Back to basics: test-retest reliability of multisegment foot kinematics for youth with cerebral palsy

Liz R. Boyer[1,2], Jean L. Stout,[1] Adam Rozumalski[1]
[1]Gillette Children's Specialty Healthcare, St. Paul, USA
[2]University of Minnesota, Department of Orthopedic Surgery, Minneapolis, USA
Email: lizrboyer@gillettechildrens.com

Summary

It is important that measurements are repeatable between days and clinicians. Reflective markers can be placed on the feet to measure foot shape and motion during walking. The repeatability of these measures is suboptimal, even on typical adult feet. For children with foot deformities in conditions like cerebral palsy, the repeatability is expected to be worse. We measured the repeatability of multisegment foot motion during walking in 26 youth with cerebral palsy on two visits. Many of the angles of the foot segments showed poor repeatability. For example, the up/down tilt of the front half of the foot differed by ±10°, meaning that most repeat measures will fall within a 20° window. Some angles were better, like the front half of the foot tilt inwards/outwards (±3°). These findings need to be transparent to clinicians using these data; refinement is necessary to improve repeatability.

Introduction

Multisegment foot kinematics and projection angles are used clinically to detect abnormal motion or foot posture, both as a diagnostic tool and outcome. For any measurement, the signal to noise (i.e., measurement error) ratio needs to be large enough for the measurement to be useful on both a population and individual basis. Measurement error due to skin artifact or marker misplacement is a known challenge with foot models [1]. In clinical practice, the same patient may see different clinicians visit to visit; therefore, test-retest reliability studies are necessary to identify the signal: noise ratio. To date, only 1 reliability of multisegment foot kinematics (Oxford model) in children with neuromuscular conditions exists, which quantified inter-rater reliability for clubfoot and intra-rater reliability for cerebral palsy (CP) [2]. Other studies have included adult feet with typical morphology, which does not reflect clinical use. Our purpose was to assess the absolute inter-rater test-retest reliability of multisegment foot kinematics and projection angles in youth with CP.

Methods

Twenty-six ambulatory youth (age: 11±3 range 6-16 y) with CP undergoing a clinical gait analysis were recruited from 2019-2024. All provided consent/assent. One of five experienced physical therapists applied reflective markers [3]. Participants performed 3 walking trials. Up to 25 days later (mean: 15), a different therapist repeated the gait analysis. The 9 angles most often used clinically are presented. *Statistics.* Generalizability Theory was used, which allows different D-study scenarios to be calculated [4]. ANOVA was used to calculate the standard error of measurement (SEM) was calculated for each variable for every 2% of the gait cycle (Table 1). The mean SEM for the entire gait cycle is reported.

Results and Discussion

Two different scenarios are presented in Table 1. The majority of variance comes from the participant×day interaction, not variance between trials, so averaging across multiple trials is not helpful. Three outcomes (midfoot sagittal, medial and lateral longitudinal arch) had SEMs >10°. The SEM for midfoot coronal exceeded the typical range of motion (ROM) during gait. Only subtalar-coronal had SEM <5° and SEM <33% of ROM during gait.

Conclusions

Measurement error is inevitable, which must be communicated to clinical decision-makers who interpret these data. The poor inter-rater reliability for many clinically-utilized multisegment foot angles could mislead identification of deformity or interpretation of change and are therefore too insensitive to use at an individual level. Greater refinement of marker placement may help improve reliability. Repeat testing should be done by the same rater when possible. Alternative marker placements/models should be considered.

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References

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Table 1: Test-retest reliability (±SEM°) and ±1 standard deviation (SD) for 22 neurotypical adults from our gait lab reference database.

D-study scenario	Subtalar-sagittal	Subtalar-coronal	Subtalar-transverse	Midfoot-sagittal	Midfoot-coronal	Midfoot-transverse	Medial Longitudinal Arch	Lateral Longitudinal Arch	Hallux-to-First Ray - transverse
1 trial	8.8	3.3	4.4	10.4	8.4	7.4	10.9	10.5	7.2
3-trial average	8.5	3.0	4.1	10.3	8.3	7.2	10.5	10.4	6.4
3-trial average as % ROM in gait	42%	30%	65%	50%	157%	88%	48%	89%	34%
±1 SD reference	14.4	5.8	6.2	16.3	8.1	10.0	14.2	17.8	7.4