Does shoe stiffness affect running economy?

Owen N. Beck, Pawel R. Golyski, & Gregory S. Sawicki
Woodruff School of Mechanical Engineering & School of Biological Sciences
Georgia Institute of Technology
obeck3@gatech.edu

Background

- ↓ metabolic rate during running improves distance-running performance\(^1\)
- Shoes with moderately stiff carbon fiber midsoles ↓ metabolic rate during running
  Physiological mechanisms are unknown\(^2\)
- ↑ shoe bending stiffness yields more anterior foot CoP during walking\(^3\) & running\(^4\)
- More anterior foot CoP ↑ plantarflexor force and ↓ shortening velocities during walking\(^3\)

Hypothesis: Intermediate shoe stiffness will ↓ metabolic rate during running by optimizing the interplay between plantarflexor force production and shortening velocity

Methods

2 male runners (Avg±SD; Age: 26.5±0.71 yrs; Ht: 1.83±0.08 m; Mass: 71.5±5.6 kg)
6 footwear conditions
Shoe: Adidas adizero adios II (Adidas)

1 Barefoot
1 Adidas
4 Adidas & carbon fiber in-soles

3-point bending test (Instron 5965, Norwood, MA)
- Displaced footwear 10 mm; rate 8 mm/s; 5x cycles; 100 Hz
- Stiffness = linear force-displacement slope from 5-10 mm (R\(^2\) range: 0.90-0.99)

Metabolic session

- 5 min standing, 5 min treadmill/Adidas familiarization
- 6x5 min treadmill running trials; randomized footwear conditions
- Avg VO\(_2\)/ VCO\(_2\) during last 2 min
- Convert to metabolic power (W/kg)\(^5\)

Biomechanics session

- Ground reaction forces (1000 Hz)
  (Bertec Corp., Columbus, OH).

Future

- EMG (Delsys, Inc., Natick, MA)
- Motion capture (Vicon, Oxford, UK)
- B-mode ultrasound (Telemed, Vilnius, Lithuania) to track medial gastrocnemius and soleus fascicles

Results

Table 1. Footwear parameters, CF = carbon fiber insole

<table>
<thead>
<tr>
<th></th>
<th>Barefoot</th>
<th>Shod</th>
<th>Shod/CF1</th>
<th>Shod/CF2</th>
<th>Shod/CF3</th>
<th>Shod/CF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>k (N/mm)</td>
<td>0</td>
<td>10.5</td>
<td>33.3</td>
<td>41.1</td>
<td>75.1</td>
<td>96.5</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>0</td>
<td>258</td>
<td>258</td>
<td>258</td>
<td>258</td>
<td>258</td>
</tr>
</tbody>
</table>

Table 2. Contact time (t\(_c\)), step time (t\(_{step}\)), leg stiffness (k\(_{leg}\)), and vertical GRF parameters across footwear conditions, CF=carbon fiber insole

<table>
<thead>
<tr>
<th></th>
<th>Barefoot</th>
<th>Shod</th>
<th>Shod/CF1</th>
<th>Shod/CF2</th>
<th>Shod/CF3</th>
<th>Shod/CF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>t(_c) (s)</td>
<td>0.230</td>
<td>0.231</td>
<td>0.238</td>
<td>0.236</td>
<td>0.238</td>
<td>0.237</td>
</tr>
<tr>
<td>t(_{step}) (s)</td>
<td>0.348</td>
<td>0.370</td>
<td>0.362</td>
<td>0.365</td>
<td>0.367</td>
<td>0.366</td>
</tr>
<tr>
<td>k(_{leg}) (kN/m)</td>
<td>12.8</td>
<td>12.8</td>
<td>12.2</td>
<td>12.2</td>
<td>12.2</td>
<td>12.2</td>
</tr>
<tr>
<td>Stance Avg vGRF (BW)</td>
<td>1.80</td>
<td>1.81</td>
<td>1.83</td>
<td>1.81</td>
<td>1.84</td>
<td>1.81</td>
</tr>
<tr>
<td>Peak vGRF (BW)</td>
<td>2.74</td>
<td>2.90</td>
<td>2.79</td>
<td>2.79</td>
<td>2.83</td>
<td>2.80</td>
</tr>
</tbody>
</table>

Conclusion

Footwear longitudinal bending stiffness may affect muscle mechanics and running economy, thereby altering distance-running performance

References