

KINEMATIC MODEL FOR ASSESSMENT OF *IN VIVO* HINDFOOT MOTION DURING GAIT USING BIPLANE FLUOROSCOPY

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ABSTRACT

Understanding the biomechanics of the tarsal complex during gait is critical to the proper care of patients with a variety of orthopaedic impairments. Limitations of optical imaging systems have prevented the analysis of motion of the foot during gait in patients who require orthoses or modified footwear for functional ambulation. Fluoroscopic methods have been introduced for use in gait analysis to look at the motion of the bones directly. The purpose of this study was to develop a kinematic model to analyze *in vivo* hindfoot motion using biplane fluoroscopy. A validated biplane fluoroscopy system designed for hindfoot analysis during gait was used for the study. Static images of a trans-tibial cadaver foot specimen were used to represent the neutral position. Dynamic trials were collected by manually simulating gait through the capture volume. Geometric bone models of the calcaneus, talus, and tibia were created from a CT scan of the specimen. Fluoroscopic images were corrected for image distortion before trials were tracked using validated model-based tracking software to determine position and orientation of each bone during walking. Anatomical coordinate systems were defined for each bone according to International Society of Biomechanics (ISB) recommendations. Kinematic models of the talocrural and subtalar joints were developed using the joint coordinate system method. Joint motion was defined as the distal segment relative to the proximal for both joints. Kinematics were reported relative to neutral position and normalized to 100% of stance phase. The results showed correlations of gait patterns with previously published studies. The talocrural and subtalar joint models developed are promising and offer a viable, noninvasive, method suitable for quantifying hindfoot kinematics in the bare and shod foot.

Keywords: biplane fluoroscopy, model-based, hindfoot, gait, biomechanics

INTRODUCTION

Dynamic assessment of skeletal kinematics is necessary for understanding normal joint function, in addition to effects of injury or disease [1, 2]. For lower extremity evaluation, external markers are typically placed on specific bony landmarks on the skin so that optical cameras can track the motion of the underlying bones [3-5]. Software is then used to define the markers as a sequence of four rigid-body segments of the pelvis, thigh, shank, and foot with three universal rotary joints representing the hip, knee, and ankle joints [6]. Conventional gait analysis has been validated and is used frequently in research and clinical settings [6-8]. Although these optical motion analysis systems are easy to implement and are clinically relevant for several applications, they have issues that need to be addressed when looking more in depth at the foot. Conventional methods do not allow for obtaining intertarsal kinematics of the hindfoot. A single rigid body assumption of the foot fails to take into account the major joints and can lead to errors regarding subtalar joint kinematics, especially when applied to the deformed foot [9, 10]. It has been found that the most significant source of error in gait analysis is skin movement artifact (SMA) [3, 11]. When the markers are placed on the surface of the skin, a motion artifact is introduced that has the potential to greatly affect the kinetics results to estimate the dynamic loads in joints [1].

Understanding the biomechanics of the tarsal complex during gait is critical to the proper care of patients with a variety of orthopaedic impairments. Orthopaedic disorders, such as cerebral palsy, clubfoot, tarsal coalition, and myelomeningocele, often require lower extremity orthoses for ambulation.