In Vivo Kinematics of the Ankle during Walking and Running using Dynamic Stereoradiography (DSX)

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Introduction

Background

- Orthopaedic disorders are a leading cause of disability in the United States.[1]
- Ankle joint dysfunction has been found to contribute to poor health outcomes such as reduced balance, gait speed, fractures and fall risk[2,3].
- Common imaging techniques (CT, MRI, ultrasound, etc.) are ineffective for assessing dynamic joint function.
- Dynamic stereoradiography (DSX) is an imaging modality that holds promise in identifying subtle abnormalities in joint function.
- Knowledge of the natural variability between the left and right ankle in healthy individuals can serve as a benchmark for assessing post-operative patients and pathological populations.

Aim(s)

- The purpose of this study was to quantify the differences in the left versus the right ankle kinematics in healthy subjects during walking and running, and to determine trial-to-trial variability in ankle kinematics.

Methods

- 4 healthy participants provided informed consent to participate in this IRB-approved study (3 M, 1 F, 26.2 ± 2.9 years).
- Synchronized biplane radiographs were collected at 100 Hz for walking trials and 150 Hz for running trials (Figure 1).
- 3-D ankle kinematics during static standing, overground walking and overground running were determined using a validated volumetric model-based tracking process. [4]
- Subject-specific bone models, derived from CT, were matched to synchronized biplane radiographs (Figure 2).
- Coordinate systems were defined in the tibia, talus, and calcaneus of the right ankle for each participant and mirror imaged onto corresponding left ankle bones.
- Bone kinematics and subject kinetics were determined for one static trial, two walking trials and two running trials for both ankles of each participant.
- Shoes were standardized, with all participants wearing Nike Zoom ® running shoes, in which the soles are composed of a medium density, highly responsive foam (Nike Cushlon ® foam) and Zoom Air ® units under the forefoot.

Scan for supplementary content (videos, photos, etc.).

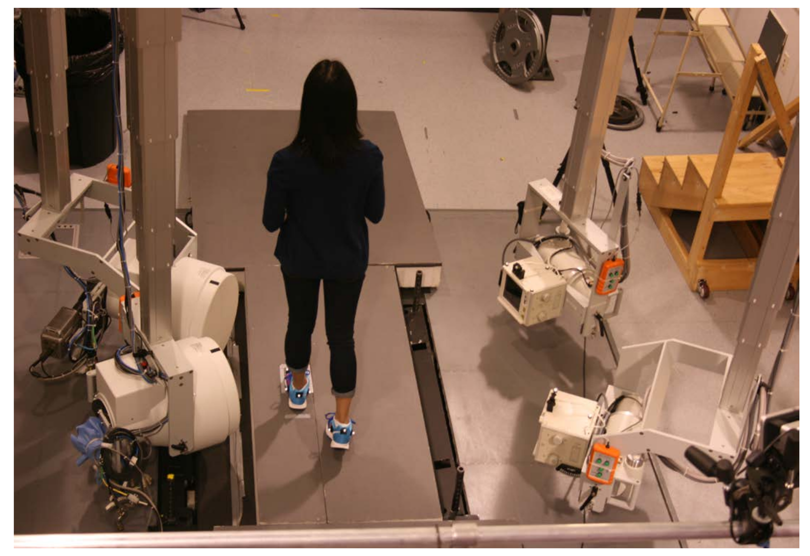


Figure 1. Data collection setup – the x-ray generators (right) and image intensifiers (left).

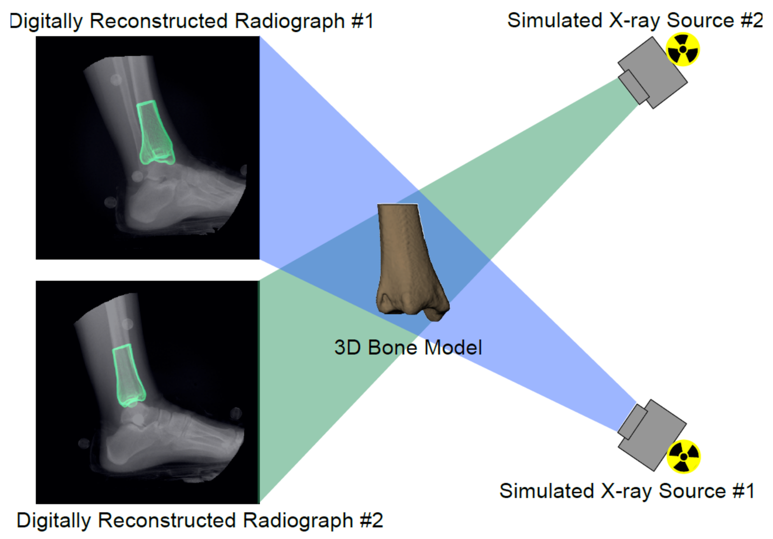
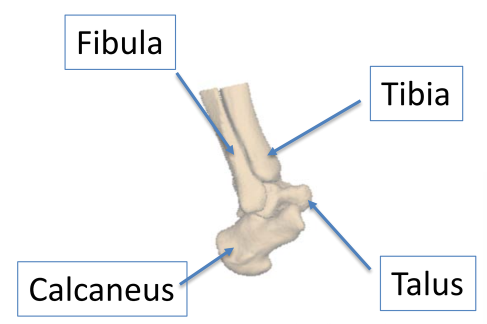


