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Comparison of three-dimensional multi-segmental foot models used in clinical gait laboratories

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ABSTRACT

Background: Many skin-mounted three-dimensional multi-segmented foot models are currently in use for gait analysis. Evidence regarding the repeatability of models, including between trial and between assessors, is mixed, and there are no between model comparisons of kinematic results.

Research question: This study explores differences in kinematics and repeatability between five three-dimensional multi-segmented foot models. The five models include duPont, Heidelberg, Oxford Child, Leardini, and Utah.

Methods: Hind foot, forefoot, and hallux angles were calculated with each model for ten individuals. Two physical therapists applied markers three times to each individual to assess within and between therapist variability. Standard deviations were used to evaluate marker placement variability. Locally weighted regression smoothing with alpha-adjusted serial T tests analysis was used to assess kinematic similarities.

Results: All five models had similar variability, however, the Leardini model showed high standard deviations in plantarflexion/dorsiflexion angles. P-value curves for the gait cycle were used to assess kinematic similarities. The duPont and Oxford models had the most similar kinematics.

Conclusions: All models demonstrated similar marker placement variability. Lower variability was noted in the sagittal and coronal planes compared to rotation in the transverse plane, suggesting a higher minimal detectable change when clinically considering rotation and a need for additional research. Between the five models, the duPont and Oxford shared the most kinematic similarities. While patterns of movement were very similar between all models, offsets were often present and need to be considered when evaluating published data.

1. Introduction

Many three-dimensional multi-segmented foot models are currently in use for gait analysis [1,2]. There are two common methods for placing markers on feet: intra-cortical pins and skin-mounted markers. Intra-cortical pins often present clinical complications and are not practical for routine use in gait analysis, especially pediatric gait analysis [3]. Shown to have adequate reliability compared with intra-cortical pin markers [4–6], skin-mounted markers are commonly used in three-dimensional multi-segmented foot models as they are less invasive and easier to implement on a routine basis [1,2]. Development and validation studies for these models have adequate procedures and sample sizes, however evidence regarding the repeatability, including between trial and between assessors, is mixed [2,7]. More importantly, there are no between model comparisons of kinematic results. Since each model utilizes different terminology and marker sets and calculates local anatomical coordinate systems and intersegment rotations differently, there is no technical uniformity. This poses a problem in interpreting data from work published in literature utilizing different models. Few studies test multiple kinematic foot models concurrently [8]. Due to these differences and discrepancies there are also no clinical recommendations on which model to use and why.

This study aimed to explore differences in kinematics and repeatability between five three-dimensional multi-segmented foot models. The five models chosen for comparison were selected based on their prevalence and utilization in the literature and pediatric gait laboratories as well as their similarity in defined segments and marker sets. These similarities allowed all marker sets to be applied simultaneously for direct comparative measures. The five models include duPont [9], Heidelberg [10], Oxford Child [11], Leardini [12], and Utah [13].

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between all models, offsets were often present and need to be considered when evaluating published data. Comparing findings between labs using the same model and using normative data for that specific model should still allow for the appropriate clinical analysis to be made. Such findings have an important clinical relevance in showing that these models could be used to provide a detailed analysis of walking gait as well as have ease in application of the markers.

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Conflict of interest

The authors declare no conflicts of interest.

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