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# A kinematic description of dynamic midfoot break in children using a multi-segment foot model

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ABSTRACT

Midfoot break (MFB) is a foot deformity that occurs most commonly in children with cerebral palsy (CP), but may also affect children with other developmental disorders. Dynamic MFB develops because the muscles that cross the ankle joint are hypertonic, resulting in a breakdown and dysfunction of the bones within the foot. In turn, this creates excessive motion at the midfoot. With the resulting inefficient lever arm, the foot is then unable to push off the ground effectively, resulting in an inadequate and painful gait pattern. Currently, there is no standard quantitative method for detecting early stages of MFB, which would allow early intervention before further breakdown occurs. The first step in developing an objective tool for early MFB diagnosis is to examine the difference in dynamic function between a foot with MFB and a typical foot. Therefore, the main purpose of this study was to compare the differences in foot motion between children with MFB and children with typical feet (Controls) using a multi-segment kinematic foot model. We found that children with MFB had a significant decrease in peak ankle dorsiflexion compared to Controls ($1.3 \pm 6.48$ versus $8.6 \pm 3.48$) and a significant increase in peak midfoot dorsiflexion compared to Controls ($15.2 \pm 4.98$ versus $6.4 \pm 1.98$). This study may help clinicians track the progression of MFB and help standardize treatment recommendations for children with this type of foot deformity.



## 1. Introduction

Midfoot break (MFB) is a severe foot deformity that can cause chronic pain and reduced ankle power, which can make walking difficult. This type of foot deformity occurs most commonly in children with cerebral palsy (CP) [1]. CP is defined as a group of permanent disorders of the development of movement and posture causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain [2]. MFB can also affect children with other developmental disorders, such as spina bifida. At the Shriners Gait Lab (SGL) at Sunny Hill Health Centre for Children in Vancouver, BC, Canada, at least 10% of all children diagnosed with CP present to the lab with a MFB. In addition several children with diagnoses other than CP present to the lab with MFB every year.

Classically, as the severity of MFB worsens, surgical management becomes necessary. Prolonged weight-bearing in the face of a MFB may lead to the development of painful calluses over prominent osseous anatomy (e.g. navicular or plantarflexed talus). This may make the wearing of any potential corrective or supportive orthoses difficult or even impossible. The existing surgical treatment modalities aim to establish a plantigrade foot whereby both the hindfoot and forefoot are on the ground together during standing [3]. The long term morbidity following surgical treatment of MFB can be serious, thus early diagnosis and preventative treatments for MFB are critical.

### 1.1. Traditional MFB diagnosis

Clinical: MFB is a 3-dimensional foot deformity that can be described in terms of forefoot and hindfoot positioning in the coronal, sagittal, and transverse planes. MFB can be fixed or dynamic (flexible). In a foot with MFB, increased tightness in the gastroc-soleus complex pulls the hindfoot and talus into equinus. These increased muscle forces overpower the tibialis posterior and spring ligament, causing a collapse of the longitudinal arch. This results in a forefoot position that is dorsiflexed, abducted and supinated relative to the hindfoot. In addition, the navicular becomes subluxated dorsally and laterally on the talus [1].

Diagnosing a dynamic MFB is done on clinical exam by stabilizing the sub-talar joint, and observing whether or not dorsiflexion occurs through the midfoot. In a typical foot, there is no dynamic motion at the midfoot; therefore, midfoot motion observed during this exam indicates the presence of midfoot break.

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Hindfoot:

- Sagittal plane: plane formed by PCAL, HFV1 and CAL2.
- A–P axis: vector from PCAL to HFV1, set parallel to "Smart Surface" within the sagittal plane.
- M–L axis: lateral vector from PCAL, perpendicular to sagittal plane.
- S–I axis: superior vector mutually perpendicular to A–P axis and M–L axis.
- Technical markers: PCAL, MCAL, LCAL.

Forefoot:

- Transverse plane: plane set parallel to "Smart Surface".
- A–P axis: vector from MT23B to MT23H, projected onto the transverse plane.
- S–I axis: superior vector from MT23B, perpendicular to the transverse plane.
- M–L axis: lateral vector mutually perpendicular to A–P axis and S–I axis.
- Technical markers: MT23H, MT1B, MT5H, MT5B.

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