Figure 2. Model-based tracking technique.



3D model of ankle joint complex

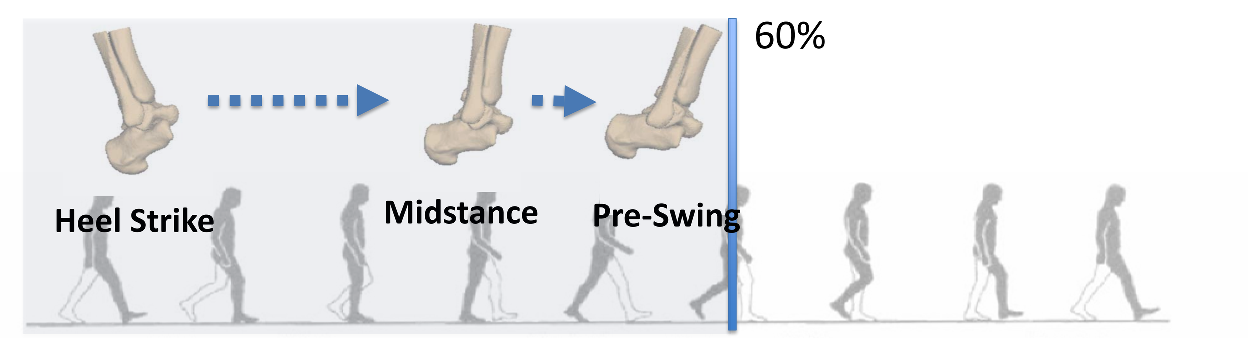


Figure 3. Ankle kinematics were determined for ~60% of gait cycle for walking and ~40% for running.

