3D Statistical Shape Modeling of Foot Type Spectrum and Ankle/Hindfoot Osteoarthritis

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Summary

Classifying foot types is a valuable tool for facilitating communication in studying foot and ankle pathologies; however, standard 2D radiograph evaluations fall short of accurately capturing the complexity of ankle morphology. This research leverages 3D modeling to provide an improved, multiplanar assessment, revealing distinct foot patterns that can differentiate joints affected by osteoarthritis and offer new insights into foot type as a potential confounding variable.

Introduction

Feet are commonly categorized into three types: cavus (high arch), rectus (neutral arch), and planus (flat foot) [1]. This classification relies on clinical and/or radiographic assessment and lacks the precision to capture the complexity of foot morphology [1]. Foot type can profoundly impact the development and progression of foot and ankle pathologies by influencing biomechanics and force distribution [2]. The relationship between foot type and osteoarthritis (OA) remains underexplored, despite its potential relevance for preventative strategies. This study aims to employ 3D modeling to enable an improved multiplanar assessment of foot type and hindfoot OA.

Methods

A hindfoot multi-bone statistical shape model was created from weight-bearing computed tomography (WBCT) data of 254 patients: 36 Charcot-Marie-Tooth (CMT), 21 cavus, 48 rectus, 26 planus, 42 progressive collapsing flatfoot deformity (PCFD), 44 tibiotalar OA (TTOA), and 37 subtalar OA (STOA). Principal component analysis (PCA) assessed the modes of variation. In-house MATLAB code calculated Meary's angles of patient WBCT bony segmentations in the sagittal plane. This angle is clinically used to assess the longitudinal arch of the foot [3]. Angles for each foot type group were compared via t-test (α=0.05).

Results and Discussion

PCA mode 1, explaining 56.9% of the variance, demonstrated significant differences between main foot types with Meary's angles aligning with the expected foot type spectrum (Table I) and showing statistical differences between foot types, but not between hindfoot OA groups. Mode 3, accounting for 8.47% variance, distinguished OA from non-OA participants (p=0.0014), correlating with subtalar joint space narrowing and tibia/fibula motion from anterior to posterior. Subtle foot features in STOA and TTOA joint orientations appeared more similar to planus and cavus foot types, respectively.

Table I: Average Meary's Angles for each patient group

Group	PCFD	Planus	STOA	Rectus	TTOA	Cavus	CMT
Meary's °	-14.18	-5.28	5.39	7.95	9.21	20.19	25.65

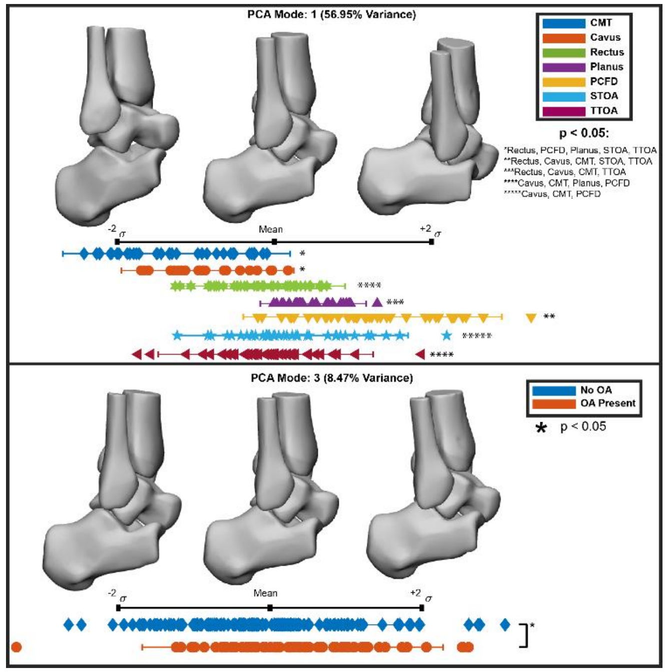

Fig.1: PCA Mode 1 and Mode 3 for a hindfoot SSM of 254 patients with varying foot types and OA. Mode 1 delineates foot type between groups, and Mode 3 differentiates the presence of STOA or TTOA.

Conclusions

This 3D model represents a nuanced, multiplanar understanding of foot type and its biomechanical implications. PCA results highlight the value of shape modeling in assessing foot type and distinguishing between OA and non-OA cases. While the study does not confirm that foot type directly influences OA progression, it is an essential first step that suggests foot type may be an important risk factor. The cohort of OA patients in this study represents various etiologies beyond post-traumatic or post-surgical cases, broadening the applicability of the findings. This diversity underscores the need for further research to explore the relationship between foot deformities and OA progression, as the trends identified by SSM appear present across this varied OA population. Ultimately, the goal is to develop preventative strategies and refine treatment approaches beyond end-stage interventions.

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References

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