Loading Asymmetry Before and After Metatarsal Stress Fracture: A Case Study

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Introduction

Metatarsal stress fractures are a running-related overuse injury that comprise 23% of all stress fractures affecting collegiate cross country athletes [1]. Stress fracture recovery can take several months, often preventing an athlete from training or competing. Determing biomechanical changes that precede an injury like metatarsal stress fractures could inform coaches and athletes of an increased injury risk.

Previous research suggests that runners with a history of metatarsal stress fractures have similar peak vertical ground reaction forces (vGRFs) as those without a history of injury, but a causal relationship between peak vGRF and metatarsal stress fractures in runners is lacking [2]. A history of running-related overuse injuries may be associated with increased vertical loading rate, but to our knowledge, no prospective work has established an association between increased loading rate and metatarsal stress fractures in runners [3]. We measured peak vGRF and loading rate for each leg over the freshman year of collegiate running during which an athlete sustained a metatarsal stress fracture.

Methods

Data from one male athlete (18 yrs, 75 kg, 1.85 m) were analysed for this case study. The athlete ran on a force-measuring treadmill (Treadmetrix, Park City, UT) at 3 speeds (3.8, 4.1, 5.4 m/s) for 30 seconds each during the fall, winter, and spring competition seasons. The athlete was diagnosed with a Grade 3 bone stress injury of the 2nd metatarsal between winter and spring data collections. The fall data collection was 20 weeks prior to injury, winter data collection was 3 weeks prior to injury, and spring data collection was 11 weeks after injury.

Kinetic data were filtered using a lowpass zero-lag 4th order Butterworth filter with a 14 Hz cutoff. We analyzed the final 10 sec of each trial and used a 30 N threshold to determine stance phase. The athlete was a habitual forefoot strike runner. Peak vGRF was calculated as the maximum value during stance phase. We calculated loading rate as the average slope of vGRF versus time from 10-20% of stance phase because no transient impact peak was visually present.

We calculated the percentage difference in peak vGRF and loading rate for the injured and uninjured leg (Fig. 1). A positive percentage difference indicates a greater magnitude of the given variable for the athlete's injured leg.

Results and Discussion

We observed similar trends across speeds and report the results for the fastest speed (5.4 m/s). We found that the percentage difference between the injured and uninjured leg changed over time for peak vGRF and loading rate (Fig. 1). Peak vGRF of the injured leg was 2.2-3.7% greater than the uninjured leg prior to injury. However, the difference between peak vGRF of the injured and uninjured leg was only 0.6% 11 weeks after metatarsal stress injury (Fig. 1). In addition to these changes in peak vGRF asymmetry, peak vGRF values for the injured and uninjured leg increased 0.2 and 0.3 BW from 3 weeks prior to injury to 11 weeks after injury. Between step variation in peak vGRF was qualitatively similar between legs over the year.

The loading rate of the injured leg was 2.8% lower than the uninjured leg 20 weeks prior to injury, but 6.2% greater than the uninjured leg 3 weeks prior and 8.2% greater than the uninjured leg 11 weeks after metatarsal stress injury. In addition to changes in loading rate asymmetry, loading rate values for the injured and uninjured leg increased 4.7 and 3.2 BW/s from 3 weeks prior to injury to 11 weeks after injury. Between-step variability in loading rate was qualitatively similar for the injured and uninjured leg at 3 weeks prior to injury and 11 weeks after injury, but differed at 20 weeks prior to injury.

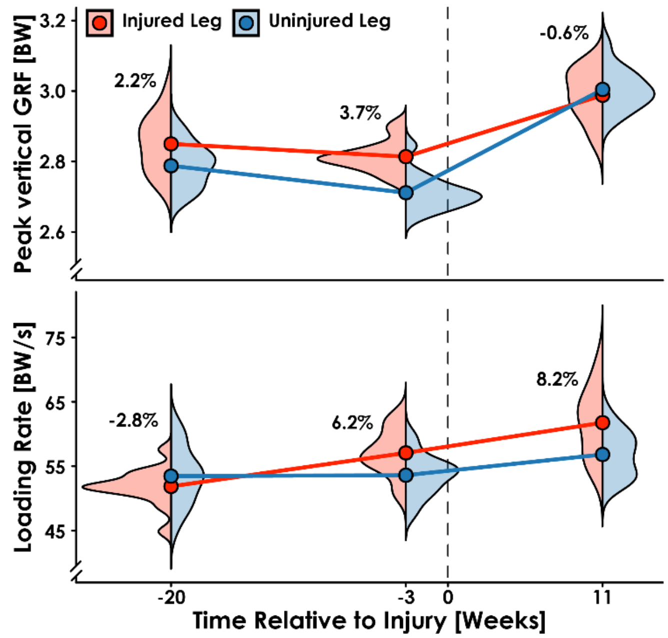

Figure 1. Peak vertical ground reaction force (GRF) and loading rate for the injured and uninjured leg across three data collection sessions. Violin plots illustrate the distribution of values across steps, colored dots represent the mean, with percentage differences between the injured and uninjured leg annotated.

Significance

These preliminary findings suggest peak vGRF asymmetry may differ before and after a metatarsal stress fracture, but it is unclear if loading rate is associated with prospective metatarsal stress fractures. This work provides insight into changes in asymmetry and between-step variability before and after sustaining a metatarsal stress fracture. Future work is planned to quantify how leg-specific external loading metrics predict running-related overuse injuries.

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References

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