Results

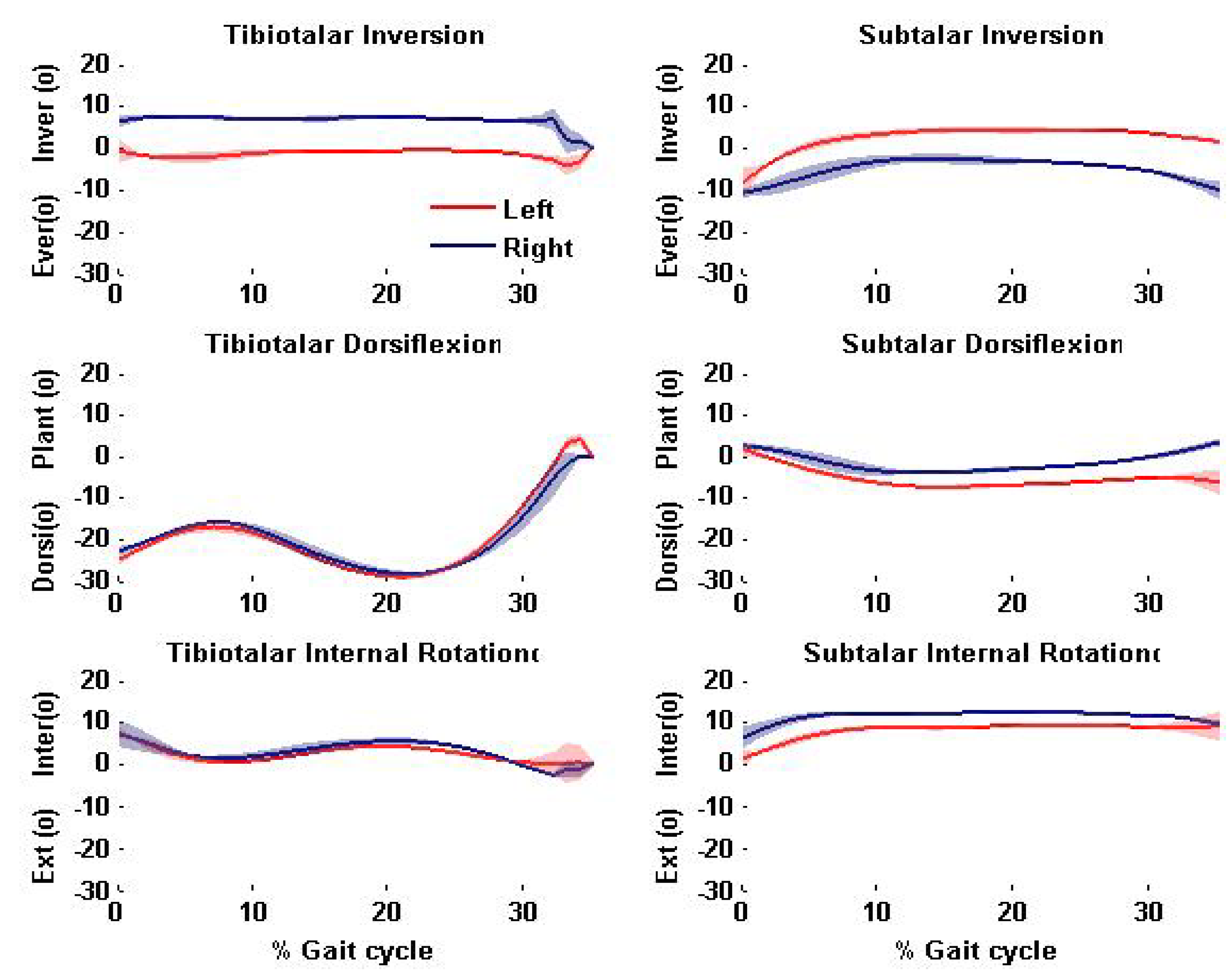


Figure 4. Tibiotalar and subtalar joint rotations during running (Subject 1). The opaque shade surrounding the plot lines denote the standard deviation of the two trials. Note, the walking trajectories are not shown, but are similar. Red = left ankle; Blue = right ankle.

