Science Meets Practice: The Great Foot Strike Debate

Obsession with Foot Strike: Enough Already

Bryan Heiderscheit, PT, PhD
Professor
Department of Orthopedics and Rehabilitation
Department of Biomedical Engineering
Director, UW Runners' Clinic
Director, Badger Athletic Performance Research
Co-director, UW Neuromuscular Biomechanics Lab

Where We Agree

- Well-aligned and controlled landings during running are important to reduce injury risk

Where We Differ

- Well-aligned and controlled landings during running are important to reduce injury risk
- Forefoot strike is the key to doing so
- Many effective strategies exist but none are universal

Vertical GRF

- Loading Rate
  - Associated with bone stress injuries
- Active Peak
  - Less frequently studies
  - Associated with joint moments and compression

“Ideal” Foot-strike

- “…a natural barefoot landing is described typically as a very mild forefoot strike with the foot landing slightly plantarflexed and the heel slightly off the floor…Running with this type of mild forefoot landing may be ideal…”

Is Loading Rate Actually Less?

Unpredictable Loading Rate

- Increased thigh position at mid swing and increased step rate are weakly associated with reduced loading rate

Loading Rate and Foot Angle

- Loading rates increase with speed
- Loading rates are highest with foot angles of -3 to 10

Foot Strike Classification

- Forrester & Townsend, 2015
- Altman & Davis, 2012
- Lieberman et al., 2015

Two Types of Rearfoot Strike

- Forrester et al. (2015). Gait Posture
- Altman & Davis (2012) Gait Posture

Foot Angle and GRF Metrics

- Peak GRFv increases as foot angle decreases
- Braking impulse minimally affected by foot angle

Injury Occurrence

- No clear relationship between foot strike and injury
- Injuries were distributed across loading rates
  - 2016-2017, injuries were more common with lower loading rates
**Sagittal Plane Mechanical Power**

- Positive work
  - similar distribution across joints between RFS and FFS
- Negative work
  - Greater at knee for RFS
  - Greater at ankle for FFS
- Considerable implications on transitioning to FFS

**No Single Optimum Form for All**

- Physical differences prevent everyone from using the same form
  - Strength, bony structure, range of motion, tissue stiffness, mass distribution, general fitness, running history...
- Instead, there are key characteristics to avoid
  - Overstriding
  - Bounce
  - Compliance

**Over-striding and Excessive Bounce**

- Benefits of Increased Step Rate
  - Increased step rate:
    - reduces COM vertical displacement (bounce)
    - reduces Heel to COM distance (overstriding)
    - increases lower extremity stiffness (compliance)

**Excessive Compliance**

- Patellofemoral Joint Forces
  - Reduced patellofemoral joint compression force with increased step rate
    - Patellofemoral Force over Single Stride
      - Preferred step rate (PSR)
      - PSR +10%
      - PSR -10%
      - Preferred (100%)
      - 90%
Step Rate and Injury Risk

- Step rate among high school runners (n=68) measured pre-season
  - fixed speed (8 min/mile) and preferred
- Lower extremity injuries tracked through subsequent competitive season
  - 18.1% of runners experience lost day(s) due to shin injury
- Runners with step rate < 166 steps/min were more likely to sustain a shin injury than those with step rate > 174
  - [OR 5.85 (1.1-32.1, p<0.04)]

Pre-activation and Step Rate

- Gluteus medius pre-activation in swing may facilitate reduction of hip adduction angle and abduction moment in stance

Less Crossover with Greater Step Rate

- Increased base of gait (less crossover) associated with increased step rate across all running speeds
  - not the case for foot strike angle

<table>
<thead>
<tr>
<th>Foot Strike Angle</th>
<th>Speed</th>
<th>p-value</th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.86 m/s (9:30 min/mile)</td>
<td>3.30 m/s (8:20 min/mile)</td>
<td>3.63 m/s (7:20 min/mile)</td>
<td>4.11 m/s (6:30 min/mile)</td>
<td>4.85 m/s (5:30 min/mile)</td>
</tr>
<tr>
<td>All Subjects</td>
<td>Men</td>
<td>Women</td>
<td>All Subjects</td>
<td>Men</td>
</tr>
<tr>
<td>Crossover (+)</td>
<td>Crossover (-)</td>
<td>Crossover (+)</td>
<td>Crossover (-)</td>
<td>Crossover (+)</td>
</tr>
<tr>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
</tr>
<tr>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
</tr>
<tr>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Cross-Over

- More likely to crossover at higher speeds
- Women less likely to crossover

Step Rate vs Forefoot Strike

- Reduced PFJ stress per stride
  - Step rate – 15%
  - Forefoot – 10%
- Reduced PFJ stress over 1-km
  - Step rate – 9%
  - Forefoot – 12%

Foot Strike

- Patellofemoral Contact Area and Pressure
  - Multibody Knee Model
  - 6 dof tibiofemoral and patellofemoral joints added to lower extremity musculoskeletal model

Step Rate and Injury Risk

- Step rate among high school runners (n=68) measured pre-season
  - fixed speed (8 min/mile) and preferred
- Lower extremity injuries tracked through subsequent competitive season
  - 18.1% of runners experience lost day(s) due to shin injury
- Runners with step rate < 166 steps/min were more likely to sustain a shin injury than those with step rate > 174
  - [OR 5.85 (1.1-32.1, p<0.04)]

Pre-activation and Step Rate

- Gluteus medius pre-activation in swing may facilitate reduction of hip adduction angle and abduction moment in stance

Less Crossover with Greater Step Rate

- Increased base of gait (less crossover) associated with increased step rate across all running speeds
  - not the case for foot strike angle

<table>
<thead>
<tr>
<th>Foot Strike Angle</th>
<th>Speed</th>
<th>p-value</th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.86 m/s (9:30 min/mile)</td>
<td>3.30 m/s (8:20 min/mile)</td>
<td>3.63 m/s (7:20 min/mile)</td>
<td>4.11 m/s (6:30 min/mile)</td>
<td>4.85 m/s (5:30 min/mile)</td>
</tr>
<tr>
<td>All Subjects</td>
<td>Men</td>
<td>Women</td>
<td>All Subjects</td>
<td>Men</td>
</tr>
<tr>
<td>Crossover (+)</td>
<td>Crossover (-)</td>
<td>Crossover (+)</td>
<td>Crossover (-)</td>
<td>Crossover (+)</td>
</tr>
<tr>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-0.57</td>
</tr>
<tr>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
<td>-0.19</td>
</tr>
<tr>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Changes in Running Economy

- No increase in submax VO₂ after 6 wks of running at +10% step rate among recreational runners
  - >15 miles/wk

- 8% increase in submax VO₂ after 12wks of training with forefoot strike

Does One Foot-strike Fit All?

NYC Marathon

- 1970
- early 1990s

- History does not tell the full story

Thank You