

COMPARATIVE ANALYSIS OF ANATOMIC COORDINATE SYSTEMS TO CALCULATE HINDFOOT KINEMATICS USING BIPLANE FLUOROSCOPY

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ABSTRACT

Accurate measurement of hindfoot kinematics during walking and other functional activities is essential for understanding pathologic foot conditions, tracking progression of deformity, evaluating impact of injury, and determining effectiveness of interventions. Multi-segmental foot models are now clinically used to evaluate hindfoot motion in a variety of populations; however, they are unable to isolate talocrural or subtalar motion because the talus lacks reliable palpable landmarks to place external markers. Biplane fluoroscopy provides a means to track motion of these joints by directly measuring the motion of each bone but there is currently no standard method for embedding local coordinate systems for measurement of talocrural and subtalar motion. Previous biplane work has assigned talar and calcaneal bone coordinate systems to be parallel to the tibia, though this may not accurately reflect the true orientation of these bones, particularly in cases of malalignment and deformation. The purpose to this work was to compare kinematic differences between a model with this coordinate system (tibia-aligned) and one in which each bone was assigned a local coordinate system based on anatomic landmarks (bone-independent). Biplane fluoroscopy data were collected for eight healthy subjects during over-ground walking. Bone-based coordinate systems were defined using anatomic landmarks visible on bone surfaces. Model-based tracking was used to align the digitally reconstructed radiographs of each bone with the fluoroscopic images from each time point. Kinematics were calculated using the tibia-aligned and bone-independent coordinate systems and talocrural and subtalar joint positions and excursions were compared. Results showed shifts in kinematic curves of up to 45° and range of motion differences of up to 6° in all three planes of motion. These results are important in recognizing the differences between these approaches to establishing coordinate systems, and the potential of each to be able to identify atypical joint motion and alignment. In addition, this work illustrates the importance of establishing a consensus for coordinate systems as biplane fluoroscopy assessment becomes more wide-spread.

Keywords: Biplane fluoroscopy, Foot, Tibiotalar joint, Subtalar joint, Kinematics, *In vivo Kinematics*, Coordinate System

INTRODUCTION

The talocrural and subtalar joints provide unique contributions to the complex, six degree-of-freedom articulation of the ankle. Deleterious motion from injury or disease may contribute to the development of overuse injuries and osteoarthritis at the ankle [1]. Therefore, valid kinematic data of the talocrural and subtalar joints is important to ensure that clinicians can distinguish typical from atypical motion, track progression of injury/deformity over time, inform clinical decision making, and accurately evaluate post-interventional outcomes.

Multi-segment foot models have gained popularity to evaluate 3-D hindfoot kinematics among both healthy adults and individuals with foot deformity [2]. However, multi-segment models are limited as they produce hindfoot kinematics representing the motion of the calcaneus relative to the tibia. Existing models typically do not provide individual kinematic contributions from the talocrural or subtalar joints which are frequent sites of surgical concern and dynamically critical to triaxial foot and ankle kinematics. Traditionally, the combined contributions of the talocrural and subtalar joints are reported as hindfoot kinematics because the talus lacks reliable palpable landmarks to place external markers and talar motion