**Assessment of Plantar Pressure in Hindfoot Relief Shoes of Different Designs**

Thomas Hahn, MD*
Hans-Dieter Carl, MD*
Andreas Jendrissek, MD*
Matthias Brem, MD*
Bernd Swoboda, MD*
Philipp Rummel, MD*
Johannes Pauser, MD*

**Background:** Although there are several different concepts of hindfoot relief footwear, there are no studies on the extent of pressure reduction to be achieved by this footwear. Therefore, we sought to evaluate the reduction in plantar pressure to be achieved with two different hindfoot relief shoes.

**Methods:** Ten healthy volunteers performed three trials at a self-selected speed. Peak pressure values in mass-produced shoes (normal gait) were considered as 100% and were compared with measurements in two differently designed hindfoot relief shoes. Foot portions were defined as heel (0%–15% of total insole length), hindfoot (16%–30%), midfoot (31%–60%), and forefoot (61%–100%).

**Results:** Heel and hindfoot peak pressures were significantly reduced in both shoes compared with normal gait ($P < .05$), but the extent of peak pressure reduction under the heel and hindfoot varied significantly between the tested shoes. Midfoot peak pressure was not significantly reduced in tested shoes compared with baseline ($P > .05$) but differed significantly between the two shoes. Forefoot peak pressure was significantly reduced with one of the tested shoes (to a median 73% baseline; $P = .004$) but not with the other (median, 88% baseline).

**Conclusions:** Hindfoot relief shoes leave a considerable amount of peak pressure, predominantly under the hindfoot. The extent of peak pressure reduction for the heel and the hindfoot varies between different hindfoot relief shoes. Depending on the affected foot area, the kind of hindfoot relief shoe should be carefully chosen. (J Am Podiatr Med Assoc 104(1): 19-23, 2014)
Methods

Ten healthy volunteers (seven men and three women; mean ± SD age, 35 ± 5 years; mean ± SD body mass index [calculated as weight in kilograms divided by height in meters squared], 29.5 ± 3.2) with no history of foot complaints were recruited from the hospital staff. The institutional review board of the University of Erlangen-Nuremberg Germany approved the conduct of the study with no requirements. Walking speed was kept constant for each volunteer between the trials to fulfill previously published recommendations; individual differences between volunteers were accepted. Three trials were performed. During the first trial, the volunteers were asked to walk with their normal gait in sports shoes without any orthotic devices to assess baseline values, defined as 100%. For a comparative study, peak plantar pressure values from two frequently used hindfoot relief shoes were assessed. Insurance companies regularly reimburse for both shoes. The Mars (Streifeneder Inc, Emmering, Germany) and the München (Fior and Gentz Inc, Lueneburg, Germany) hindfoot relief shoes display a plastazone heel of 50% shore density under the midfoot and forefoot, defined as 20% to 80% of total sole length. Their designs differ regarding foot padding, the position of a foot roll, and the design of the hindfoot support. The Mars shoe is supplied with prefabricated soft padding and a slight midfoot roll. Its hindfoot support is sloped toward the sole at an angle of 50°. The München shoe has no foot padding. It features a 5° angled heel under the midfoot and a slight forefoot roll. The hindfoot support of this shoe ends with a rectangular edge under the hindfoot (Fig. 1).

Pedobarographic data were obtained using the pedar-X system (novel GmbH, Munich, Germany) consisting of insoles holding 99 capacitive sensors that capture dynamic in-shoe pressure and force information at a frequency of 50 Hz. The size of the sole was adjusted individually. Peak pressure values (the highest values during the trial under the foot) were obtained for the right foot from 15 left and right steps. The following foot portions were defined for data analysis: heel (0%–15% of total insole length), hindfoot (16%–30% of total insole length), midfoot (31%–60% of total insole length), and forefoot (61%–100% of total insole length). The novel multiprojects-ip software package (novel GmbH) was used to calculate means, medians, and standard deviations. Data were then transferred to Prism 5 software (GraphPad Software Inc, San Diego, California). Paired medians were compared with the two-tailed nonparametric Wilcoxon matched-pairs signed rank test; \( P < .05 \) was considered statistically significant. No adjustments for multiple comparisons were made. The statistical power setting was calculated with StatMate 2.0 software (GraphPad Software Inc). Accordingly, the ten pairs of feet allow describing a difference of 10% between means (referred to results from full weightbearing) with a power of more than 90%.

