

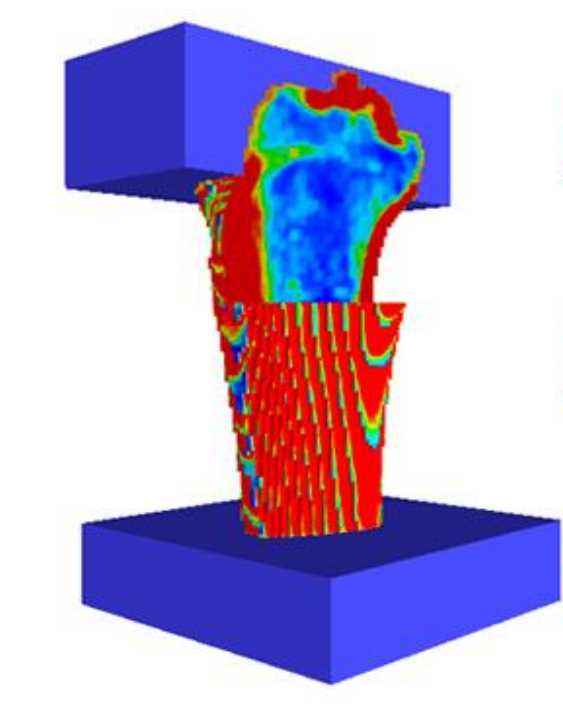
WPI

Bone Architecture and Foot Muscle Strength Are not Different in Healthy Male Versus Female Runners

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**Musculoskeletal
Biomechanics
Laboratory**



INTRODUCTION

- Bone stress injury (BSI) is a significant detriment to military recruits and competitive runners
 - Recruits who sustain a BSI are 3x more likely to be discharged than those who don't [1]
 - BSI accounts for 20% of injuries reported at sports medicine centers [2]
- A recent report found 37% of BSIs occurred in the metatarsals of college athletes and the most season-ending fractures were metatarsal injuries [3]
- High running volume and impaired bone microarchitecture increase risk for developing BSI [2]
- Female athletes are 2-3 times more likely to develop BSI more than men [4]
- Epidemiologic evidence links intrinsic foot muscle weakness to metatarsal BSI risk, but the mechanism is unclear [5]

Hypothesis: Female runners will present with lower bone strength and weaker intrinsic foot muscle strength compared to male runners

METHODS

Subjects

- 16 runners (9 male, 7 female), age = 25 ± 8 yrs, height = 176 ± 8 cm, body mass = 72 ± 12 kg
- Inclusion criteria: each healthy subject runs > 15km/week, no history of BSI or metabolic disorders
- Demographics, running history, injury history were collected

Data Collection

- Bilateral scans using high-resolution computed tomography (HRpQCT) were taken of the entire metatarsals
- 2nd and 3rd metatarsals (MT2 and MT3, respectively) were segmented and integral masks were analyzed using Matlab
- Arch doming (Figure 1) was used to quantify intrinsic foot muscle strength using a custom-made foot dynamometer, described previously [6]

