

## THE FIRST METATARSAL AS A FIXED STRUT: NEW INSIGHTS INTO DYNAMIC ARCH FUNCTION

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### INTRODUCTION

The truss and tie rod theory has long provided the framework through which motion of the medial longitudinal arch during loading is viewed [1,2]. Early insights gained from static loading of cadaveric feet resulted in a conventional understanding that describes arch lowering during the stance phase of gait via simultaneous downward motion of the proximal first metatarsal and distal calcaneus. In the process of quantifying the effects of ankle arthroplasty and fusion on dynamic foot function it was observed that arch motion occurred in a manner different than commonly accepted. The purpose of this work is to define the segmental kinematics that expose a new perspective on arch motion during gait in which arch elongation occurs about a stationary first metatarsal.

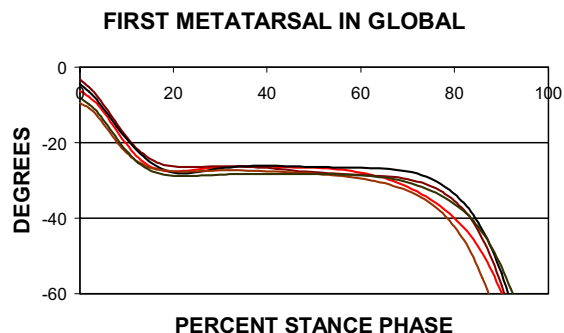
### METHODS

Motion of the first metatarsal in the global (relative to the floor) and of the first metatarsal relative to the calcaneus (arch elongation) was assessed in a total of 23 limbs. Of the limbs tested 7 had undergone ankle fusion, 9 had undergone ankle arthroplasty and 7 had no previous surgical intervention. An Optotrak motion analysis system was used to record the 3-D position of the first metatarsal and calcaneus during gait. Motion of the first metatarsal was tracked with a lightweight marker triad mounted on the first metatarsal, medial to the extensor hallucis longis tendon in a manner similar to Leardini et al. [3]. Hindfoot motion was assessed by two markers on the lateral and one on the posterior aspect of the calcaneus. A digitizing process in conjunction with lateral and AP x-rays of the foot in the patient population, and palpation of the foot in control subjects were used to identify the location of underlying bony geometry relative to each segment's marker triad. Visual 3D (C-motion Inc.) was used to calculate 3-D displacements. The mean of five trials at self selected, 0.9, 1.1, 1.3 and 1.6 m/s were used for variables of interest.

To determine arch kinematics during gait motion of the first metatarsal relative to the calcaneus (arch motion) and sagittal plane angular motion of the first metatarsal in the global (lowering of the proximal end of the first metatarsal) were assessed during stance phase.

### RESULTS AND DISCUSSION

Kinematic patterns and peak values were highly consistent both within and between walking velocities with standard deviation values of less than 1 degree on average. To our surprise arch and first metatarsal kinematics were not significantly different between groups and therefore, grand mean values were used. Once forefoot contact occurs the first metatarsal was found to maintain a nearly static position from  $17.0 \pm 3.3\%$  until  $67.0 \pm 6.4\%$  stance (Figure 1). During this



**Figure 1:** Sagittal plane kinematics of the first metatarsal relative to the floor for five subjects demonstrating nearly static positioning for approximately 50% of stance.

interval the first metatarsal was found to lower only  $1.5 \pm 1.2$  degrees while the arch flattened  $10.5 \pm 3.0$  degrees on average. These data suggest that during the stance phase of gait arch elongation occurs as the calcaneus is pulled up and over the nearly stationary first metatarsal. The elevation and resulting unloading of the calcaneus that produces this motion is substantiated by plantar pressure data in which the calcaneus is unloaded in mid stance

Contrary to the current understanding of normal arch motion, the first metatarsal appears to maintain a nearly static sagittal plane orientation during midstance. These findings are quite robust and exist following surgical interventions and across different walking velocities where the stress on the arch would vary.

### CONCLUSIONS

These data suggest a new insight into medial longitudinal arch motion in which the calcaneus is pulled over a nearly stationary first metatarsal causing arch elongation. This calls into question the current understanding of medial longitudinal arch lowering and may in part explain the mixed results observed with current interventions used to control arch motion during gait.

### REFERENCES

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