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Level of subject-specific detail in musculoskeletal models affects hip moment arm length calculation during gait in pediatric subjects with increased femoral anteversion

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ABSTRACT

Biomechanical parameters of gait such as muscle's moment arm length (MAL) and muscle-tendon length are known to be sensitive to anatomical variability. Nevertheless, most studies rely on rescaled generic models (RGMo) constructed from averaged data of cadaveric measurements in a healthy adult population. As an alternative, deformable generic models (DGMo) have been proposed. These models integrate a higher level of subject-specific detail by applying characteristic deformations to the musculoskeletal geometry. In contrast, musculoskeletal models based on magnetic resonance (MR) images (MRMo) reflect the involved subject's characteristics in every level of the model.

This study investigated the effect of the varying levels of subject-specific detail in these three model types on the calculated hip MAL during gait in a pediatric population of seven cerebral palsy subjects presenting aberrant femoral geometry.

Our results show large percentage differences in calculated MAL between RGMo and MRMo. Furthermore, the use of DGMo did not uniformly reduce inter-model differences in calculated MAL. The magnitude of these percentage differences stresses the need to take these effects into account when selecting the level of subject-specific detail one wants to integrate in musculoskeletal. Furthermore, the variability of these differences between subjects and between muscles makes it very difficult to a priori estimate their importance for a biomechanical analysis of a certain muscle in a given subject.

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1. Introduction

Today, treatment of gait disorders often relies on 3D gait analysis results and clinical examination (Gage, 2009; Narayanan, 2007; Simon, 2004). Recent research shows that parameters derived from musculoskeletal models (e.g. force generating capacity, muscle moment arm lengths (MAL) and muscle-tendon lengths (MTL)) have a unique potential to predict treatment outcome (Brand and Pedersen, 1984; Delp et al., 1994a, 1994b; Schmidt et al., 1999).

These biomechanical parameters are known to be very sensitive to inter-individual variations in musculoskeletal geometry due to differences in age, height, weight, sex and more important pathology (Delp et al., 1996; Duda et al., 1996; Schutte et al., 1997). Nevertheless, most studies rely on rescaling of generic musculoskeletal models constructed from averaged data of cadaveric measurements in a healthy adult population. This inherently limits an easy transfer of the results to predict patient-specific treatment outcome (Blemker et al., 2007). Previous research already indicated that musculoskeletal deformities with associated variations in size and age dramatically affect the calculated hip MAL when using rescaled generic models (Scheys et al., 2008a). Furthermore, the impact during gait is yet unknown.

Deformable generic models allow adapting specific features of the musculoskeletal model to subject-specific characteristics (Blemker et al., 2007). Schutte et al. (1997) modified Delp's model to accommodate the femur bone and hip muscle paths for excessive femoral anteversion angles (FA) (Beals, 1969; Bleck, 1987; Fabeck et al., 2002). Arnold et al. (2001) further extended this model to accommodate for the neck-shaft angle (NSA) and the lesser trochanter torsion angle. They showed, based on data of four subjects with cerebral palsy (CP), how these models, combined with simple normalization techniques, can provide accurate estimates of the muscle-tendon lengths of the semimembranosus, semitendinosus and psoas muscle in these subjects.

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