Comparison of Anatomical Coordinate Systems in Foot and Ankle Biomechanics Across Pathologies

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Summary

This study contributes to the ongoing global effort to establish standardized anatomical coordinate systems (ACS) in foot and ankle biomechanics as part of a world-wide task force. By analyzing four ACS methodologies across seven pathologies, we identified variability in consistency between definitions, with implications for both research and clinical practice. The findings emphasize the importance of developing robust and standardized ACS approaches to enhance reproducibility, accuracy, and the overall utility of 3D biomechanical analyses.

Introduction

Biomechanical 3D analyses are crucial for researchers and clinicians to understand the complex nature of the foot and ankle. A key piece to these 3D analyses is defining reliable and consistent ACSs, and yet there is a lack of standardization amongst the foot and ankle community on methodological approaches which limits ability to compare data across sites. This study builds upon prior efforts from an international task force focused on standardizing ACS methodologies. We aim to compare four approaches for the definition of coordinate systems to evaluate their reliability, similarities, and differences across multiple pathologies to assist in standardizing ACSs.

Methods

We analyzed four ACSs approaches [1-4] across healthy subjects and six pathologies (cavovarus, clubfoot, Charcot-Marie-Tooth, ankle/hindfoot osteoarthritis, progressive collapsing foot deformity, post-op pilon fracture). Weightbearing computed tomography (CT) scans from seven individuals representing each pathology were used to generate 3D models of 14 bones (tibia/fibula through metatarsals). ACS definitions (Conconi, Peterson, Siegler, Thorhauer) were applied as appropriate to the bones. Angular differences were calculated by comparing each ACS with an arbitrary unit coordinate system, using rotation matrices to derive three principal angles based on XYZ convention. Two primary analyses were performed with the angles: 1) the standard deviation (SD) across pathologies to assess consistency and 2) the average angle differences between ACSs for methodology comparisons.

Results and Discussion

A range of variability was observed across pathologies, with the Conconi definition showing an average SD of 3.70°, the Peterson definition 2.14°, the Siegler definition 7.42°, and the Thorhauer definition 2.55°. Pairwise comparisons revealed notable differences, with the tibia, fibula, and first metatarsal being the most consistent across methodologies, while the calcaneus and fifth metatarsal showed the greatest discrepancies, with angular differences reaching up to 71.12°. These findings highlight inconsistencies in existing ACS definitions and the need for more robust, standardized methodologies to improve reproducibility and clinical utility.

Conclusions

This study highlights variability in ACS definitions, reinforcing the need for ongoing standardization efforts. Ongoing research and collaborations continue to improve reproducibility and clinical utility for ACSs in foot and ankle biomechanics. Future efforts should focus on independent, robust definitions suitable for weightbearing evaluations, with consideration of manual versus fully automated applications to enhance accuracy and usability in clinical and research settings.

References

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