INTRODUCTION

From an architectural perspective, feet are shaped differently and can be generally categorized as pes cavus (PC, high arch), neutrally aligned (NA, neutral arch), or pes planus (PP, low arch). Current classification schemes are typically 2-D and may contain subjective components (Razeghi and Batt 2002). The purpose of this study was to develop and validate a 3-D, objective method for determining foot type.

METHODS

Forty subjects were recruited and examined by an orthopedic surgeon to identify their foot type. If the foot type was bilateral both feet were analyzed otherwise only the foot of interest was studied. This recruitment resulted in a total of 64 feet (31 PP, 20 NA, and 13 PC). The PP foot type was further divided into asymptomatic and symptomatic groups for other studies, thus more PP feet were analyzed in this analysis.

Simulated weight bearing CT scans of the subject’s foot and ankle were studied. From the CT scans 3-D models of each bone were created using NIH Image v.1.6.2 and custom developed software. Based on each bone’s surface geometry, inertial matrices were computed (assuming homogeneous bone density) to establish local Cartesian coordinate systems. These axes were then used to describe bone to bone orientation using the Z, Y’, X” Euler angles (Camacho et al. 2002).

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). The resulting twenty-four angles were used in a classification tree analysis (CTA) to determine if Euler angles can be used to classify feet into the 3 clinical foot type groups. The CTA recursively partitions the 64 feet into subgroups, which most closely approximate the three clinical foot type groups using the Euler angles. A misclassification rate was computed using a cross-validation algorithm.

RESULTS

The CTA classified the feet into subgroups using 3 partitions of data using 3 different Euler angles (Figure 1). The first measure CunTal X” represents a combination of dorsi/plantar flexion and ab/adduction of the cuneiforms relative to the talus. Thus feet with CunTal X” < 23.55° have cuneiforms that are less dorsiflexed, and more adducted and represent the PC population. The first measure that separates PP from NA is the dorsi/plantar flexion of the 1st metatarsal
(M1Tal X”). Feet that have 1st metatarsals that are plantar flexed less than 4.92° relative to the talus were classified as PP. The final determinate used to separate NA from PP was the CunNav X” angle. Feet that had cuneiforms that were adducted less than 32.14° relative to the navicular were identified as NA, whereas cuneiforms with more than 32.14° were classified as PP.

**Figure 1:** The Classification tree. The numbers in each branch represent the number of feet according to foot type NA/PP/PC, whereas the label indicates the category the feet should be classified as.

This classification tree demonstrates that our methods were capable of classifying 62 of the 64 feet correctly. However, the cross validated misclassification error was 20%, reflecting some degree of instability in our classification tree. Figure 2 illustrates how if partitions lines are moved by a small distance, subjects are classified into different groups.

**DISCUSSION**

This methodology was able to successfully classify 97% of the feet. Figure 1 shows that one PP foot was incorrectly classified as a NA foot, and a PC foot was misidentified as a PP foot. Since the cross validation analyses showed some instability, we believe this method as a classification tool would be able to successfully classify foot types from another data set with an 80% success rate. As this method is objective and based on 3-D morphology it may be a better mechanism for classification in the future than the current means. Accurate classification of foot types can assist and improve in orthotic prescription and surgical correction.

**REFERENCES**


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