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# Hindfoot kinematics during a double limb heelrise in persons with end-stage ankle arthritis

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## INTRODUCTION

The ability to complete a heelrise task is an important component of independent function. Despite observational and clinical trials little is known about the functional characteristics of the peritalar (subtalar and talonavicular) joints with respect to ankle arthritis compared to healthy individuals. Without such information rigorous evaluation of pathology or intervention cannot occur. The purpose of the present work was to describe and contrast kinematics of peritalar joints during the heelrise task in persons with ankle arthritis and healthy control subjects. This information is necessary to quantify abnormal motion as a first step towards measuring pathological and treatment states.

## METHODS

Data were collected from seven individuals diagnosed with end-stage ankle arthritis (64.8 ± 8.0 yrs of age; 6 Males), identified through an orthopaedic foot and ankle surgery clinic. Sex and age-matched healthy control subjects were also recruited. Any control subjects with bilateral ankle disease, orthopaedic or neurological disease that affects gait and/or balance were excluded from the study. A fellowship-trained orthopaedic foot and ankle surgeon clinically examined all subjects to ensure no subjects with undiagnosed pathologic conditions of the foot and ankle were included in the control group. The protocol was approved by the Institute's research ethics boards and all subjects provided informed consent prior to participation in the study.

Motion of the shank, hindfoot, midfoot, forefoot and hallux was tracked in three dimensions utilizing a previously validated multi-segment foot model [1, 2]. According to this model, infrared emitting diodes (IREDs) were directly mounted over subcutaneous landmarks. Additionally, clusters of 4 IREDs were secured bilaterally on the shank and hallux segments (Figure 1). An instrumented probe identified virtual landmarks not tracked directly with IREDs. To complete the task, subjects were asked to rise slowly on their toes to the maximum height they are able and lower their heels back to the ground. This was repeated three times. Bilateral data was acquired at 60Hz using four optoelectric motion capture camera banks (Phoenix Technologies Inc., Burnaby, BC) positioned around the subject.

Kinematic profiles of the various segments were provided throughout the task. Peak angles and ranges in the sagittal and frontal planes were extracted from the data for the following: (1) Hindfoot-shank angle, (2) Hindfoot-forefoot angle). All data were normalized to a static, reference posture. Independent sample t-test was used to compare variables of interest between groups (affected side arthritis group and dominant side control group). Statistical significance considered at $p < 0.05$.

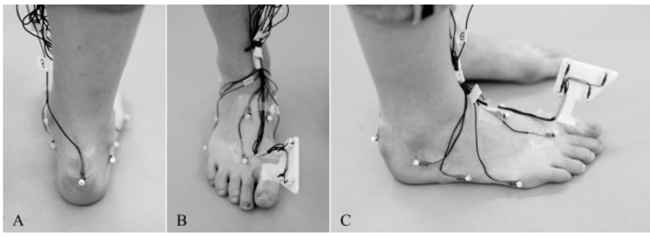


**Figure 1.** The multi-segment foot model utilized [1,2], identifying IREDs on the various landmarks.

## RESULTS AND DISCUSSION

*Shank-hindfoot kinematics*

Figure 2 illustrates the angular displacement of the shank-hindfoot during the heelrise task. The arthritis group demonstrated significantly reduced plantarflexion (peak and range) compared to controls ($p<0.01$). Additionally, range of motion in the frontal plane was significantly less in the arthritic group ($p= 0.001$) due to the loss of hindfoot inversion motion through the task, although this was not borne out to be statistically significant ($p=0.06$).

*Hindfoot-forefoot kinematics*

The total range of motion for the hindfoot-forefoot were significantly affected by the presence of ankle arthritis in both the sagittal and frontal planes of motion ($p<0.01$). Figure 3 illustrates the angular displacement of hindfoot-forefoot during the heelrise task demonstrating the altered kinematics of the task due to the arthritic state. Noteworthy is the illustrated reversal of motion in the frontal plane in the arthritic group. These results demonstrate that along with the anticipated loss of hindfoot sagittal plane motion, related changes in the motion of the forefoot contribute to alterations in the heelrise task in persons with end-stage arthritis. Loss of normal relative forefoot plantarflexion and valgus motion could lead to a loss of the rigidity of the hindfoot-midfoot-forefoot structure.

