FOOT STRIKE PATTERN DOES NOT PREDICT LOADING RATES DURING SHOD OR BAREFOOT RUNNING

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SUMMARY
The ability of strike pattern to predict maximal instantaneous vertical loading rate (VILR) under both shod and barefoot running conditions, as well as changes in VILR between conditions was assessed. Overall, foot strike pattern was a poor predictor of VILR and changes in VILR between shod and barefoot conditions were highly variable between individuals. Finally, it was observed that differences in strike pattern, as quantified by the center of pressure trajectory, do not necessarily correspond to changes in VILR.

INTRODUCTION
Traditionally, it has been thought that running with a rear foot strike (RFS) pattern results in a distinct impact peak in the vertical ground reaction force (vGRF) while running with a midfoot (MFS) or forefoot (FFS) strike results in a significant attenuation of this peak [1]. Based on these findings, it has been suggested that adopting a MFS or FFS pattern may help individuals avoid injuries by reducing impact forces imparted to the body [2, 3]. However, a recent meta-analysis suggests it may be VILR, not the magnitude of the impact peak, which is more important in development of running injuries [4]. Additionally, it has been reported there are no differences in VILR in RFS shod runners who are asked to run with a FFS [5]. Clearly more work is required to clarify relationships between lower limb loading, injury, and foot strike patterns.

Running barefoot or using minimalist shoes is one way individuals can force their body to adopt a MFS or FFS strike pattern. Interestingly, pilot data collected in our lab showed several individuals who, while running barefoot with a MFS, still displayed significant impact peaks in their vGRF curve (Figure 1). This observation suggests foot strike pattern alone may not be the main factor determining the load applied to the body during running. Therefore, one purpose of this study was to examine whether foot strike pattern predicts VILR under both shod and barefoot running conditions.

Since individuals running barefoot usually adopt a MFS or FFS pattern, a second purpose was to examine changes in VILR when individuals switched from shod to barefoot running. Switching from a RFS to a MFS or FFS pattern should result in a different pattern in the center of pressure (COP) trajectory. Therefore, a final purpose of this study was to examine whether changes in foot strike pattern, as indicated by COP trajectories, from shod to barefoot running were associated with changes in the VILR.

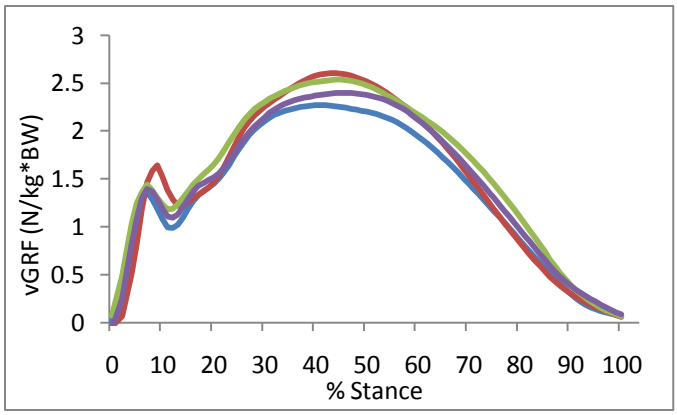

Figure 1. Example GRFs from four subjects showing an impact peak despite running barefoot with a MFS.

METHODS
This study is part of a larger, ongoing study examining the relationship between running biomechanics and injury. To date 11 subjects (6 female 5 male) have been analyzed. All subjects were habitually shod, recreational or competitive runners currently running at least 20 miles per week. Subjects ran continuous laps around a 25 meter track in the laboratory under both shod and barefoot conditions. Whole body kinematics were collected over a 5 meter section at 200 Hz using an 8 camera motion capture system (Motion Analysis Corp.) Ground reaction forces were recorded at 1000 Hz by three AMTI (Advanced Mechanical Technology, Inc.) force plates located in series along the capture region. Subjects ran at a self selected speed approximating their normal training run pace.

The VILR and COP trajectory were calculated for all trials with a clean force plate strike. Foot strike pattern was identified using the strike index (SI) [1]. Simple linear regression was used to assess the ability of SI to predict VILR under both shod and barefoot conditions. Paired *t*-tests were used to assess changes in VILR between shod and barefoot conditions and to confirm that there were no differences in running speed between conditions within an individual. Left and right feet were analyzed separately for each subject. Since it is highly likely that responses to barefoot running are unique to the individual, the above statistical tests were also performed with a single subject analysis approach where trials under the shod condition were compared to trials under the barefoot condition within each individual.

Changes in COP trajectories between shod and barefoot conditions were visually examined by plotting the COP trajectory within a rough outline of the individual's foot generated from the position data of the foot markers during the foot flat phase of stance and comparing between conditions.

