MODELLING FIBULAR KINEMATICS USING SKIN MARKER MOTION CAPTURE

Chloe E. Baratta B.S.[1], Karley D. Baringer[1], Christopher W. Reb D.O.[2] and Jennifer A. Nichols Ph.D.[1]
[1]University of Florida, Gainesville, FL
[2]Pennsylvania State University, Hershey, PA
Email: chloebaratta@ufl.edu

Introduction

The fibula is important for lower extremity function, as it provides load transmission [1], knee joint stability [2], and ankle joint stability [3]. Yet, fibular biomechanics are not well understood. For example, the only study characterizing fibular kinematics using fluoroscopy lacks data during the most common lower limb task, gait [4]. Measuring fibular kinematics with skin markers would provide an alternative with lower equipment cost, data processing, and irradiation demands than fluoroscopy. However, skin marker motion capture, to our knowledge, has not been used to explicitly measure fibular kinematics. Using skin-markers also requires a model for inverse kinematics that includes fibular motion, but most common open-source models define the fibula as a rigid segment concomitant with the tibia. Validated, easy to use experimental and computational methods for analysing the fibula are needed for understanding the biomechanical implications of pathologies that affect the fibula (e.g. syndesmosis injury). In this context, the primary objective of this study is to evaluate whether skin marker motion capture can measure fibular motion. We specifically develop a novel marker set to track the fibula, augment a full-body kinematic model [5] with a novel mobile fibula, and characterize fibular motion using inverse kinematics.

Methods

Three healthy subjects (2 female, 24 ± 1 years, 63 ± 9 kg) participated in this IRB-approved study (UF#202100793). Kinematic data were recorded for each subject during 6 trials of overground gait and double-leg heel rise. Skin marker motion capture data were collected at 200 Hz with a 30-camera Motion Analysis system. A full-body marker set that combined the Helen Hayes marker set with the Rizzoli multi-segment foot marker set was used. To track the fibula, additional markers were added to the proximal, shaft, and distal bony landmarks of the fibula.

Anthropometrically-scaled models were generated for each subject in OpenSim v4.0 by scaling a version of the Rajagopal full-body model [5] that was augmented with a mobile fibula capable of moving in 6 degrees of freedom relative to the tibia. Fibular motion was calculated from inverse kinematics. Fibular internal/external rotation is primarily reported, as the fibula had the largest motion in this direction.

Given that the magnitude of fibular motion is known to be small, we also tested whether estimated fibular motion exceeded soft-tissue artifact by calculating inter-marker Euclidean distance between tibial and fibular markers at the proximal and distal ends of the shank. These distances were compared to skin marker motion artifact, reported as inter-marker translational range of motion (ROM) during gait [6].

Results and Discussion

Subjects displayed a mean ROM of 16.5±1.4 degrees for internal-external rotation of the fibula during gait (Fig 1). During double-leg heel rise, subjects displayed a mean ROM of 7.7±0.4 degrees for external-internal rotation of the fibula. Heel rise data for one subject necessitated exclusion due to outliers (~19°).

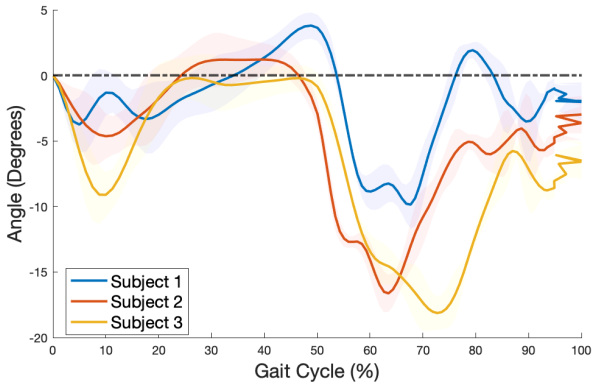

Figure 1: Fibular rotation in gait. Shading is st. dev. across 6 trials.

To our knowledge, fluoroscopic data quantifying fibular kinematics has not been published for gait. Computed internal-external rotational ROM of the fibula agrees well with the internal-external rotational ROM quantified by Cornejo et al. for double-leg heel rise (8.1±3.3 degrees) using fluoroscopy. This suggests that our novel fibular marker set and augmented full body musculoskeletal model successfully leverage skin marker motion capture to measure fibular kinematics.

Maximum inter-marker Euclidean distance over the gait cycle at the proximal and distal tibiofibular joints exceeded known inter-marker translational ROM due to skin motion, giving further credence fibular motion measurements. Specifically, inter-marker translational ROM at similar marker locations to those studied herein varies between 4.4 to 9.3 mm across the shank [6]. We found maximum translational ROM to be 4.7 mm and 10 mm at the proximal and distal tibiofibular joints, respectively (Table 1). This suggests our novel fibula marker set tracks fibular motion despite the presence of soft tissue artifact.

Table 1. Summary of computed marker translational tibiofibular ROM

	Min (°)	*Max (°)*	*Mean (°)*	*Std. Dev (°)*
Proximal	1.7E-3	4.7	1.7	0.9
Distal	0.0	10.0	0.8	0.8

Significance

Leveraging skin marker motion capture to characterize fibular motion provides an exciting step toward easily studying fibular biomechanics. Expanding musculoskeletal models to include fibular motion also builds a foundation for evaluating complex ankle pathologies through computer simulations.

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