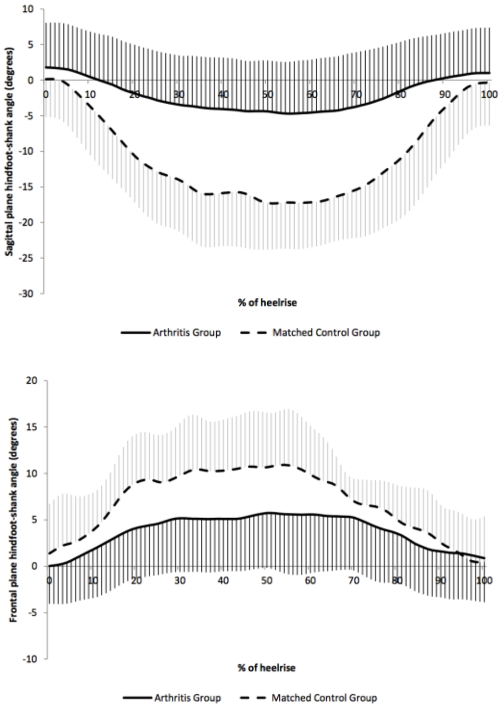


**Figure 2.** Sagittal (top) and frontal (bottom) plane motion occurring between the shank and hindfoot during heelrise. Data are normalized to 100% of the heelrise task. Plantarflexion = Negative (sagittal plane). Eversion = Negative (frontal plane).

## CONCLUSIONS

The current study is the first to describe the kinematics of the multi-segment foot during a double-limb heelrise in persons with end-stage ankle arthritis. Not surprisingly, our results indicate that end-stage ankle arthritis has a significant effect on the biomechanical relationship between the lower leg and hindfoot. However, the current data also highlight the altered motion of the between the hindfoot and forefoot segments, indicating a more complete understanding of the entire foot and ankle complex is required during dynamic movement in this population to better guide treatement. This research can help inform physical examination of the diseased state with direct functional observations.

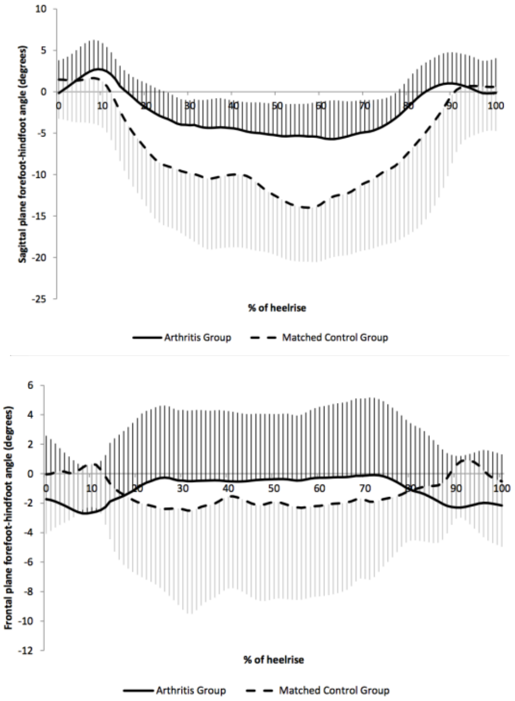


**Figure 3.** Sagittal (top) and frontal (bottom) plane motion occurring between the hindfoot and forefoot during heelrise. Data are normalized to 100% of the heelrise task. Plantarflexion = Negative (sagittal plane). Eversion = Negative (frontal plane).


## ACKNOWLEDGEMENTS

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