THE EFFECTS OF SHOE ARCHITECTURE ON IMPACT FORCES DURING GAIT

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INTRODUCTION

In the current athletic footwear market, there exists a wide range of shoe architectures that offer a variety of options in terms of flexibility and support. The importance of footwear type has proved to be significant in the prevention of an assortment of injuries, including knee osteoarthritis [1, 2]. Footwear type has also been shown to affect the lower extremity kinematics as well as the regulation of leg stiffness for a subject during dynamic activities [3]. An important attribute used to categorize athletic footwear architecture is the inherent flexibility of the shoe. The natural flex observed in the sole of the shoe determines the level of flexibility; a more flexible shoe will flex closer to the mid-foot region while a shoe designed for stability will flex closer to the ball of the shoe.

The main objective of this study is to examine the effect that varying shoe architecture has on the impact forces exerted on the foot during the gait cycle. The results from this study will be used in the future to examine both shoe design as well as injury prevention. This document represents an initial, exploratory study where one subject (a 21 year old male) was examined in order to compare the impact force profiles produced during gait while wearing two different architecture types from the same shoe company.

METHODS

In order to map the force versus time profile for our subject, we utilized the F-Scan® in-shoe system by Tekscan that consists of in-shoe force sensors which are tethered to a personal computer. These sensors collect the numerical values of the forces exerted on the foot while walking. A force versus time profile was collected for each of two different shoe types while completing a forced walking scenario over a distance of approximately 30 feet (a metronome was used to dictate when each step should occur). The subject completed three trials in the flexible shoe and three trials in the stability shoe for a total of six forced walking trials. The subject was allowed to rest between trials in order to prevent fatigue. Force measurements were binned for three different regions: the entire foot sole, the ball of the foot, and the heel of the foot. By examining these three regions, we were able to look at the distribution of forces over the entire foot during the gait cycle and were also able to study the forces in the heel and ball of the foot in order to evaluate the interplay (or transition) between the two regions of the foot.

Following the completion of the data acquisition, the force versus time profiles from the three regions for each of the six trials were further analyzed using MATLAB®. The F-Scan® in-shoe system outputs contour maps of the force distribution and files containing the force values. For each of the trials, one period (heel strike to toe off) of the gait cycle was truncated from the remaining data and was normalized to the time associated with that period. This normalization allowed us to compare force profiles across the trials due to varying walking speeds despite the use of the metronome. The truncated and time-normalized data sets for the three associated trials (i.e. Left Foot, Flexible Shoe) were then averaged to obtain a more accurate representation of the force versus time profile. The standard deviation of the three trials was also calculated for each shoe type in order to better observe the variability across trials.

The force versus normalized time curves were individually analyzed for both the heel and ball regions in order to study the variation in slope and compare time periods where the impact force maintained an approximately constant value. These time periods represent dwells during the gait cycle where the respective region of the foot would endure prolonged contact with the ground. This analysis was achieved by using a paired t-test to determine whether the slope between two neighboring data points was statistically different from zero over the entire range of normalized time.

RESULTS

The results from our statistical analyses indicate that there existed a significantly larger dwell period in the heel region for the flexible shoe than for the stability shoe ($p<0.05$), while there were no significant dwells in the ball region for either shoe (Table 1).

Table 1: Comparison of time periods maintaining constant force for different shoe types and regions of the foot.

	Heel	Ball
Flexible Shoe	0.1663 seconds	0.0000 seconds
Stability Shoe	0.0959 seconds	0.0000 seconds

The forces in the heel while the subject was wearing the flexible shoe had a dwell period where the slope was similar to zero for 0.1663 seconds as opposed to 0.0959 seconds while the subject was wearing the stability shoe ($p<0.05$). There were no time periods in either profile where the forces in the ball region exhibited any dwell.

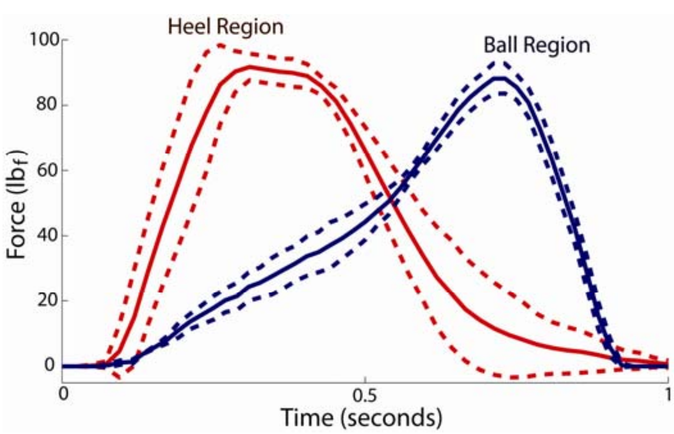

Figure 1: Force versus normalized time curves for the left foot of the subject while wearing the flexible shoe (solid: mean; dashed: ± s.d.).

The force versus normalized time curves provided an opportunity to qualitatively compare the force profiles for the heel and ball regions. For example, the force curves for the left foot while wearing the flexible shoe demonstrate that the heel profile contains a flat region around the maximum force that remains relatively constant while the ball profile shows the force reaching the maximum and immediately beginning to lessen (Fig.1).

DISCUSSION

From this preliminary study, we were able to observe a distinct difference between the stability and flexible shoe. In the flexible shoe, the heel of the subject's foot had a longer duration of contact than the stability shoe. This dwell corresponds to a prolonged pronation effect in the foot due to lack of support in the mid-foot region of the shoe. This pronation is compensating for a momentary lack of ankle dorsiflexion and causes the delay in off-loading of the heel that was observed. However, our results also indicate that for this particular subject there was no dwell in the forces on the ball while wearing either shoe type, thus resulting in a smooth toe-off during gait. We expect that this will not prove to be the case for all subjects in the future.

The implications of these initial results provide us with a basis for future studies comparing the difference between stability and flexible shoes and the impact they may have in detecting and preventing injury. This work will include looking at stability and flexible shoe types across multiple companies while collecting data from a variety of subjects with varying weight, age, gender, and foot type.

REFERENCES

1.Kerrigan DC, et al. *Physical Medicine and Rehabilitation* **1**, 1058-1063, 2009
2.Butler RJ, et al. *Gait & Posture* **26**, 219-225, 2007
3.Bishop et al. *J Athl Train* **41** (4), 387-392, 2006