INTRODUCTION
Stiffness of the lower extremity characterizes the relationship between the applied load and the corresponding displacement of the leg or joint and can be related to load attenuation. As stiffness of the lower limb and lower limb joints has been correlated with certain running injuries [1], it is important to understand how these variables may vary due to an individual’s gender and age. It is also important to determine if shoe midsole hardness has an effect on stiffness of the lower extremity as cushioning guidelines have been recommended in the literature for older individuals [2]. While previous publications have investigated the effects of age and shoe midsole hardness on lower extremity stiffness, these studies were limited to male participants from a narrow age range. Therefore, this study investigated the influence of shoe midsole hardness, gender, and age on the lower extremity apparent leg stiffness and joint stiffness during heel-toe running.

METHODS
Ninety-three recreational runners (47 male, 46 female) aged 16-75 years who ran at least 30 minutes per week participated in this study. Kinematic data were collected using an eight camera, 240 Hz motion capture system (Motion Analysis, CA, USA) with 12 retro-reflective markers mounted on the pelvis, right lower extremity and shoe. Kinetic data was collected simultaneously using a force plate (Kistler Instruments AG, Winterthur, Switzerland). Participants performed heel-toe running trials at 3.33 ± 0.15 m/s on a 30 meter long runway with soft (Asker C 40) and hard (Asker C 65) single density EVA midsole shoes. Apparent leg stiffness was calculated as the ratio of the peak vertical ground reaction force and the maximum leg length change during the stance phase. Leg length was estimated as the distance between the average pelvis marker location and the average shoe marker location. The average joint stiffness in the sagittal plane for the ankle and knee joint was calculated as the ratio of the peak vertical ground reaction force and the moment to the joint angular displacement during the stance phase. A least square linear regression equation was used for the joint-moment versus joint-angle curves and the slope of this line was identified as joint stiffness. A three-way ANOVA (IBM SPSS Statistics 19.0, IL, USA) was used to determine interaction and main effects for shoe midsole hardness, gender, and age. Tukey post hoc tests were used for pair-wise comparisons where applicable. All tests were performed using a significance level of $\alpha=0.05$.

RESULTS
The soft midsole shoe demonstrated higher average ankle (p<0.001) and knee joint (p=0.025) stiffness compared to the hard midsole shoe (Figure 1). Female subjects demonstrated increased ankle joint stiffness compared to male subjects (p=0.001). Apparent leg stiffness was not significantly affected by shoe midsole hardness or the gender of the runner. Apparent leg stiffness was affected by age, while joint stiffness was not significantly changed across age groups.

DISCUSSION AND CONCLUSIONS
The rise in joint stiffness found with increased running speed has previously been explained by the need for increased stiffness as the motor task becomes more difficult. The elevated joint stiffness found for the soft midsole condition may be due to the increased difficulty in controlling movements in the sagittal plane with a softer shoe midsole. Stiffness of the lower extremity at both the joint and the full limb level have been correlated with particular injuries, including shin splints. Understanding the effects of shoe midsole cushioning on lower extremity stiffness should be considered when developing cushioning guidelines for users. Additionally, understanding how lower-extremity stiffness changes with the gender and age of a runner may help to explain why certain injuries occur more frequently for certain groups of individuals.

REFERENCES

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