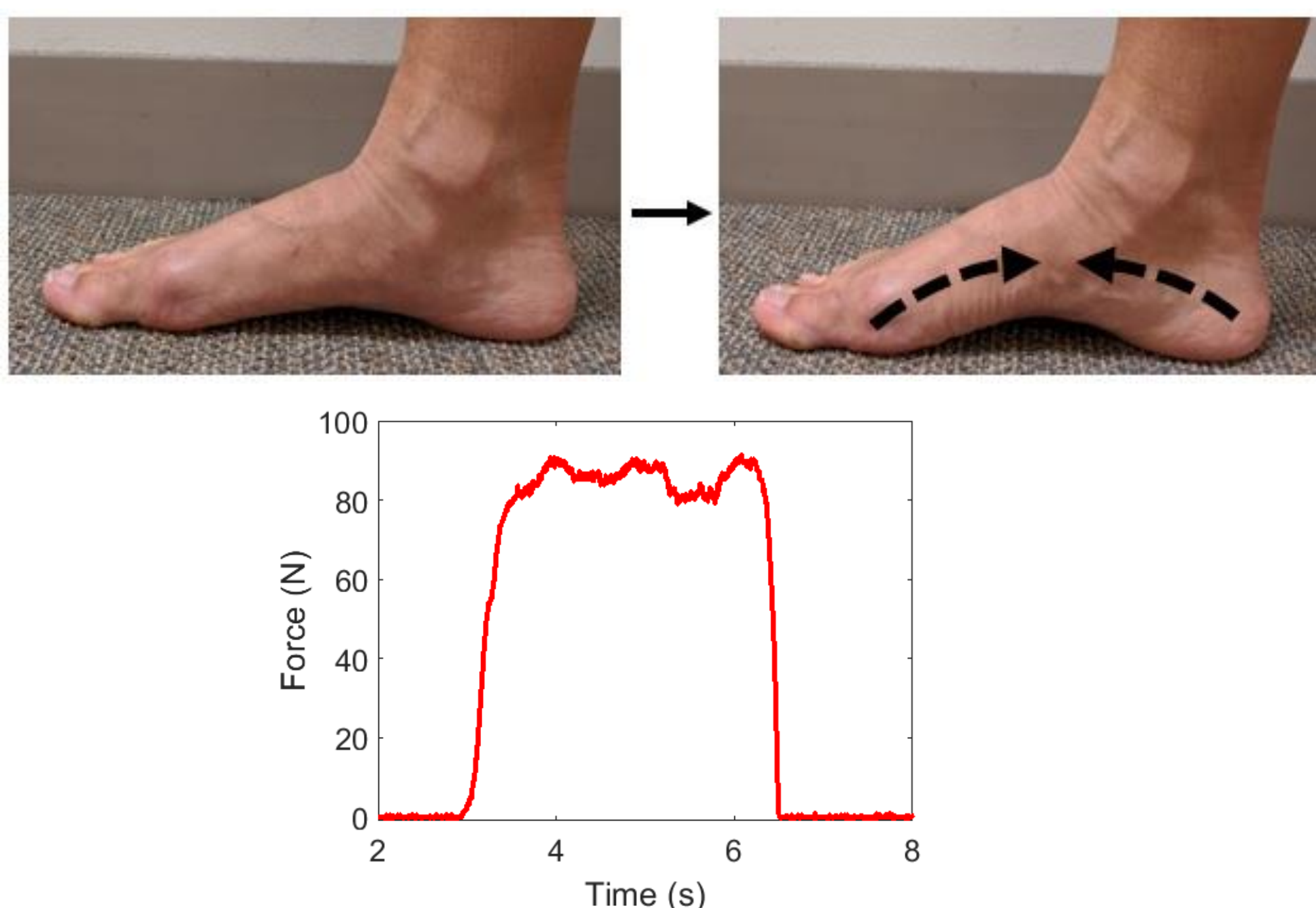


Figure 1. Arch doming (top) was recorded using a load cell (not shown) and force-time data (bottom) was processed in Matlab.

METHODS

Data Processing

- Strength index (SI) was calculated as the ratio of polar moment of inertia and metatarsal width [4]

$$SI = \frac{I_x + I_y}{W} \quad I_x = \frac{1}{E_c} \sum_i E_i \cdot (x_i - \bar{x})^2 \cdot dA$$

$$W = 2 \cdot \sqrt{\frac{CSA}{\pi}} \quad I_y = \frac{1}{E_c} \sum_i E_i \cdot (y_i - \bar{y})^2 \cdot dA$$



Figure 2. Reconstruction of foot bones (left) with cross-sectional density (middle) shown. Density-weighted center of mass and principal moments of the 2nd metatarsal (right).

- Data from male and female runners were compared using Student's T-test

RESULTS

Results

- Geometric strength indices of MT2 and MT3 were not significantly different between men and women ($p=0.42$ and $p=0.16$, respectively), even when normalized to body mass, ($p=0.53, p=0.81$, respectively)

