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Short communication

# O 105 – The effect of mono- versus multi-segment musculoskeletal models of the foot on simulated triceps surae lengths

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## 1. Introduction

Muscle-tendon complex (MTC) lengths and length changes during gait are important to inform planning of soft tissue surgery and evaluation, e.g. in children with cerebral palsy (CP). In conventional musculoskeletal modelling, the foot is represented as a single segment (e.g. based on Plug-in gait (PIG) marker model [1]). However, the use of multiple foot segments (e.g. Oxford foot model (OFM) [2]) in clinical gait analysis is becoming more common. It is known that a mono-segment foot model overestimates the ankle dorsiflexion angle, particularly in pathological feet, due to a lack of representing internal foot motions [3]. Therefore, it is likely that a single segment foot model yields erroneously longer MTC lengths of the triceps surae than a multi-segment model.

## 2. Research question

What is the effect of mono- versus multi-segment musculoskeletal foot models on the simulated MTC lengths of the triceps surae during normal gait, and in children with CP presenting with different foot deformities?

## 3. Methods

50 Subjects were included, both healthy and pathological (Table 1). Subjects walked barefoot at comfortable speed while skin-mounted markers were captured by a Vicon system. Four strides for each subject were time-normalized to 100% of the gait cycle. Musculoskeletal representations of PIG and OFM were constructed in OpenSim (v3.3) and

**Table 1**
Characteristics of the subject groups and the experimental setup.

| | Healthy adults | Healthy children | Children with CP |
|---|---|---|---|
| Number of subjects | 10 (4 male) | 10 (4 male) | 10 equinus (7 male)<br>10 cavovarus (9 male)<br>10 planovalgus (6 male) |
| Age (years) (mean ± SD) | 26.6 ± 2.6 | 10.2 ± 2.3 | 10.3 ± 2.3<br>9.3 ± 0.7<br>10.8 ± 1.4 |
| Data collection location | VUmc gait lab | VUmc gait lab | Oxford gait lab |
| Marker models | PIG (lower body)<br>OFM (right foot) | PIG (lower body)<br>OFM (right foot) | PIG (lower body)<br>OFM (most affected foot) |

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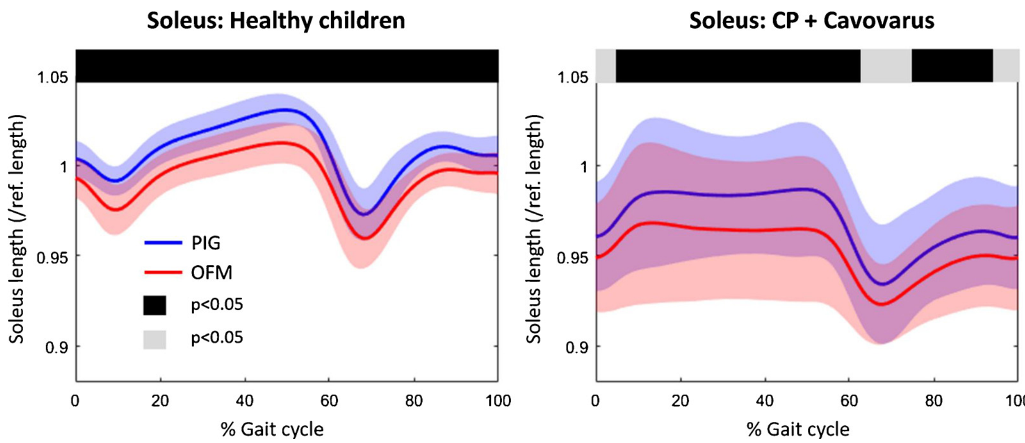


**Fig. 1.** The normalized soleus MTC length for healthy children (left) and children presenting with a cavovarus foot deformity (right). The shaded areas are SD around the group mean for PIG and OFM. The significant differences during the gait cycle are marked at the top of the graphs.

**Table 2**
Mean maximal RMS value differences between PIG and OFM for the different components of the triceps surae. ns = not significant.

| mean (SD) | Gastrocnemius medialis | Gastrocnemius lateralis | Soleus |
|---|---|---|---|
| Healthy adults | 0.7% (0.4) | 0.8% (0.5) | 1.0% (0.6) |
| Healthy children | 1.1% (0.6) | 1.1% (0.7) | 1.5% (0.8) |
| Equinus | 1.1% (0.9) $^{ns}$ | 1.2% (0.9) $^{ns}$ | 1.6% (1.3) $^{ns}$ |
| Cavovarus | 2.0% (0.7) | 1.9% (0.7) | 2.9% (1.0) |
| Planovalgus | 1.1% (0.9) | 1.2% (1.1) | 1.7% (1.5) |

used to calculate MTC lengths of the triceps surae. MTC lengths were normalized to reference lengths (i.e. lengths when all joint angles are set at zero). Simulated MTC lengths were compared between PIG and OFM, both within and between subject groups, using RMS values and statistical parametric mapping (SPM) [4] RM-ANOVA's.

## 4. Results

OFM lengths were significantly shorter than PIG lengths during the stance phase for all MTC's and subject groups without an equinus deformity (Fig.1, Table 2). Additionally, OFM lengths for all MTC's were significantly shorter during the swing phase, but only for healthy participants and cavovarus deformities (Fig.1). RMS differences were largest in cavovarus deformities and smallest in healthy adults (Table 2).

## 5. Discussion

The shorter OFM lengths during the stance phase for most subject groups is mostly in line with our hypothesis, but contrary to previous findings [5]. This study suggests that especially the stance phase is prone to erroneous MTC length estimates, because the foot deforms under load. Length differences between models are likely the result of a discrepancy between the estimated orientation of the calcaneus, and thus the insertion of the Achilles tendon. Larger differences were found for all foot deformities except for equinus, possibly due to the fixed nature of this deformity. This study shows that the use of mono- versus multi-segment foot models can lead to erroneous estimates of MTC lengths, therefore it is advised to use a multi-segment foot model to capture the effect of dynamic foot deformations when using MTC lengths for treatment selection.

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