Comparison of in-shoe plantar pressure between Korean combat boots and running shoes

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Combat boots

• Special shoes worn by soldiers during activities in rough terrains
  • Such as long-term marches or military training

• Combat boots cause high plantar pressure
  • Foot pain is related to increased plantar pressure  

• High incidence of musculoskeletal injuries
  • Such as stress fracture and tendinitis  
    (Nye et al J Athl Train 2016)
The other studies between combat boots and running shoes

- Comparison of ground reaction force (GRF)
  - Combat boots have higher GRF than running shoes.  
    (Bini et al. Biomechanics 2021)

- Comparison of electromyography (EMG)
  - Combat boots caused increased activity in the tibialis anterior muscle.
    (Schulze et al. Open Orthop J 2011)
Purpose

• To compare difference of in-shoe plantar pressure
  • between the newly developed Korean combat boots and running shoes
Materials and methods

• Prospective comparative research
• 33 young male participants

• Inclusion criteria
  • Absence of subjective symptoms during gait.
  • Korean shoe size : 265 – 285
  • AOFAS ankle hindfoot scale > 90

• Exclusion criteria
  • History of lower extremity injuries such as fracture, surgery and so on
  • Deformity of foot and ankle
Materials and methods

• Type of shoes
  • A : Running shoes
    • The model : New balance ML 574 EVG
    • EVA midsole
    • Rubber outsole
    • 405g based on size of 270mm
  
  • B : Korean combat boots
    • The model adapted in Korean army since 2020.
    • Leather cover
    • Rubber outsole
    • 1,200g based on size of 270mm

EVA : Ethyl Vinyl Acetate
Materials and methods

• Clinical score (before test)
  • American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scale

• Radiographic measurement
  • Lateral talus-first metatarsal ankle (Meary’s angle)
  • 1-2 intermetatarsal angle
  • 1st metatarsophalangeal angle

• Pedobarographic measurement
  • The pedar®-X in-shoe pressure measurement system (novel corporation, Munich, Germany)
    • Proven reliability and validity
  • After subjects wore two types of shoes, the data was collected.
    • Peak pressure (PP), and pressure time integral (PTI)
    • Contact area, and contact time
Materials and methods

• The foot was divided into eight regions, for the analysis of data

• Modification from S.A. Bergstra’s methods for pressure parameters

  (A) Hallux. (B) 2-5 toes. (C) medial forefoot(FF). (D) central forefoot. (E) lateral forefoot. (F) midfoot. (G) medial heel. (H) lateral heel.

(Bergstra et al J Sci Med Sport 2015)
Results

• Demographic data
  • Thirty of 33 participants were included to the study

• Clinical scores
  • The average AOFAS ankle-hindfoot scale
    • 98.63 ± 0.90.

• Radiographic measurement
  • The Meary’s angle : 0.43 ± 1.98 degrees
  • The 1-2 intermetatarsal angle : 7.94 ± 1.41 degrees
  • The 1st metatarsophalangeal angle : 9.61 ± 2.59 degrees

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Age, year</td>
<td>21.7 (1.2)</td>
</tr>
<tr>
<td>Height, cm</td>
<td>176.7 (3.6)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>72.8 (8.8)</td>
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<tr>
<td>Body mass index, kg/m²</td>
<td>23.4 (3.2)</td>
</tr>
<tr>
<td>Foot length, cm</td>
<td>272 (5.7)</td>
</tr>
</tbody>
</table>
Results

• Pedobarographic measurement
  
  • PP & PTI
  
  • PP of the combat boots
  Higher than those of the running shoes at the region of central FF, and lateral FF.

• PTI of the combat boots
Higher than those of the running shoes at the region of central FF, and lateral FF.
Results

- Pedobarographic measurement
  - Contact area
    - Contact area of combat boots
      Lower than those of running shoes at the region of hallux, 2-5 toes, medial FF, central FF, and midfoot.

