Asymmetry and Sex Differences in Ankle and Hindfoot Kinematics During Gait

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Introduction

Background
- Ankle sprains are the most common injury in sports and recreation and can lead to chronic ankle instability (CAI), which may affect lower limb biomechanics.
- To properly evaluate the effects of surgery and rehabilitation in CAI and other ankle pathologies, it is necessary to characterize typical side-to-side differences in ankle and hindfoot kinematics in healthy adults.
- Sex differences in ankle and hindfoot bony morphology and injury rates have been reported.
- Few studies have assessed healthy bilateral symmetry or evaluated sex-dependent kinematics differences.

Hypotheses
- Females would have greater tibiotalar and subtalar range of motion (ROM).
- Sex-dependent differences would exist in ankle and hindfoot continuous kinematics.

Aims
- Determine within-subject ankle and hindfoot kinematics differences between the dominant and non-dominant sides.
- Identify sex-dependent differences in ankle and hindfoot kinematics over the support phase of gait.

Methods

Data Collection
- 20 healthy adults with no history of major knee or ankle injuries were enrolled with IRB approval and informed consent (10 female, 10 male; average age: 30.8 ±6.3 years).
- Two overground walking trials were collected for each side.

Data Processing
- Computed Tomography (CT) scans were used to create subject-specific 3D models of the distal tibia, talus, and calcaneus.
- A validated volumetric model-based tracking technique was used to match the subject-specific bone models to the bplane radiographs with a precision of 1.2° and 0.5 mm (Figure 1).

Results

- No differences between dominant and non-dominant side ROM were observed at the tibiotalar (all $p > 0.18$) or subtalar joints (all $p > 0.32$).
- The average absolute difference between dominant and non-dominant sides in the continuous kinematics curves was 4.1° and 1.5 mm or less for all rotations and translations, respectively, for the tibiotalar joint and 3.3° and 1.1 mm or less for the subtalar joint.
- Significant differences between continuous kinematics curves of males and females were observed in tibiotalar anterior-posterior (AP) ($p = 0.011$) and medial-lateral (ML) ($p = 0.004$) translation and eversion ($p < 0.001$), and subtalar AP ($p = 0.003$) and proximal-distal (PD) translation ($p = 0.030$) (Figure 2).
- Males had greater AP ($p = 0.04$) and ML ($p = 0.02$) translation ROM at the tibiotalar joint and greater ML translation ROM at the subtalar joint ($p < 0.01$). All differences were less than 1 mm.

Discussion

- Side to side kinematic differences were minimal, while male and female kinematics were generally offset but followed similar patterns, which may be due to bone size.
- A previous study using single plane fluoroscopy found greater rotational ROM in females than in males when slowly walking barefoot. We did not find any sex differences in rotation ROM and found only small differences in translation ROM.
- Strengths include a relatively large sample size compared to similar studies, and a precise measuring system. Study results are limited to gait in healthy young adults.

Clinical Significance

- This study provides data to guide evaluation of ankle kinematics after surgical intervention or rehabilitation.
- More tibiotalar eversion and subtalar inversion during gait may predispose females to higher rates of ankle and knee injury.
- Male versus female differences in translational kinematics suggest sex-dependent ankle reconstruction techniques may be beneficial. Future studies should account for patient sex when investigating ankle kinematics.

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