Comparing Bone Alignment of Asymptomatic Flatfoot and Progressive Collapsing Foot Deformity Using 3D Radiographic Measurements

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DISCLOSURES: None

INTRODUCTION: Flatfoot, or pes planus, is commonly characterized by collapse of the medial longitudinal arch, often accompanied by hindfoot valgus and forefoot abduction [4]. While some individuals remain asymptomatic, others progress into a more advanced and painful state known as progressive collapsing foot deformity (PCFD). These symptomatic cases often exhibit more pronounced structural abnormalities and experience functional impairments [1]. However, the differences in bone alignment between individuals with asymptomatic flatfoot and PCFD are not well understood. PCFD is commonly evaluated using two-dimensional (2D) radiographs, though three-dimensional (3D) analyses offer a more comprehensive assessment of this complex condition [2]. The Automatic Anatomical Foot and Ankle Coordinate Toolbox (AAFACT) and the 3D Foot and Ankle Radiology Measurements (3D FARM) toolbox are both 3D tools developed to automatically calculate 2D and 3D joint measurements from bone models [3]. This study aims to utilize these toolboxes to compare joint measurements between PCFD and asymptomatic flatfoot populations to identify potential differences in bone alignment.

METHODS: 79 participants (41 females, 38 males) underwent weight-bearing computed tomography (WBCT) scans, including 28 rectus individuals, 22 asymptomatic flatfoot individuals, and 29 individuals with PCFD, which was diagnosed by a foot and ankle fellowship-trained orthopedic surgeon. These scans were semi-automatically segmented using Bonelogic and DISIOR and manually cleaned up using Mimics v22.0 (Materialize). Segmented models were then smoothed in 3-matic v16.0 (Materialize) and run through 3D FARM, which leverages calculations from AAFACT [3]. This provided joint measurements that were then compared across rectus, PCFD, and asymptomatic flatfoot populations to identify significant differences between the average values for each group. Statistical analysis was performed using a one-way ANOVA followed by Tukey's post hoc with a significance value of 0.05. The seven evaluated measurements included sagittal Meary's angle (SMA), axial Meary's angle (AMA), talonavicular angle (TNA), foot and ankle offset (FAO), calcaneal inclination angle (CIA), tibiotalar angle (TTA), and talocalcaneal angle (TCA) (Fig. 1).

RESULTS: TNA, SMA, and CIA were significantly different across all three pairwise group comparisons (rectus vs. asymptomatic, rectus vs. PCFD, and asymptomatic vs. PCFD), Fig. 2. FAO and AMA were significantly different for two of the comparisons, though not asymptomatic vs. PCFD. TTA and TCA were not significantly different between any populations. All measurements except TTA increased in severity going from rectus to asymptomatic flatfoot to PCFD groups.

DISCUSSION: Comparative analysis of joint measurements across rectus, asymptomatic flatfoot, and PCFD populations suggests there is a progression in bony misalignment correlating with the onset of pain (Fig. 2). This pattern indicates that asymptomatic flatfoot may represent an intermediate morphology on a continuum toward PCFD, although longitudinal studies are required to confirm progression. Additionally, it appears that TNA, SMA, and CIA may be more sensitive and relevant measurements capable of distinguishing bone structure between the three groups, since these measurements were significantly different between all groups. It is also possible that deformities in the regions relating to these measurements, specifically the subtalar joint, may drive the transition from asymptomatic flatfoot to PCFD. Future work includes using statistical shape modeling to analyze morphological differences between the three groups.

SIGNIFICANCE/CLINICAL RELEVANCE: Radiographic measurements calculated in this study could help establish relative measurement ranges for asymptomatic flatfoot and PCFD populations, which may be used to distinguish bone alignment between the two groups. Clinicians could track these measurements as potential longitudinal markers such that as measurements become more severe, the onset of pain becomes apparent.

REFERENCES: [1] Arain, A. et al. Statpearls. 2024 [2] Lintz, F. et al. Foot Ankle Surg. 2022 [3] Peterson, A Front Bioeng Biotechnol. 2023 [4] Raj MA et al. Statpearls. 2023

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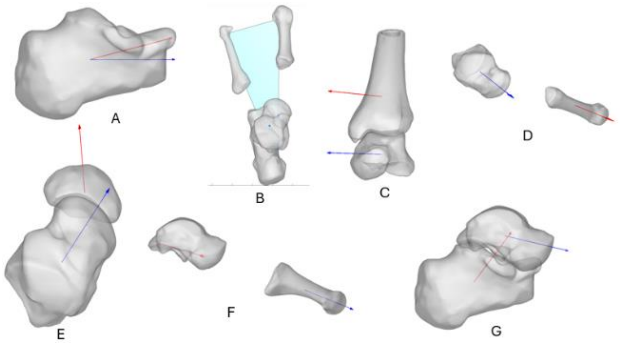

Figure 1. Joint measurements analyzed: (A) Calcaneal Inclination Angle, (B) Foot and Ankle Offset, (C) Tibiotalar Angle, (D) Axial Meary's Angle, (E) Talonavicular Angle, (F) Sagittal Meary's Angle, (G) Talocalcaneal Angle

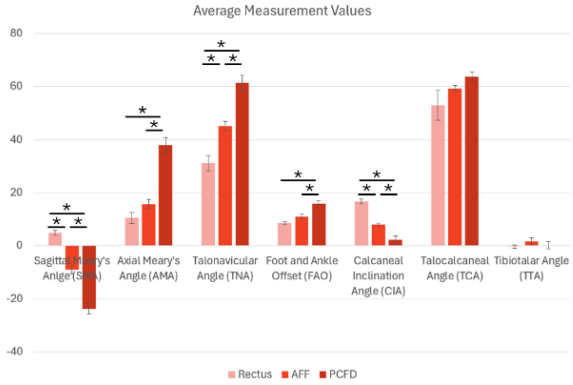

Figure 2: Figure 2. Average measurement values for each of the three populations. Y axis is in degrees for all measurements except for FAO, which is in percentage. * Indicates significance with p <0.5