FOREFOOT PLANTAR PRESSURE IS RELATED TO 3-D CT DERIVED MEASURES

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INTRODUCTION

The relationship between foot structure and foot function is complex and not completely understood. Previous research has employed static X-ray parameters[1] or static X-ray parameters in conjunction with additional measures of foot structure and function,[2] including, among others, joint range of motion, tissue parameters, EMG, etc., to explain 35% and 50% of the variability of the plantar pressure, respectively. Our group has recently completed a study of the 3-D structure of feet ranging from flat to high arched feet.[3] Additionally, we compared plantar pressure data between these subjects.[4] In both studies, we found significant differences between foot types. The purpose of this study was to combine the work of the previous two studies to determine if 3-D measures of foot shape were related to forefoot plantar pressure.

METHODS

A total of 40 subjects were enrolled with ten in each of four foot type groups: pes cavus (high arch), neutrally aligned, asymptomatic pes planus (low arch) and symptomatic pes planus. If the foot type was bilateral both feet were included (n=64 feet). Foot type was determined via clinical examination by an orthopaedic surgeon. Each foot was X-rayed (AP and lateral) and a weight-bearing CT scan was performed. Age, weight, height and gender were recorded. Ten trials of barefoot plantar pressure data were collected with an EMED-SF system and velocity was recorded. Peak pressure was determined over the entire foot as well as 6 subdivisions: the hallux and the 1st through 5th metatarsal heads. These subdivisions were obtained by overlaying the AP X-ray on top of an actual-size composite peak plantar pressure print out. Simulated weight bearing CT scans of the subject's foot were generated. Using techniques defined elsewhere, local coordinate systems (inertial matrices) were determined based on the bone morphometry.[5] These axes were then used to describe bone to bone orientation using the Z, Y', X" Euler angles. Euler angles were calculated between the 1st Metatarsal-Talus (M1Tal), 5th Metatarsal-Talus (M5Tal), Calcaneus-Talus (CalTal), 2nd Metatarsal-1st Metatarsal (M2M1), Calcaneus-Fibula (CalFib), Cuneiforms-Talus (CunTal), Cuneiforms-Navicular (CunNav), and Navicular-Talus (NavTal), resulting in 24 total angles. Linear regression models of mean pressures (per subject) on Euler angles were calculated; age, BMI and mean velocity were adjusted for.

RESULTS

To visualize trends for each location, a plot of the data with a loess-smoothed curve was generated (Figure 1). The regression for each location required only 3 or 4 of the 24 possible angles; additional angles made no improvement. For the hallux, the CunTalZ, M1TtalZ, and the M2M1Y' angles explained 46.4% of the variability in peak plantar pressure. The 1st metatarsal data indicated that the CalFibX", M2M1Z, M1TalY', and CalTalX" angles were significant and could account for 47.7% of the variability in peak plantar pressure. The 2nd and 3rd metatarsals only showed significance with one angle, the NavTalX" and M2M1Z, respectively, and only 21.5% and 3% of the variability could be explained. The 4th metatarsal showed that the CunTalZ, M2M1Z, CalFibX", CalTalZ angles were significant and able to describe 51.2% of the variability in peak plantar pressure. And finally for the 5th metatarsal we found that 44.7% of the pressure variability over this region could be accounted for when the M5TalX", M1TalX", CalFibX", and CunNavX" angles were analyzed.

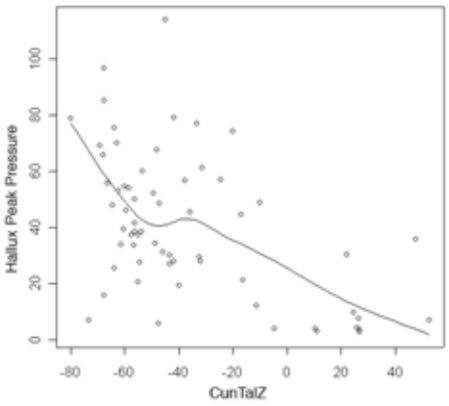

Figure 1: The hallux peak pressure vs. the CunTalZ angle.

DISCUSSION

This study indicates that for several locations on the forefoot (hallux, and the 1st, 4th and 5th metatarsals) the 3-D static angles describe more of the variability of the plantar pressure then just X-ray parameters.[1] In fact, for these areas the 3-D static angles were as predictive as the range of foot structure and functional parameters used elsewhere.[2] However, for other locations, our analysis was a very poor predictor (2nd and 3rd metatarsal). It is not clear why these locations did not perform well; they were not emphasized in the selection of bony relationships to study, but neither was the 4th metatarsal and it had the highest percentage. Nevertheless, areas such as the hallux and the 1st and 5th metatarsals are important areas for ulcer occurrence. The data present here demonstrate that 3-D CT angles useful for predicting peak plantar pressure.

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