

PERSONALIZED MR-BASED MUSCULOSKELETAL MODELS COMPARED TO RESCALED AND DEFORMED GENERIC MODELS OF SUBJECTS WITH INCREASED FEMORAL ANTEVERSION

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INTRODUCTION

Calculating biomechanical parameters of the lower limb such as moment arm lengths (MAL) and muscle tendon lengths requires computer models of the musculoskeletal system. Although these parameters are known to be very sensitive to inter-individual variations in musculoskeletal geometry, most studies rely on rescaling of generic musculoskeletal models constructed from averaged data of cadaveric measurements in a healthy adult population. As alternatives, deformable generic models were proposed as well as models that are based on information extracted from magnetic resonance (MR) images [1].

The aim of this study is to quantify differences between these different model types in the calculation of inverse kinematics and MAL during gait in a paediatric population with increased femoral anteversion (FA).

METHODS

Five male and two female subjects (aged 8–12 years), suffering from cerebral palsy with increased FA (ranging from 25° to 56°) and neck-shaft angles (ranging from 133° to 157°) were included in this study. Each subject was instrumented with reflective markers of which the three-dimensional positions were captured during a standing trial and during level, barefoot walking at a comfortable, self-selected speed. Each subject received a full leg MR scan. For this, reflective markers were replaced with radio-opaque, MR-compatible markers, allowing precise calculation of their position in segmental reference frames.

For the right lower limb of each subject three musculoskeletal models were defined: (1) a MRMo, defined using a custom built workflow [2], (2) a RGMo based on [3] and rescaled using the marker positions of the standing trial in SIMM (Motion Analysis Corp), (3) a DGMo, created by adapting the FA, NSA and neck length using SIMM's Deform Tool (Motion Analysis Corporation, USA) on the proximal femur of the RGMo.

All models were imported in SIMM to calculate inverse gait kinematics. Inter-model differences in hip and knee kinematics were calculated and referenced to MRMo. Next, hip MALs were calculated for every hip muscle's primary function using MRMo, RGMo and DGMo and their associated joint kinematics. Signed inter-model differences between MRMo and RGMo and between MRMo and DGMo were calculated for each instant of the gait cycle and expressed as a percentage of the value of the MAL, as calculated by the MRMo.

RESULTS AND DISCUSSION

When gait kinematics of the generic models are compared to MRMo, errors in the estimation of joint centers as well as differences in the relative position of the reflective markers in their segmental reference frames introduced an increase of $9.0 \pm 5.1^\circ$ of hip flexion, $2.9 \pm 4.1^\circ$ of hip abduction, $9.2 \pm 3.2^\circ$ of hip exorotation and $10.0 \pm 1.8^\circ$ of knee flexion. Except for hip adduction, these differences are maximal at pre-swing.

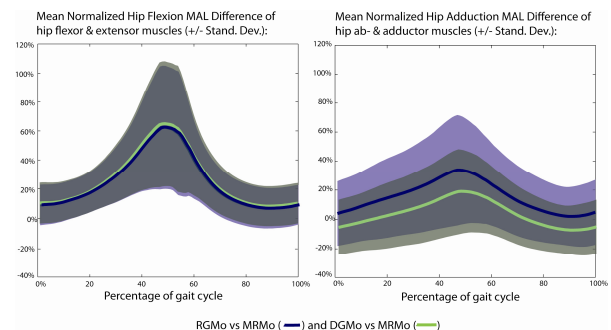


Figure 1: Mean (\pm standard deviation) inter-model differences in hip MAL as a function of the gait cycle.

RGMo and DGMo overestimated the hip flexion and extension MAL of MRMo by $25.4 \pm 35.9\%$ and $27.3 \pm 35.8\%$ respectively. Since the additional deformations in DGMo only further increased the hip extension MAL of gluteus maximus, the overall effect on calculated hip flexion and extension MAL is very small (Figure 1). RGMo and DGMo overestimate hip ad- and abduction MAL by $15.5 \pm 43.7\%$ and $4.1 \pm 33.2\%$ respectively (Figure 1). The additional deformations in DGMo caused a decrease in hip abduction MAL of all hip abductors, resulting in less overestimation. For hip adductors the effects of the deformations were less pronounced. In general, MAL differences between MRMo and RGMo corresponded with previous findings [2]. Their maxima coincide with the maxima of the differences in joint kinematics at pre-swing. (Figure 1)

CONCLUSION

Rescaled generic models and deformed generic models fail to accurately estimate moment arm lengths and joint kinematics in the presence of increased femoral anteversion.

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REFERENCES

1. Arnold AS, et al. *Ann. Biomed. Eng.* **29**:1-11, 2001.
2. Scheys L, et al., *Gait & Posture.* **28**:358-365, 2008.
3. Delp SL, et al. *IEEE Trans. Med. Imaging.* **37**:757-767, 1990