The Effect of Stiffer Footwear on Metatarsal Stress in High School Football Players

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Introduction: About 10% - 20% of stress fractures occur in the metatarsal bones, long thin bones in the feet [1]. The 2nd, 3rd, and 5th metatarsals are the common sites of stress fracture [2]. In a survey of nearly 400 stress fracture injuries in high school athletes, football players experienced the highest proportion of stress fracture (16.5%) with the majority occurring in the foot and a return to play time exceeding three weeks [3. Bending loads during the propulsive phase of sports activity contributes to high metatarsal stress levels [4]. Footwear with higher bending stiffness could mitigate injurious metatarsal stress by reducing bending loads. [5]. We examined the effect of cleat stiffness on peak normal and shear stress at the 2nd, 3rd, and 5th metatarsals (met) during a football related task.

Materials and Methods: Data from 13 high school American football players (age: 15.6 ± 1.6 yrs; mass: 84.67 ± 17.25 kg; height: 1.76 ± 0.08m) who volunteered to participate in the study were analyzed. Participants were instrumented with retroreflective markers on the trunk, pelvis, arms, legs, and cleats for 3D motion capture. Participants performed a weighted sled push (75% of body weight) on synthetic turf with two embedded force platforms in two types of football cleats that differed in sole stiffness. Each participant underwent a dual-energy x-ray absorptiometry scan (DEXA) of their feet. 3D metatarsophalangeal (MTP) joint reaction forces were calculated (Visual3D) during the push and distributed regionally to the 2nd, 3rd, and 5th met heads [6]. 3D MTP moments were calculated using corresponding moment arms from the point of force application to regions of interest (ROI) along the metatarsal shaft that corresponded to typical sites of metatarsal stress fractures [3]. Inner and outer radii at the ROI, measured from DEXA, were input a subject-specific cylindrical bone model to quantify stress on the 2nd, 3rd, and 5th mets during the sled push using beam theory. Shoe effects on peak normal and shear bone stress were examined with a paired t-tests ($\alpha = 0.05$ and Cohen's dz effect sizes (d)).

Results and Discussion: Peak tension occurred plantarly, compression dorsally and shear medially. The stiffer cleat moderately reduced plantar tension and dorsal compression on the 3rd met by 6.5% and 6.3%, respectively ($p<0.05$, d=0.72, d=0.68). Stiffer cleats also exhibited small to moderate effects on medial shear (2nd: 4% ↓, p=0.16, d=0.46; 3rd: 7%↓, p=0.06, d=0.39; 5th : 7%↓, p=0.14; d=0.33).Due to bone's non-linear response to loading, small reductions in bone stress could meaningfully reduce metatarsal stress fracture risk.

Conclusions: Our preliminary results on a subset of athletes from a larger dataset (N=93) indicate cleats with a greater bending stiffness should be considered for American football players to reduce the bending stress. Muscle forces and finite element models will be considered in future models of the metatarsals.

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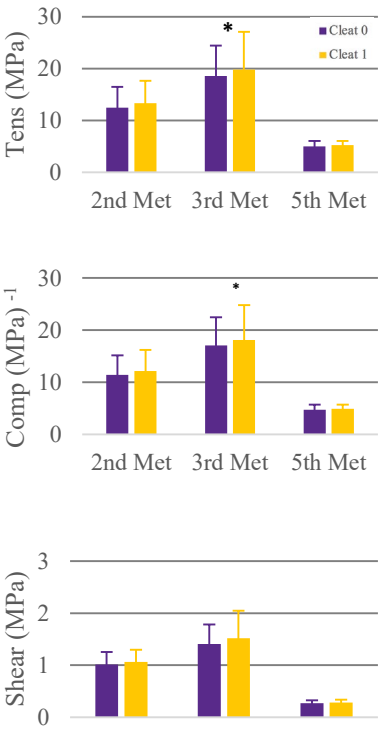

Average metatarsal stress during a sled push task in a stiff cleat (cleat 0) and a typical cleat (cleat 1).

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