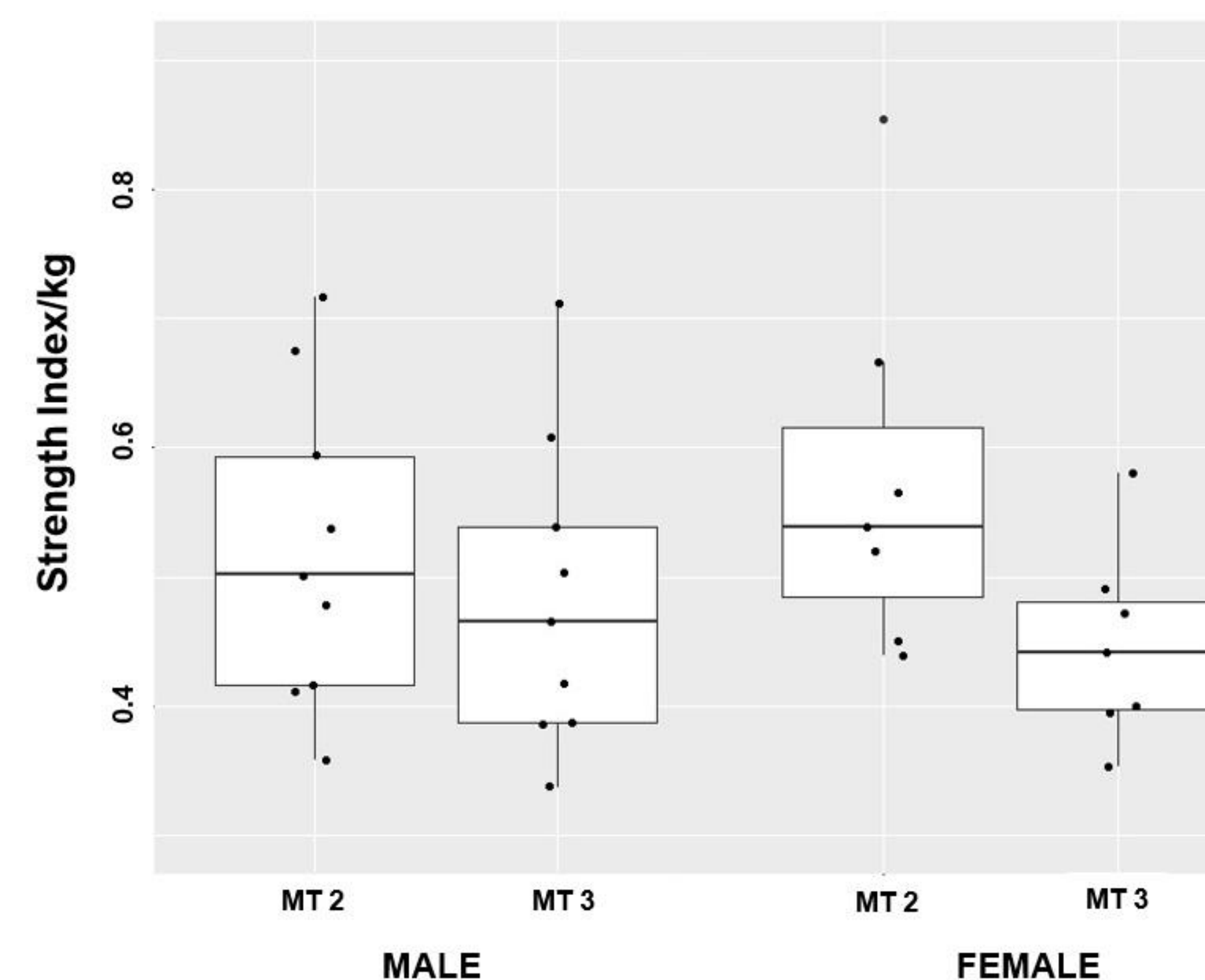


Figure 3. Comparison of MT2 and MT3 SI, normalized to body mass.

