Noninvasive Measurement of Normal Foot and Ankle Joint Reaction Force

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Introduction/Purpose: Various biomechanical studies have examined pressure changes across the foot and ankle joints. However, most of these studies disrupted the capsuloligamentous complex surrounding the joint to insert pressure sensors, compromising the integrity of the natural joint structure and the accuracy of biomechanical assessments. This is the first noninvasive study to report measurement of natural joint reaction forces (JRF) across the foot and ankle while preserving all soft tissue structures. Since articular surfaces experience equal and opposing compression forces, we aimed to evaluate the distraction force needed to overcome these compression forces.

Methods: Ten fresh-frozen cadavers of the lower extremity were obtained that were disarticulated at the knee joint. Steinmann pins were percutaneously placed across the distal tibia, and the center of the talus, navicular, cuboid, and calcaneus while preserving all surrounding soft tissues. A custom fixation device was utilized in conjunction with a tensile testing machine to allow distraction in line with the axis of the tibiotalar, subtalar, talonavicular (TN), and calcaneocuboid (CC) joints. Displacement was measured as distance between Steinmann pins on either side of the joint examined. Under progressive axial distraction, displacement and force were measured. Best-fit polynomials were calculated to fit the force-displacement curves. The inflection point, representing the joint reaction force (JRF) where distraction forces across the joint equal the compression forces, was calculated for each curve.

Results: All force-displacement curves demonstrated an inflection point. Prior to the inflection point, relatively large increases in distraction force resulted in minimal displacement. Once the inflection point was reached, relatively small increases in distraction force resulted in large increases in displacement. Each cadaver was measured three times with high reproducibility. The mean JRF were tibiotalar 33.8 N [standard deviation (SD) 10], subtalar 18.2 N (SD 12), TN 13.3 N (SD 4), and CC 14.7 N (5.8).

Conclusion: We present the first application of a reliable and noninvasive method of measuring JRF of the foot and ankle joints. In the medium or small joints, dissection of the capsule and surrounding ligaments can significantly alter joint stability and biomechanics. By preserving all the periarticular soft tissues, this experimental model will allow future investigation of biomechanical changes of pathologic states and efficacy of surgical intervention under conditions that most accurately reflect the in vivo state.

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