Sports-court flooring effects on 2nd Metatarsal Bone Stress during Running

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Summary

Runners undergo repetitive loading which increases risk of bone stress injuries especially when training habits prohibit adequate recovery. Running over cushioned sports-court flooring lowered the 2nd metatarsal (Met) bone stresses and bending moments at mid-shaft. These results could inform injury prevention as well as treatment efforts for this common bone stress injury site among athletes.

Introduction

Prolonged repetitive loading associated with activities like running, contributes to bone microdamage.[1] Without adequate recovery, the rate of microdamage accumulation exceeds the rate of remodeling, increasing risk of stress fractures.[1] The Mets are prone to such stress injuries, with the second and third Mets accounting for 80-90% of all Met stress fractures.[2] Increased surface compliance may reduce joint reaction forces and Met stress [3,4] but these effects are not documented. Hence, we aimed to compare peak 2nd Met bone stress and metatarsophalangeal (MTP) joint contact forces (JCF) with and without a cushioned sports-court flooring during running.

Methods

Left foot 3D marker trajectories (200 Hz), ground reaction forces (GRF, 2000 Hz), and in-shoe plantar pressures (PP, 200 Hz) were collected from 5 steps of 20 physically active healthy adults (9M, 11F, 23.7 years, 1.72 m, 72.4 kg) while running at 3.5 m/s over a runway with or without an ASTM F2772 Class 4 sports-court flooring in a random order. Stance phase MTP joint reaction forces and moments were calculated using inverse dynamics and a two-segment foot model using GRF that were partitioned to the toes and three Met regions based on PP data and scaled using foot length measurements.[5] MTP reaction forces and moments, GRF, and the free moment during gait were assigned to Met 2 using a ratio of scaled Met head widths. Toe flexor force was then computed from scaled Met head radius and Met 2 internal joint moments. Met 2 MTP JCF were calculated as the vector sum of Met 2 reaction forces, GRF, and toe flexor forces. Mid-shaft bending moments were then calculated as the cross-product of Met 2 MTP JCF in the proximal coordinate system and its moment arm to a point at 50% of Met 2 length. Finally, internal Met 2 MTP JCF and midshaft moments were input to a beam theory model to estimate dorsal and plantar midshaft stresses also using scaled Met mid-shaft segment geometry. Effects of flooring were assessed using paired t-tests (α=.05).

Results and Discussion

Met 2 peak stress without the cushioned sports-court flooring were compressive (M=-60; SD=16.2 MPa) on the dorsal surface and tensile (M=52; SD=16.0 MPa) on the plantar surface. The peak stress values we obtained were within range of running-related von Mises max stress reported in the literature using a finite element model with soft tissues (28-79 MPa) [6], but lower than other beam theory models, likely due to bone scaling differences.[7].

Peak compression at Met 2 was reduced 3.7% ($p<.05$) and peak tension decreased 4% ($p<.05$) when running on cushioned sports court flooring (Figure 1). While the resultant Met 2 JCF remained unchanged ($p=.85$), but the midshaft bending moment lowered 3.65% ($p<.05$). The reduced bone stress on cushioned flooring was likely due to a lower bending moment, possibly from an increased Met joint angle and shorter lever arm.[8] These findings support literature reporting variable relationships between MTP JCF and bone stress during running.[7] Future models should examine how flooring affects loading rates due to viscoelastic properties of bone; although not statistically significant, cushioned flooring reduced Met 2 JCF loading rate by 2% ($p=.56$);.

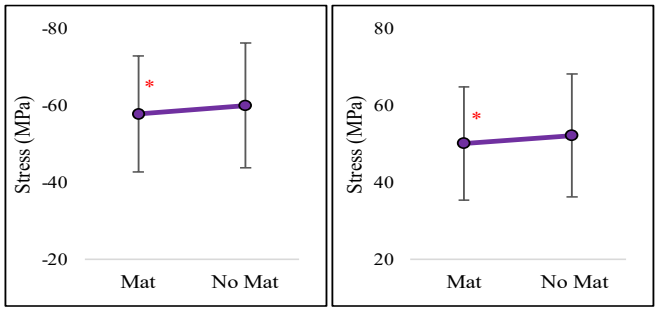

*Figure 1: Dorsal compression (left) and plantar tension (right). * p<.05*

Conclusion

In this repeated-measures study, reasonable estimates of bone stress were obtained using a low-cost, low burden bone scaling approach and suggest that cushioned flooring can lower Met stress during running even though it does not reduce joint loads. This reduction in stress may help decrease the risk of bone stress injuries. However, athletes accustomed to cushioned flooring may experience increased bone stress when transitioning to firmer surfaces.

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