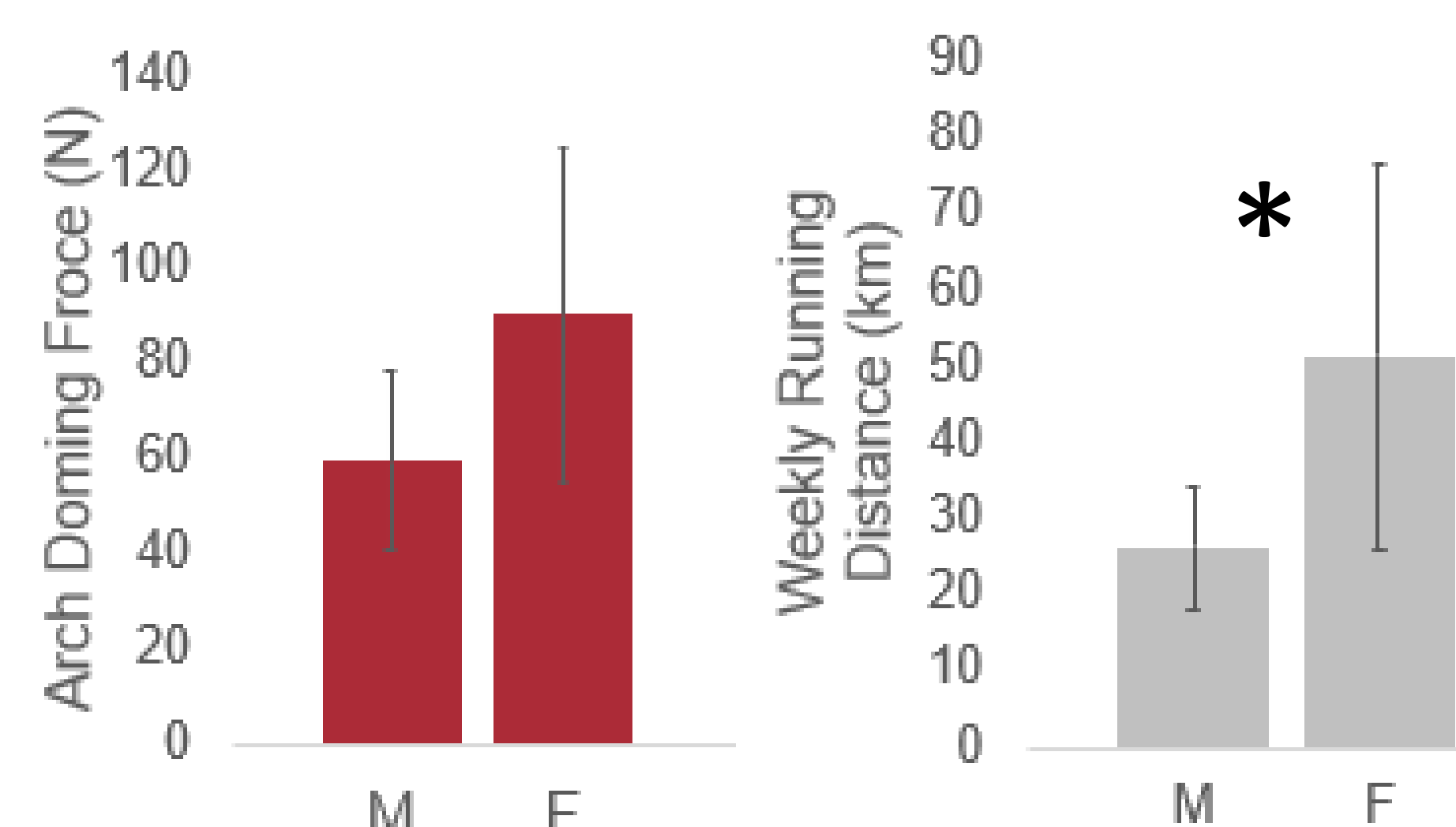


Figure 4. Comparison of average arch doming force (left) and weekly running distance (right) between men and women.

Results (Continued)

- Average weekly distance was 38 ± 21 km and all of the participants habitually ran in cushioned running shoes
- In our sample, female runners had higher weekly mileage than males ($p=0.008$; Figure 4)
- Arch doming strength was not significantly different between sexes ($p=0.11$; Figure 4)
- However, arch muscle strength scaled with weekly running distance (Figure 5)

