Femoral deformities affect gait performance more than hip muscle weakness

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Introduction

In children with Cerebral Palsy (CP) bony deformities, specifically increased femoral anteversion (FA) and neck shaft angle (NSA), in combination with weak hip muscles are very common [1]. Currently, the relative impact of bony deformities and muscle weakness on gait performance is unknown.

Research Question

The goal of this study was to determine the effect of aberrant bony deformities, i.e. increased FA and NSA, and muscle weakness on the ability to achieve normal gait kinetics.

Methods

Four hundred models were created with varying FA, NSA and muscle weakness, for one healthy child (9 years), based on marker trajectories (Vicon, Oxford Metrics, UK) and ground reaction forces (AMTI, Watertown, MA) measured during gait and starting from a scaled generic musculoskeletal model (SIMM, Motion Analysis Corp., Santa Rosa, CA). In each of the models, the FA and NSA were increased, in steps of 10° from 20° to 60° and from 120° to 160°, respectively. In all created models, the maximal isometric muscle force of the rectus femoris, gluteus maximus, gluteus medius, psoas or biceps femoris was decreased by 0% to 75% in steps of 25%. A reference gait pattern was calculated for the original scaled model based on the measured marker trajectories in Opensim 3.3, which was imposed to all models. Next, muscle forces were calculated using static optimization. If muscle forces were unable to restore the moment balance, reserve actuators were activated. These indicate the capability gap, i.e. the gap between the required hip joint torques for normal gait and the maximal joint torque the muscles could produce. A regression analysis related the FA, NSA and hip muscle weakness to the maximal absolute capability gap for the hip.

Results

Figure 1. Regression analysis of the frontal plane capability gap and A) the femoral anteversion (FA), B) neck shaft angle (NSA) and C) muscle strength. In all subplots the maximal absolute capability gap for all 400 simulations is presented. The yellow line shows the overall trend of altering the FA (A), NSA (B) and muscle strength (C).

The capability gap was largest in the frontal plane, however trends were similar in the sagittal and transversal planes. Increasing the FA and NSA increases the capability gap (figure 1A and 1B). When FA was larger than 40° the capability gap was persistent, irrespective of the NSA and muscle weakness (figure 1A). Similarly, when NSA was larger than 150° the capability gap was persistent, irrespective of the FA and muscle weakness (figure 1B). Decreased muscle strength only slightly increased the capability gap (figure 1C).

Discussion

When large bony deformities were presented, i.e. FA>40° or NSA>150°, a normal gait pattern could no longer be performed. Muscle weakness only had a limited effect. When decreasing the muscle force to 25% of the normal strength, the subject was still able to perform a normal gait pattern when no or small bony deformities (FA<40° or NSA<150°) were presented. This indicated that the correction of bony deformities has a larger effect on the ability of CP children to perform a normal gait pattern than increasing muscle strength.

References

- [1] G. Chan, F. Miller, Assessment and treatment of children with cerebral palsy, *Orthop. Clin. North Am.* 45 (2014) 313–325, <https://doi.org/10.1016/j.ocl.2014.03.003>.