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Peak and average pressure correlations and their ratio at different plantar regions of the foot
Roozbeh Naemi a, Aoife Healy a, Dave Dunning a, Robert Leslie Ashford b, Panagiotis Chatzistergos a & Nachiappan Chockalingam a
a Staffordshire University, Stoke on Trent, ST4 2DF, United Kingdom
b Birmingham City University, Faculty of Health, City North Campus, Perry Barr, Birmingham, B42 2SU, United Kingdom

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Discussion and conclusion
In general, with the Unstable shoes the subjects burned more kilocalories during walking, and managed to do so without increasing the peak loads experienced by the knee joint. The greater EE could be explained by the greater mass of the Unstable shoes which were approximately 120 grams heavier than the Control shoes. It has been shown that 100 grams of additional shoe mass increases EE by about 1% per minute (Frederick 1984), therefore the 3.4% increase cannot be attributed to mass alone. It is unknown exactly how long an individual would need to be exposed to this benefit in order to achieve noticeable changes compared to using a typical walking shoe, but this small difference suggests that this would not occur over a short period of time.

Although the Unstable shoe reduced the peak moments experienced by the knee joint, it increased the initial peak ankle inversion moment substantially compared to the Control shoe. Further research would be required to understand if this increase places the wearer at a high risk of injury.

Overall, the results of this study show that Unstable shoes may promote a slight increase in metabolic energy cost during walking. However a relatively large increase in the initial peak ankle inversion moment should be scrutinised.

References
the foot. The peak plantar pressure on the other hand has been widely linked to the risk of injuries like foot ulceration in people with Diabetes (Yuk San Tsung et al. 2004, Lyons et al. 2012).

While at each instant during stance phase the average pressure in each region reveals the average value of the pressure across all points in that region, the peak pressure shows the highest pressure in a particular point. It is therefore hypothesised that a peak to average pressure ratio may provide an outcome measure which can be related to efficacy of footwear.

Purpose of the study
The purpose of this study was to investigate the correlation between the peak and the average pressures at different plantar regions of the foot and to investigate the ratio between the two at different regions.

Methods
Eight participants, 4 male and 4 female, (weight 76.8 ± 24.4 kg) and (shoe UK size 7.8 ± 1.4) participated in this study. The Fscan* (Tekscan Inc, USA) in-shoe plantar pressure assessment system was used to measure the pressure between the foot and the insole.

The data was sampled at 100 Hz and a timing gate was used to assess the walking speed across a 10 m walkway. Data from three baseline trials from each participant were collected to assess the average speed which was used a preferred speed for that individual. Only trials that fell within ± 10% of this speed were selected for data reduction and analyses. The average preferred speed across all subjects was 1.54 ± 0.19 m/s.

The plantar surface of the foot was divided into 10 regions, including hallux, lesser toes, first metatarsal head, mid metatarsal heads, fifth metatarsal head, midfoot lateral, midfoot centre, arch, centre of the heel and heel. Both the average and peak plantar pressure in each region were extracted from six consecutive stance phases from each both feet and averaged across five trials for each participant. These data then averaged across eight participants. A 6-mm flat insole/footbed made from Poron* (Algeos, UK) was used in conjunction with a plimsoll to avoid any confounding introduced by footwear design.

Results
A significant correlation was found between the average and peak plantar pressure corresponding to different regions of the plantar surface of the foot. Results for the Pearson correlation and descriptive statistics are presented in Table 1. The ratio of peak to average plantar pressure was also calculated as presented in Figure 1.

Discussion and conclusion
Despite the significant correlation between the peak and average plantar pressure at different regions of the plantar surface of the foot, the ratio of these two parameters varies across different regions. The greatest ratio was observed in the heel region (3.4) followed by under the arch (2.5). The area underneath the fifth metatarsal head and lesser toes on the other hand showed the lowest ratio (1.15 and 1.46 respectively). The ratio of peak to average pressure

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![Figure 1](image-url)  
**Figure 1.** The peak–average pressure ratio for the different plantar regions of the foot.
can have implications with regards to identifying the critical regions vulnerable to injuries. While the average and peak pressure are important parameters that can identify the pressure distribution and injury potential, the ratio of peak to average plantar pressure may reveal other aspects of the tissue breakdown. Furthermore this will be a useful outcome measure for the influence of footwear and orthotics while investigating footwear biomechanics.

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References

Influence of basketball shoe mass, traction and bending stiffness on athletic performance
John William Wannop*

University of Calgary, Human Performance Lab, Faculty of Kinesiology, 2500 University Drive NW, Calgary, Alberta, T2N 1N4 Canada

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Introduction
Footwear properties such as shoe mass, outsole traction and forefoot bending stiffness can enhance athletic performance (Frederick 1984, Stefanyshyn and Nigg 2000, Muller 2010). However, the practical importance of each of these properties is currently not communicated to consumers.

For example, when selecting a basketball shoe, there is no general guideline available to help a player decide if they should choose the lightest shoe, the shoe with the most traction, or the shoe with the greatest forefoot bending stiffness.

Purpose of the study
The study aimed to study the influence of basketball shoe mass, outsole traction, and forefoot bending stiffness on jumping, sprinting, and cutting performance.

Methods
Several pairs of Nike Kobe V (US 10) basketball shoes were used in the study. The shoes were modified in order to create three sets of three shoes. For each set, one property of the three shoes was varied by ±20%. Therefore, three shoe conditions of varying mass were compared (331, 414 and 497 grams), three shoe conditions of varying outsole traction were compared (traction coefficients of 0.8, 1.0 and 1.2), and three shoe conditions of varying forefoot bending stiffness were compared (0.22, 0.28 and 0.33 Nm·deg⁻¹).

Three series of data collection sessions were completed, one per shoe property. Each shoe property was tested by 20 recreational basketball players completing maximal effort 10 m sprints, vertical jumps (running approach, one-foot takeoff), and a cutting drill (Figure 1). All testing took place in the same hardwood floor gymnasium. Data for three trials in each shoe condition were collected for each performance test, and the average value of these three trials was calculated for analysis. Shoe condition and performance test order were randomised for each subject.

Repeated measures analyses of variance were used to identify statistically significant differences between shoe conditions for each property, at a level of confidence of

| Table 1. Average and peak plantar pressure values for different regions of the foot and the correlation (‘ significant p < 0.01). |
|---|---|---|---|---|---|---|---|
| Arch | Mid-foot centre | Hallux | Heel | 1st MTP | 5th MTP | Lateral Mid-Foot | Centre MTPs | Lesser toes |
| Pearson Correlation | 0.872* | 0.759* | 0.963* | 0.945* | 0.979* | 0.9* | 0.869* | 0.950* | 0.98* |
| Covariance | 353.7 | 466.0 | 2291.9 | 10686.2 | 3679.5 | 749.6 | 278.0 | 5256.1 | 1001.5 |
| Peak Pressure Mean(kPa) | 67.4 | 82.9 | 89.1 | 229.1 | 115.0 | 78.4 | 61.7 | 141.2 | 63.2 |
| Peak Pressure Stdev. | 43.0 | 53.8 | 62.7 | 194.2 | 91.8 | 37.9 | 33.9 | 102.0 | 43.7 |
| Average Mean (kPa) | 27.0 | 39.2 | 52.7 | 67.3 | 59.0 | 67.3 | 37.9 | 93.3 | 42.9 |
| Average Stdev. | 9.5 | 11.7 | 37.2 | 54.7 | 40.9 | 22.3 | 9.3 | 53.9 | 23.1 |

*Corresponding author. Email: bwannop@kin.ucalgary.ca

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