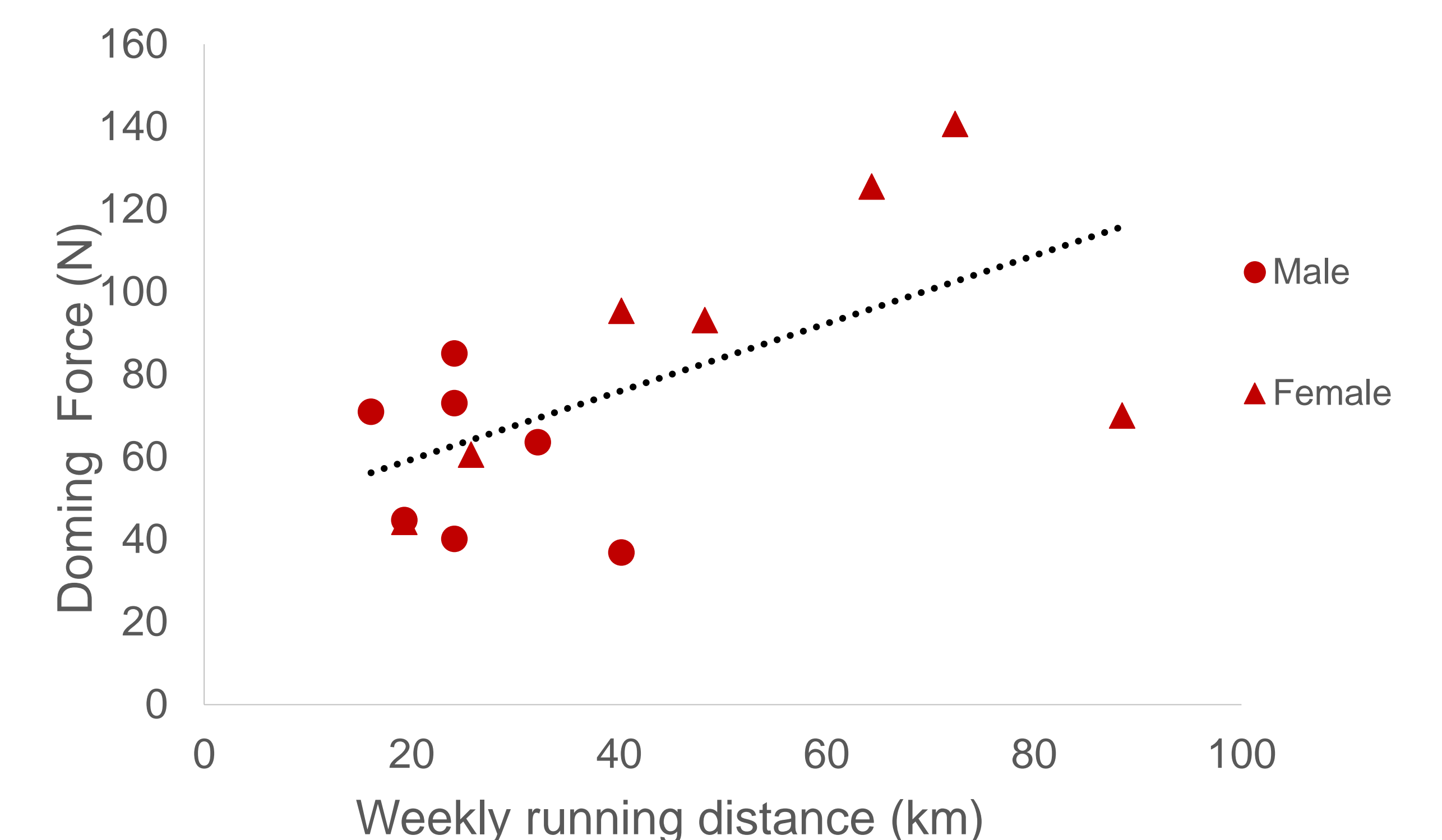


Figure 5. Runners with a high weekly distance generated higher forces during the arch doming exercise.

DISCUSSION

- Our hypothesis was not supported by our findings.
 - Neither geometric bone strength, nor foot muscle strength were significantly different between male and female runners.
- It is known that women have greater risk for developing BSI compared to men. However, in this sample female runners ran greater weekly distances than males.
- We observed increased strength in runners with high weekly running distance, so weekly distance may explain why we did not observe any male/female differences.
- Increasing foot muscle strength has been proposed as a method for mitigating BSI risk. Running in cushioned shoes, appears to be effective at increasing foot strength in these healthy runners.
- Individuals with BSI may not display the same bone and muscle adaptation shown here.

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