Quantifying the Effect of Ankle Posture on the Positions of Bones of the Foot/Ankle Complex

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Abstract

The ankle is the most common site of injury for occupants during frontal vehicular collisions [1]. This injury is also associated with impacts with the ground after falling from a height, as well as improvised explosive device detonations in combat zones. Damage to this region can result in considerable impairment due to poor vascularization and healing, and leads to long-term monetary healthcare costs and emotional distress. By understanding the factors which cause ankle injury, suitable protective systems can be designed, thus reducing these negative outcomes.

Injury to the ankle in different loading scenarios has previously been evaluated experimentally and numerically with the ankle in a neutral position (e.g., [2]). However, little attention has been given to variation in ankle posture that may occur during these traumatic events, thus altering the load path, with fractures having been noted in the tibia, talus and calcaneus. For falls involving the wrist, the orientation of the scaphoid and lunate affect both the fracture location and load in the radius [3]. Therefore, the hypothesis of this work is that ankle posture will affect the positions of the bones of the foot/ankle, altering the fracture threshold and location.

To test this hypothesis, a 50th percentile male cadaveric lower leg, sectioned at the tibial plateau, was potted proximally and attached to a CT-compatible test frame, which can adjust the angles of the ankle independently in three dimensions while applying axial loads up to 150 lbs. Under load, CT scans were taken of the ankle in four different postures (plus the neutral posture). These postures were chosen to correspond to positions which the ankle frequently assumes during injurious events and in which fractures are commonly reported [4-6]. Coordinate systems were developed for the calcaneus, talus and tibiofibular complex based on attached strain gauge locations and anatomic landmarks. The difference in the location of each bone between the neutral and repositioned posture was quantified by the rotation of the coordinate axes (using an Euler z-y-x decomposition) and the displacement of the chosen origin.

The greatest rotational and positional changes were in 25° of plantarflexion for the calcaneus, but both the talus and calcaneus experienced noticeable displacements and rotations for all postures tested (talus range: 0-21˚, 4-11 mm; calcaneus range: 1-23˚, 5-25 mm). These positional and rotational changes of the bones of the hind foot likely affect the load pathway of the foot/ankle complex under axial impact loading, potentially reducing the fracture threshold

and changing the location of fracture. This effect does not appear to have been previously investigated in the literature, and the results from this study will be useful in determining injury limits of the ankle and for developing postural guidelines to minimize injury. This postural geometric data, coupled with strain data acquired from gauges attached to the ankle, will also allow for the development of an injury-predicting finite element model.

[1] Morris, et al., STAPP CAR C., 1997.
[2] Funk, et al., J. Biomech. Eng., 2002.
[3] Troy and Grabiner, J. Biomech., 2007.
[4] Daftary et al., Radiographics., 2005.
[5] Lauge-Hansen, Arch. Surg., 1950.
[6] Lestina et al., SAE., 1992.