Results

All of the results are listed in Table 1 and illustrated in Figure 2. Mean ± SD (median) peak pressure values in mass-produced shoes (baseline) were 241 ± 50 kPa (229 kPa) under the heel, 235 ± 48 kPa (227 kPa) under the hindfoot, 187 ± 33 kPa (186 kPa) under the midfoot, and 303 ± 95 kPa (289 kPa) under the forefoot. The Mars shoe showed a

Figure 1. Views of the two hindfoot relief shoes. A, The Mars shoe (midfoot roll). B, The München shoe (5° wedge sole, forefoot roll).
significant reduction in heel peak pressure (0%–15% of total sole length) to a mean ± SD (median) of 90 ± 50 kPa (93 kPa) ($P = .002$), leaving a median 41% baseline value. The München shoe led to a reduction in heel peak pressure to a median 10% baseline value (mean ± SD, 48 ± 53 kPa; median, 23 kPa), which was significantly less compared with normal gait ($P = .002$) and the Mars shoe ($P = .048$). Mean

<table>
<thead>
<tr>
<th>Shoe Condition</th>
<th>Peak Pressure (kPa)</th>
<th>Heel (0%–15% of Sole)</th>
<th>Hindfoot (16%–30% of Sole)</th>
<th>Midfoot (31%–60% of Sole)</th>
<th>Forefoot (61%–100% of Sole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass-produced shoe</td>
<td>241 ± 50 (229)</td>
<td>235 ± 48 (227)</td>
<td>187 ± 33 (186)</td>
<td>303 ± 95 (289)</td>
<td></td>
</tr>
<tr>
<td>Mars shoe</td>
<td>90 ± 50 (93) 41%$^a$</td>
<td>147 ± 33 (145) 64%$^a$</td>
<td>169 ± 14 (172) 93%</td>
<td>216 ± 43 (210) 73%$^a$</td>
<td></td>
</tr>
<tr>
<td>München shoe</td>
<td>48 ± 53 (23) 10%$^{ab}$</td>
<td>178 ± 39 (186) 82%$^{ab}$</td>
<td>192 ± 27 (196) 105%$^b$</td>
<td>254 ± 52 (253) 88%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Data are given as absolute values (mean ± SD and median) and as percentages that refer to pressure values in mass-produced shoes (baseline value) obtained during normal gait.

$^aP < .05$ compared with baseline value.

$^bP < .05$ compared with the Mars shoe.

Figure 2. Mean peak pressure values for the named foot regions by shoe condition. Error bars represent SD. NS indicates not statistically significant. $^*P < .05$. 

Table 1. Peak Pressure Under the Various Foot Regions in Differently Designed Hindfoot Relief Shoes
± SD hindfoot peak pressure (16%–30% of total sole length) was significantly reduced with the Mars shoe to 147 ± 33 kPa (median, 145 kPa), or a 64% baseline value ($P = .006$), and with the München shoe to 178 ± 39 kPa (median, 186 kPa), or an 82% baseline value ($P = .037$). Hindfoot values were significantly different between both shoes ($P = .02$). Midfoot peak pressure was not significantly reduced with the Mars shoe (mean ± SD, 169 ± 14 kPa; median, 172 kPa; $P = .169$) and the München shoe (mean ± SD, 192 ± 27 kPa; median, 196 kPa; $P = .919$) but was significantly elevated with the München shoe compared with the Mars shoe ($P = .006$). Forefoot peak pressure was significantly reduced with the Mars shoe (to a median 73% baseline value; mean ± SD, 216 ± 43 kPa; median, 210 kPa; $P = .004$) but not with the München shoe (to a median 88% baseline value; mean ± SD, 254 ± 52 kPa; median, 253 kPa; $P = .139$). The difference between shoes was not significant ($P = .106$). Figure 3 illustrates typical plantar pressure pictures obtained during the trials.