RESULTS AND DISCUSSION

As a group, foot strike was not a significant predictor of VILR for either the shod (p = .64, R^2 = .01) or barefoot (p = .06, R^2 = .16) conditions. However, the single subject analysis suggested the ability of SI to predict VILR was highly variable among individuals for both conditions (Table 1).

Table 1. Single subject regression results examining the ability of SI to predict VILR for each foot under both conditions. Numbers are individual feet.

	Shod		Barefoot	
	Yes	No	Yes	No
SI significantly predicts VILR?	4	18	4	18
Average R^2	.441 (± .07)	.124 (± .13)	.545 (± .22)	.121 (± .17)

The group analysis yielded no statistically significant differences in VILR between conditions (p = .107), however this could be due to the large inter-individual variations observed in the response to barefoot running (Figures 2 & 3).

Visual inspection of the COP trajectories suggested changes in foot strike pattern from shod to barefoot conditions were not necessarily related to changes in VILR, as large changes in the COP trajectory were observed without corresponding changes in VILR (Figure 4).

The results of this study agree with previous findings that most individuals who RFS while shod adopt a MFS pattern while barefoot, and that individuals who retain a RFS pattern while barefoot experience increases in VILR [2]. However, our data suggest that whether or not VILR changes between shod and barefoot running is entirely dependent on the individual. While SI did predict VILR for a few individuals, for the most part SI was a poor predictor of VILR, regardless of condition. Additionally, the observation that some individuals have drastically different COP trajectories between footwear conditions with no differences in VILR, suggests

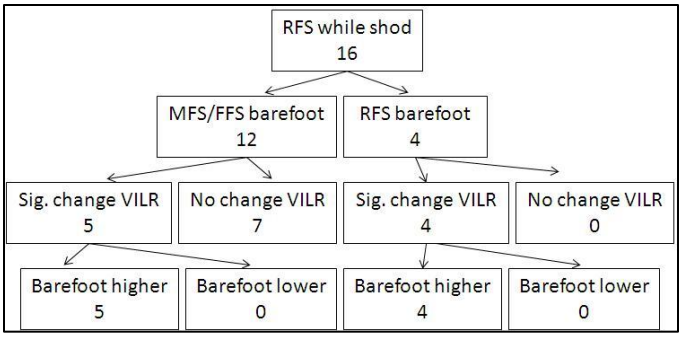

Figure 2. Changes in VILR in subjects with a RFS while running shod.

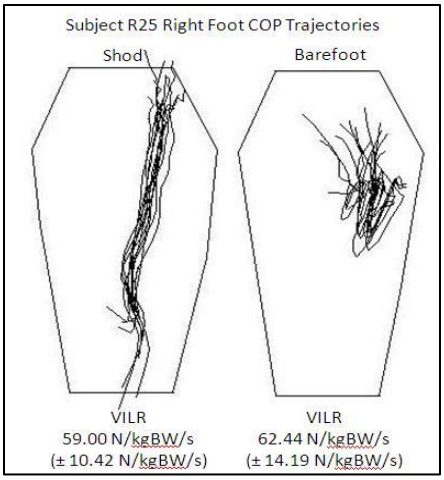

Figure 4. Example from one subject with large differences in SI and resulting COP trajectories but no differences in VILR between shod and barefoot conditions.

other variables such as joint kinematics, joint stiffness, or muscle activity, may play a more dominant role in determining the VILR. If VILR is important to consider in relation to injury, then future studies should attempt to clarify relationships between these other variables, foot strike patterns, and loading rates.

CONCLUSIONS

Based on this small sample, it appears foot strike pattern does not predict VILR under shod or barefoot conditions, and changes in VILR when one switches from shod to barefoot, or from RFS to FFS, are highly variable between individuals. Thus, generalizations regarding the benefits of one foot strike pattern compared to another should be interpreted with caution.

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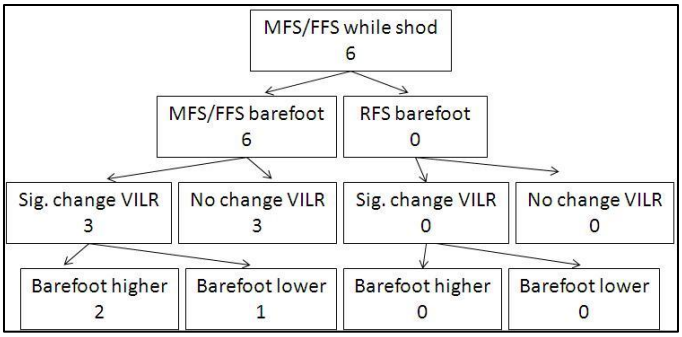

Figure 3. Changes in VILR in subjects with a MFS/FFS while running shod.