RELATIONSHIP BETWEEN FIRST RAY MOBILITY AND LOAD DISTRIBUTION IN THE METATARSALS

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INTRODUCTION
Stress fractures of the second and third metatarsals are common overuse injuries in athletes. Uneven load distribution across the metatarsals has been hypothesized as one factor related to the development of these injuries [1]. Previous research has reported the relative loading in the metatarsals during walking and shown that the first metatarsal carries approximately 30% of the total load [2]. However, how first ray mobility influences load distribution remains unclear as to date, only a few studies have reported relationships between dynamic measures of first ray mobility and plantar loading [3]. Therefore, the purpose of this study was to examine the relationship between first ray mobility under dynamic conditions and the relative load under the first, second, and third metatarsals. We hypothesized that higher first ray mobility would result in relatively lower loads under the first metatarsal and relatively higher loads under the second and third metatarsals.

METHODS
Ten recreationally active individuals participated in this study. All participants were injury free at time of testing. Participants walked along a 10-meter walkway in the laboratory while lower extremity kinematics were recorded using a 12-camera motion capture system (Motion Analysis Corp.) sampling at 200 Hz. Thirteen markers were placed on each foot to create a multi-segmented foot model consisting of the rearfoot, midfoot, metatarsals one through five, and hallux [3,4]. Ground reaction forces were recorded at 1000 Hz using a single force plate (AMTI) while synchronized plantar pressures were recorded at 500 Hz using a plantar pressure mat (Tekscan, Inc.) plate placed on top of the force plate. Five walking trials were recorded with each foot, with each trial being used separately in the analysis [3].

FScan Research software (version 7.5) was used to identify six regions under the foot (metatarsals 1-5 and all metatarsals). Forces in each individual region throughout stance phase were calculated as a percent of total forces under the metatarsals. Custom Matlab software was used to calculate sagittal plane angles of the first metatarsal relative to the ground during stance phase, from which total metatarsal range of motion (ROM) was determined. Linear regressions were used to evaluate whether first metatarsal ROM predicted relative load under the first, second, or third metatarsals at the instant of maximal metatarsal loading.

RESULTS AND DISCUSSION
Data analysis is still ongoing so results from three participants (30 trials) are presented. Mean range of motion for the first metatarsal during stance phase was 56.7 (± 8.3°) and both magnitudes and overall patterns of first metatarsal motion were consistent with previously reported values [4]. At the time of peak load in the metatarsals, the first, second, and third metatarsals carried 32.4 (± 6.5%), 29.7 (±5.4%), and 19.8 (± 6.1%) of the load, respectively. Contrary to our hypothesis, as first metatarsal ROM increased so did relative load under the first metatarsal ($R^2=.26$, $p=.003$, Figure 1A) and as first metatarsal ROM increased the relative load under the second metatarsal decreased ($R^2=.29$, $p=.001$, Figure 1B). First metatarsal ROM did not predict relative load under the third metatarsal ($R^2=.06$, $p=.17$).

CONCLUSIONS
These preliminary further support previous research [3] suggesting there is a distinct relationship between range of motion of individual foot segments and loading under the foot. However, these results call into question the idea that hypermobility of the first metatarsal results in higher loading under other regions. Future research is required to see if these same relationships are observed in additional subjects and in other activities such as running.

REFERENCES

Figure 1. Scatter plots showing first metatarsal ROM compared to relative load under the first (A) and second (B) metatarsals at the instant of maximal metatarsal loading.