**Discussion**

Recent investigations on the orthotic management of foot disorders reflected the reduction in foot loading to be achieved with different graduations of weightbearing.5 Moreover, physical strain trainers have been evaluated in mass-produced shoes15,18 and in an ankle-foot orthosis.19 There is no study, to our knowledge, on the usefulness of hindfoot relief shoes, although forefoot relief shoe work has previously been investigated with respect to foot loading.16

We selected dynamic pedobarography for this study. In general, sensor-loaded insoles seem closer to real life, collecting data from a series of steps from right and left feet. Insole systems are also more mobile and flexible enough to be used for different conditions, such as walking, running, and stair climbing. The number of analyzed steps was chosen according to a previously published recommendation.20

We chose peak plantar pressure to quantify foot load because this parameter has previously been used for many investigations. The role of further pedobarographic parameters, such as maximum force, pressure-time integral, or force-time integral, as possible risk factors has not been clarified but may be addressed in forthcoming studies.

These results indicate that both tested hindfoot relief shoes statistically significantly reduced plantar pressures compared with normal gait. Although there are, to our knowledge, no general definitions of heel and hindfoot, we chose our definitions referring to the total sole length as described by the shoe manufacturers. The statistically significant difference in heel peak pressure reduction (10% baseline versus 41% baseline in favor of the München shoe) may result from insufficient fixation of the foot in its designated position in the Mars shoe. The remaining 82% baseline peak pressure under the hindfoot in the München shoe may derive from the rectangular edge of the sole placed under the hindfoot. We conclude from these findings that there may still be room for substantial improvements in hindfoot shoes. Future studies may reveal that orthotic modifications can lead to a greater reduction in peak pressure. Such modifications may address the rectangular edge of hindfoot support or the positioning of foot rolls.

According to these findings, hindfoot relief shoes do not completely relieve heel and hindfoot peak pressures but leave a considerable amount of pressure predominantly under the hindfoot. The extent of hindfoot load that remains in both shoes seems surprising as one might expect more radical hindfoot relief in so-called hindfoot relief shoes. Moreover, the extent of peak pressure reduction for the heel and the hindfoot varies between different hindfoot relief shoes. We consider this information important for physicians involved in the treatment of plantar ulcers. The München shoe can provide subtotal relief in the heel, defined as 0% to 15% of

![Figure 3](image-url)

**Figure 3.** Typical plantar pressure patterns obtained from normal gait (mass-produced shoe) (A), from the short-soled forefoot relief shoe used appropriately (München shoe) (B), and from the complete-soled forefoot relief shoe used appropriately (Mars shoe) (C).
total sole length. This shoe may be more appropriate for the treatment of plantar ulcers that do not exceed the proximal 15% of the foot. The Mars shoe seems to be favorable in terms of hindfoot reduction, but it still allows 64% baseline peak pressure. When hindfoot relief is required, note that both shoes fail to provide even a halving of peak pressure reduction.

This study focused on plantar pressure distribution in differently designed relief shoes. Both shoes have been used in the Division of Orthopaedic Rheumatology, University of Erlangen-Nuremberg (Erlangen, Germany) for many years. In most cases, patients can walk safely in either shoe design without a tendency to fall. Some patients, however, are provided with a walking stick when they feel insecure in their relief shoe. The present participants mostly preferred the Mars shoe because walking was described as “more comfortable” and “more stable.”

As a limitation to these findings, the measurements were taken from healthy volunteers and not from neuropathic patients. There is some previous evidence that postural stability is affected by off-loading devices in such patients. This study does not allow estimating balance and walking stability when the shoes are applied in neuropathic patients. Future comparative studies in patients with plantar ulcers might reveal whether hindfoot relief shoes are safe and effective in terms of mobility and wound healing.

Conclusions

We conclude from these data that hindfoot relief shoes do not completely suspend forces under the heel and hindfoot but instead leave a considerable amount of peak pressure, predominantly under the hindfoot. Because the extent of peak pressure reduction for the heel and the hindfoot varies between different hindfoot relief shoes, the type of hindfoot relief shoe should be carefully chosen.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

References