</td>
<td>0.189 (0.017)</td>
<td>0.189 (0.018)</td>
<td>0.188 (0.020)</td>
<td>0.187 (0.021)</td>
<td>0.184 (0.022)</td>
<td>0.182 (0.022)</td>
<td>0.180 (0.023)</td>
</tr>
<tr>
<td>Obesity + Insole</td>
<td>0.251 (0.005)</td>
<td>0.221 (0.000)</td>
<td>0.214 (0.009)</td>
<td>0.209 (0.010)</td>
<td>0.205 (0.013)</td>
<td>0.203 (0.013)</td>
<td>0.200 (0.012)</td>
<td>0.193 (0.013)</td>
<td>0.196 (0.014)</td>
<td>0.194 (0.015)</td>
<td>0.190 (0.014)</td>
</tr>
</tbody>
</table>

Colored box indicate BAI less than 0.21, which reached the diagnostic criterion for a low arch.

†: S ignificantly difference between normal and obesity (p < 0.05)
§: S ignificantly difference between obesity + insole and obesity (p < 0.05)

**Figure 2.** Comparison of time-dependent change of BAI during weight bearing among normal, obesity, and obesity with insole group. Dashed line indicate the diagnostic criterion for a low arch. Low arch was defined as a BAI less than 0.21.

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