THE ROTATIONAL STIFFNESS OF FOOTBALL SHOES MAY AFFECT THE LOCATION OF A POTENTIAL ANKLE INJURY

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INTRODUCTION

In young athletes, acute ankle trauma is responsible for 10% to 30% of all sports-related injuries [1]. While medial and high ankle sprains are less common than lateral ankle sprains, they represent a more disabling problem requiring longer recovery and different treatment [2]. The mechanism of injury in medial (anterior deltoid ligament or ADL) and high (anterior tibiofibular ligament or ATiFL) ankle sprains is commonly ascribed to excessive internal rotation of the upper body, while the foot is planted on the playing surface [3]. A recent study by our laboratory showed further that ADL injury occurs during external rotation of the neutral foot, while the ATiFL is typically the site of injury for external rotation of the everted foot [4].

Excessive rotational traction (torque) from shoe-surface interface has been implicated in the high incidence of ankle injuries suffered by athletes [5]. In addition, Livesay et al. [6] showed that differences in rotational stiffness between various shoe-surface combinations are greater than those in peak torque. A recent study by Villwock et al. [7], involving football shoes and various natural and synthetic playing surfaces, suggests that the shoe-surface rotational stiffness may be associated, in part, with the design of a shoe’s upper. Yet, the effect of shoe design on patterns of ankle ligament strains during external rotation of the foot has not been directly investigated to date.

METHODS

Four football shoe designs were tested and compared in terms of rotational stiffness. Tests were conducted on a hydraulic, biaxial testing machine (MTS Corp., Eden Prairie, MN). The four football shoe types were Nike Air, Nike Merciless, Adidas Blitz, and Nike Flyposite. A surrogate lower extremity and custom football cleat molds that were made of epoxy resin were used in the tests. After a compressive pre-load of 1500 N and a rotational pre-torque of 2 Nm were applied to a neutral-positioned surrogate ankle, a dynamic torque of 60 Nm was input in load control at a frequency of 1 Hz (0.5 s to peak torque) and repeated two more times for each shoe design. The shoe rotational stiffness, defined as the slope of torque-rotation curve, was calculated in Nm/deg and compared between shoes.

Twelve (six pairs) male cadaveric neutral-positioned ankles were externally rotated 30° using two selected shoe designs. The limbs were transected ~15 cm distal to the center of the knee. Shoes with the highest (rigid) and lowest (flexible) rotational stiffnesses were randomly assigned to the left or right limbs. The same pre-load and pre-torque were used in the cadaveric tests. Internal tibial rotations of 30° were input in position control at a frequency of 1 Hz (0.5 s to peak rotation). Max torques and rotational stiffnesses were reported for each limb.

Motion capture (Vicon, Oxford, UK) was performed to track movement of the talus with a reflective marker array screwed into the bone. These motions, relative to the tibia in three directions, were determined for each limb. A computational ankle model [8] was utilized to input talus motions for estimation of ankle ligament strains. The model was constructed from a generic computer tomography (CT) scan of a cadaveric ankle. CT images were first converted into 3D models in MIMICS (Materialise, Ann Arbor, MI) and then imported into SolidWorks (TriMech Solutions, Columbia, MD) for motion simulation
Ligament strains, defined in percentage as the relative elongations of ligaments, were estimated from the model. Two-way ANOVA and SNK post hoc tests were used in statistical analysis, with p<0.05 considered significant.

RESULTS AND DISCUSSION

Among the four shoe designs, the Air showed the lowest rotational stiffness (21.9 ± 2.8 Nm/deg), while the Flyposite had the highest stiffness (50.0 ± 1.7 Nm/deg). Cadaveric tests demonstrated that torque-rotation responses overall were significantly different between limbs, with the limb in the rigid shoe stiffer than that in the flexible shoe (Fig 1). At 30º of rotation the rigid shoe generated higher ankle joint torque at 46.2 ± 9.3 Nm than the flexible shoe at 35.4 ± 5.7 Nm. While talus rotation was greater in the rigid shoe (15.9 ± 1.6º vs. 12.1 ± 1.0º), the flexible shoe generated more talus eversion (5.6 ± 1.5º vs. 1.2 ± 0.8º). While these talus motions resulted in the same level of ADL strain (~5%) between shoes, likely because of the neutral foot position used in these experiments, there was a significant increase in ATiFL strain (4.5 ± 0.4% vs. 2.3 ± 0.3%) with the flexible versus rigid shoe design (Fig 2).

The increase of ATiFL strain was largely due to the increased level of talus eversion noted in the flexible shoe. The study also showed that there was a potential direct relationship between ankle joint torque and the extent of axial talus rotation, and an inverse relationship between ankle joint torque and talus eversion.

Figure 1: Torque-rotation curves showed a toe region followed by a linear region.

Figure 2: Only two ligaments with the highest strains were reported. ADL strains were statistically greater than ATiFL strains for both shoe designs.

CONCLUSIONS

We externally rotated six pairs of cadaver limbs in two different football shoe designs, a flexible shoe and a rigid shoe, and found that while the torques developed with the more flexible shoe were lower than those with the rigid shoe, more talus eversion resulted in a significant increase in ATiFL strain. This result may suggest an increased risk of high ankle sprains with the more rotationally flexible shoe design during external foot rotation. The study showed that football shoe design may have an effect on the pattern of ankle ligament strains, and potentially the site and severity of ankle sprain resulting from external foot rotation. In future studies these data may be useful in characterizing shoe design parameters and balancing potential ankle injury risks with player performance.

REFERENCES