Sex-Based Differences in Plantar Pressure Distribution to Inform Soccer Cleat Design

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Introduction

- Soccer demands patterns of quick multiplanar movements, which vary by individual and playing position [1], [2].
- Soccer cleat designs favor male data in spite of differences in anthropometrics, anatomical alignment, movement patterns, and playing behaviors between sexes [3], [4], [5].
- Male and female plantar pressure distribution differences measured by maximum force and force-time integral (FTI) have been demonstrated in crossover cutting, side cutting, and jump-landing [6], [7].
- Force-time integral (FTI), known as impulse, shows how long an area is being loaded and with what amount of force [6].
- Bladed firm-ground soccer cleats are associated with higher traction and higher plantar loading than elliptical turf cleats [6], [8].

Question

How does plantar pressure distribution, measured by force-time integral, differ between males and females for cutting and sprinting tasks?

Methods

Participants

- 10 male and 9 female active soccer athletes ages 18-26 without lower extremity injury in the past year and without previous ACL injury

Data Collection: Modified Gauntlet Fatigue Protocol

- Plantar pressure data was collected via sensors in pedar® insoles replacing the sock liner of a bladed control cleat (Figure 1).
- Gauntlet is a validated method of assessing cardiorespiratory fitness and aerobic endurance performance [9].
- Athlete performed five stages of running (1600 m, 800 m, 400 m, 200 m, 100 m) with cuts on FieldTurf Vertex CORE (Figure 2)

Data Processing and Analyses

- Data from cutting steps and six straight running steps were used to calculate FTI normalized to body weight in nine regions of the foot using a mask in novel projects® (Figure 3).
- The last six running steps preceding the final two steps represent the maximum velocity phase that is of interest for performance [10].
- Independent t-tests were conducted in Microsoft Excel and Jamovi to determine if sex had a significant effect ($p < 0.05$) on FTI in each region.

Figure 1: Bladed control adidas Predator Edge.2 FG cleat.

Data Collection

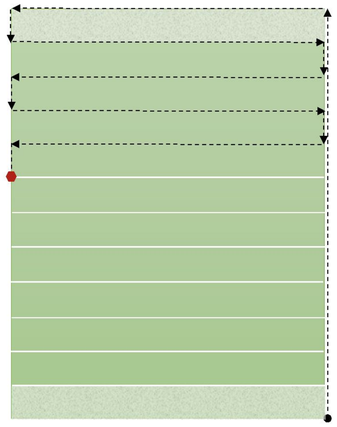

Figure 2: Third stage 400 m route of the fatigue protocol with cuts every 10 yards on artificial turf.

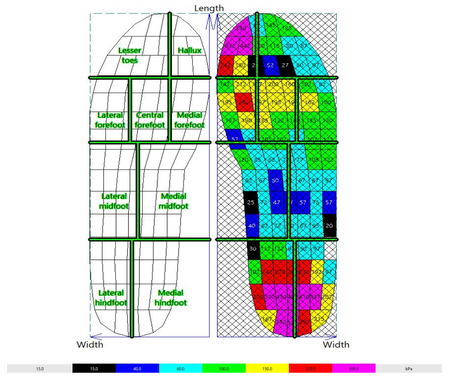

Figure 3: Plantar pressure data masked in nine regions: medial hindfoot (MH), lateral hindfoot (LH), medial midfoot (MM), lateral midfoot (LM), medial forefoot (MF), central forefoot (CF), lateral forefoot (LF), hallux (HA), and lesser toes (LT).

Results

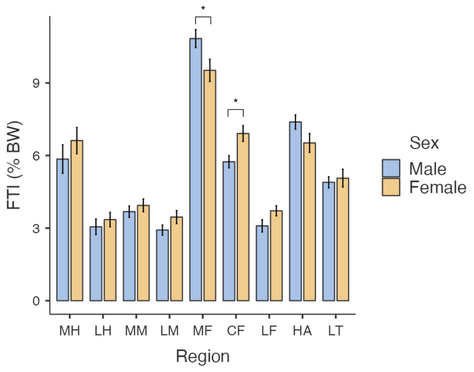

Figure 4: Side-cutting mean FTI in each foot region for each sex with significant differences in MF and CF ($p < 0.05$).

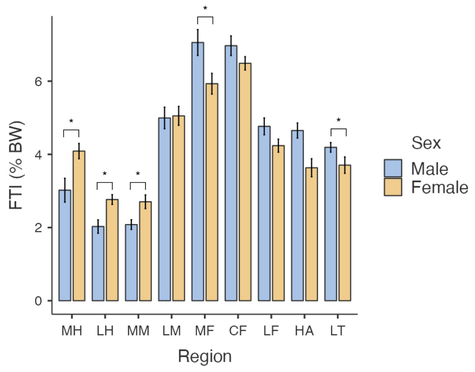

Figure 5: Running mean FTI in each foot region for each sex with significant differences in MH, LH, MM, MF, and LT ($p < 0.05$).

★ During cutting maneuvers, females had a significantly lower FTI in the medial forefoot ($p = 0.029$) and significantly higher FTI in the central forefoot compared to males ($p = 0.006$) (Figure 4).

★ While running straight, females had a significantly lower FTI in the medial forefoot ($p = 0.016$) and lesser toes ($p = 0.002$) than males, while females had significantly higher FTI in the medial hindfoot ($p = 0.008$), lateral hindfoot ($p = 0.002$), and medial midfoot ($p = 0.007$) than males (Figure 5).

Discussion

- Results align with previous soccer-specific literature suggesting FTI during cuts for both sexes is generally highest in MF, HA, and MH, and that FTI during acceleration is generally highest in the MF, CF, HA, and lesser toes [7], [11], [12].
- Results oppose the finding that male FTI in CF is greater than female FTI in cuts [7].
- Results support that male FTI in CF is greater than female FTI in cuts during sprinting [7].
- It is unclear why female FTI in the hindfoot is greater than in male FTI. It should be investigated if heel striking is a form of adapting to fatigue or to the fit of the cleat designed for male bodies.

Limitation

- Speed impacts FTI, but subject was only instructed to complete the task without regard to speed.

Future Direction for Female Cleats

- Apply insights to insole and outsole design to modify load distribution.
- Simply increasing cushioning in a high stress area (e.g. medial region) may be inappropriate and lead to ankle inversion.
- Adding more studs may interfere with traction.

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