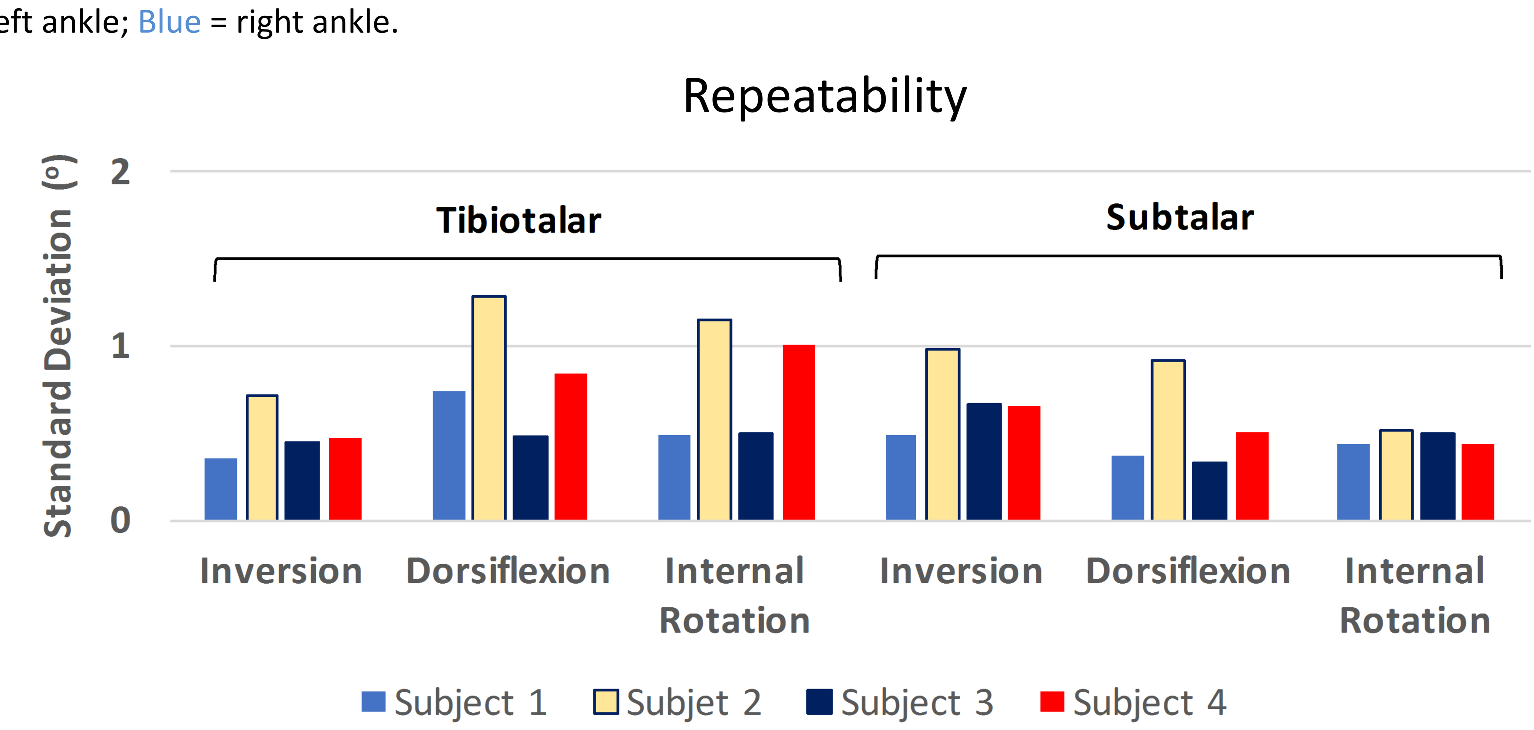


Figure 5. Trial-to-trial repeatability during walking was assessed by the standard deviation over the two trials. The graph is an average of the left and right ankle values. Running results were similar.

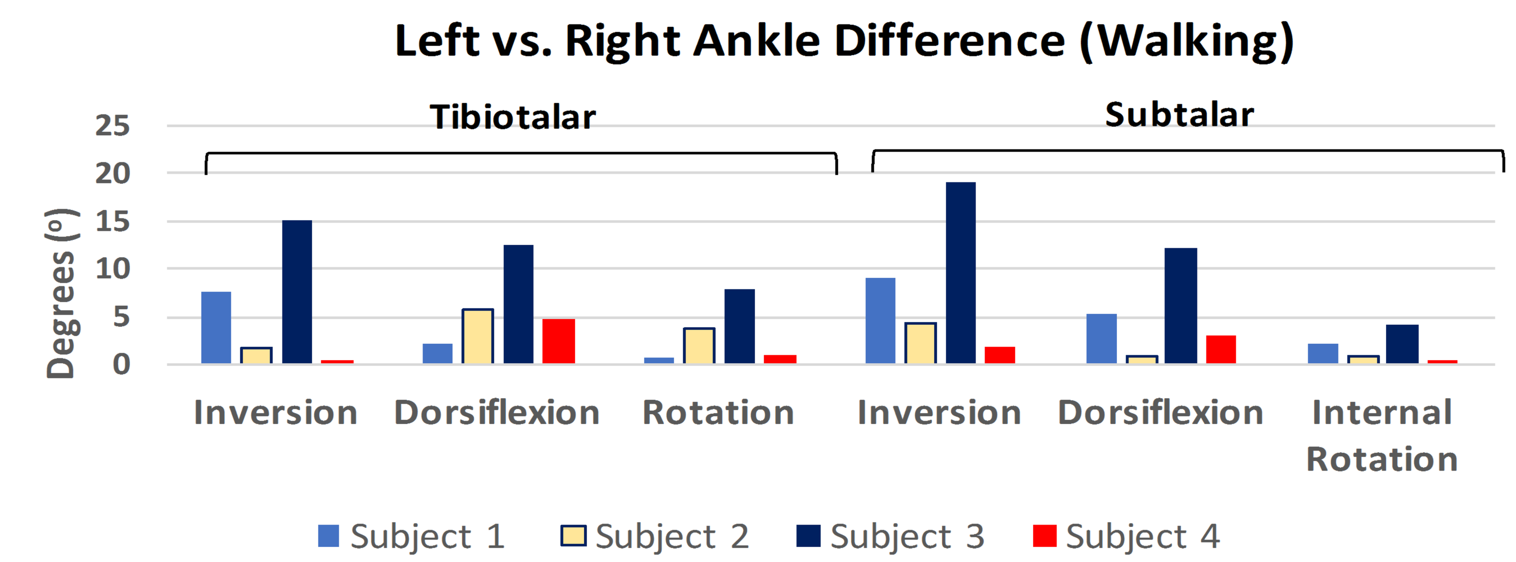


Figure 6. Average side-to-side difference between left and right ankle walking trajectories (tibiotalar and subtalar joints). Subjects 1, 2, and 4 generally showed a value ≤ 5 degrees for all rotations. Subject 3 had values ≥ 5 degrees for all rotations.