<table>
<thead>
<tr>
<th></th>
<th>Combat boots</th>
<th>Running shoes</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact area (cm²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>156.20 ± 13.65</td>
<td>164.50 ± 12.20</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hallux</td>
<td>8.07 ± 0.67</td>
<td>8.48 ± 0.65</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Second-fifth toes</td>
<td>18.00 ± 2.58</td>
<td>19.49 ± 1.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Medial forefoot</td>
<td>12.76 ± 1.88</td>
<td>13.58 ± 1.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Central forefoot</td>
<td>20.55 ± 2.01</td>
<td>20.96 ± 1.53</td>
<td>0.018</td>
</tr>
<tr>
<td>Lateral forefoot</td>
<td>13.79 ± 1.09</td>
<td>14.02 ± 1.01</td>
<td>0.051</td>
</tr>
<tr>
<td>Midfoot</td>
<td>37.92 ± 6.63</td>
<td>43.13 ± 6.44</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Medial Heel</td>
<td>26.04 ± 1.90</td>
<td>26.08 ± 1.92</td>
<td>0.085</td>
</tr>
<tr>
<td>Lateral Heel</td>
<td>19.06 ± 1.44</td>
<td>18.77 ± 1.49</td>
<td>0.012</td>
</tr>
</tbody>
</table>
Results

• Pedobarographic measurement
  • Contact time

• Contact time of combat boots
  Higher than these of running shoes at the region of central FF, and medial heel.

<table>
<thead>
<tr>
<th></th>
<th>Combat boots</th>
<th>Running shoes</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Time (ms)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>867.87±22.37</td>
<td>860.02±27.79</td>
<td>0.146</td>
</tr>
<tr>
<td>Hallux</td>
<td>611.24±114.93</td>
<td>669.91±125.60</td>
<td>0.003</td>
</tr>
<tr>
<td>Second-fifth toes</td>
<td>573.29±111.66</td>
<td>591.56±134.64</td>
<td>0.098</td>
</tr>
<tr>
<td>Medial forefoot</td>
<td>594.53±107.55</td>
<td>616.71±107.86</td>
<td>0.035</td>
</tr>
<tr>
<td>Central forefoot</td>
<td>705.16±91.18</td>
<td>683.96±98.60</td>
<td>0.040</td>
</tr>
<tr>
<td>Lateral forefoot</td>
<td>731.78±79.51</td>
<td>738.98±67.28</td>
<td>0.258</td>
</tr>
<tr>
<td>Midfoot</td>
<td>809.73±78.17</td>
<td>804.18±74.62</td>
<td>0.387</td>
</tr>
<tr>
<td>Medial Heel</td>
<td>750.46±104.29</td>
<td>633.87±92.31</td>
<td>0.000</td>
</tr>
<tr>
<td>Lateral Heel</td>
<td>776.84±102.95</td>
<td>751.07±118.41</td>
<td>0.155</td>
</tr>
</tbody>
</table>
Discussion

• Combat boots : high PP and PTI in central FF and lateral FF.
  • High shoe collar limit ROM of ankle joint.
  • Limited dorsiflexion of ankle joint elevate plantar pressure.
  • Heavy shoes increase the peak vertical GRF.
  • Central FF and lateral FF correspond to metatarsal bone.
    • Associated with the risk of stress fracture.
    • One of factors which cause foot injury.

• Combat boots : low contact area in Hallux, 2-5 toes, medial FF, central FF, and midfoot
  • In the other study, the contoured insoles ~
    • increase contact area
    • reduce local peak pressure

• Need to redistribute plantar pressure by elevating the contact area.

(Searle et al Clin Biomech 2017)
(Wilems et al Gait Posture 2012)

PP : peak pressure
PTI : pressure time integral
FF : forefoot
ROM : range of motion
GRF : ground reaction force

Limitation

• First, running shoes is not a representative model.

• Second, shoe size and sensor size may be not totally matched with foot size.

• Finally, this study didn’t consider evaluating long distance walking.
Conclusion

• We compared the in-shoe plantar pressure pattern of Korean combat boots and running shoes through the gender-controlled population

• Understanding of plantar pressure traits of the current combat boots can be helpful to develop next generation of combat boots and prevent from injury of lower leg.