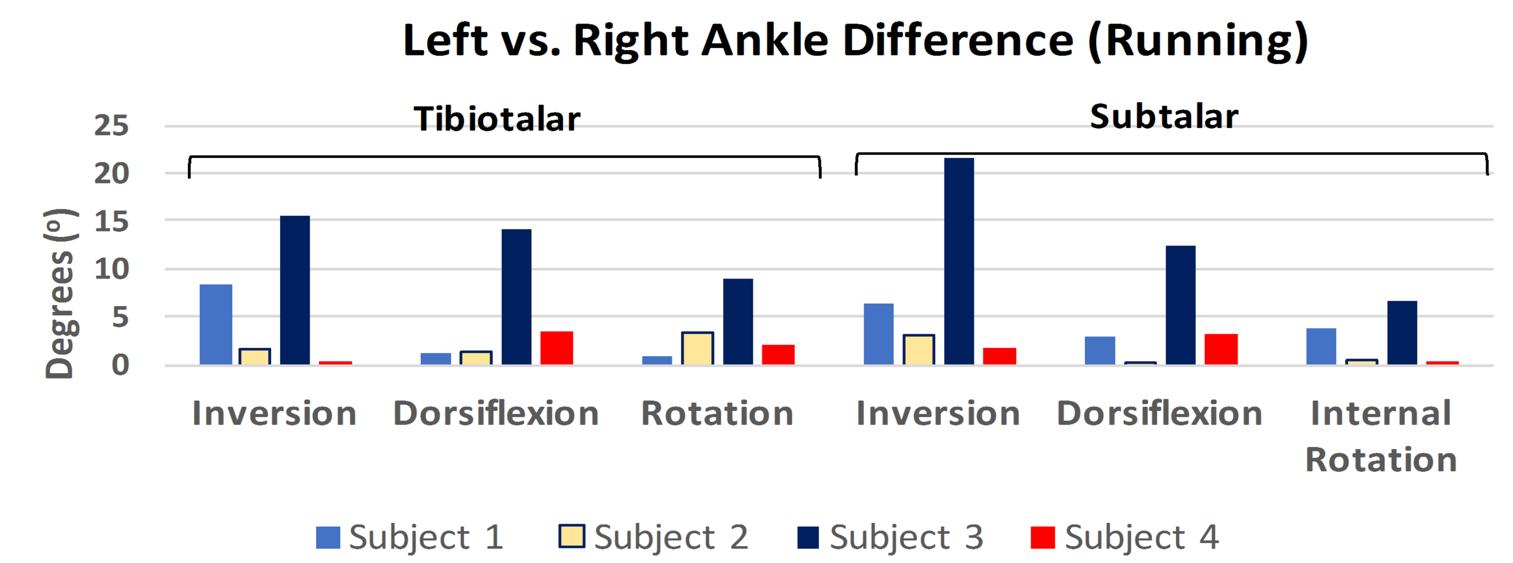


Figure 7. Average of the side-to-side difference between left and right ankle running trajectories (tibiotalar and subtalar joints). Similar to walking, Subjects 1, 2, and 4 generally showed a value ≤ 5 degrees for all rotations, while subject 3 had values ≥ 5 degrees for all rotations.

Discussion

- Left versus right ankle rotation differences were ≤ 5 º for 3 out of 4 subjects, providing a benchmark for native kinematic variability within an individual. Clinical significance: kinematic differences > 5 º suggests that surgical procedures did not restore native kinematics.
- Small trial-to-trial variability (≤ 1 º) for all rotations of tibiotalar and subtalar joints suggests that overground walking and running provide repeatable ankle kinematic measures for healthy individuals.
- These results are limited to healthy individuals performing walking and running tasks, and should not be extrapolated to pathological populations or other movements.
- The information obtained in this study will be used to design future studies investigating chronic ankle instability and surgical repair techniques.

References and Acknowledgements

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