

BIOMECHANICAL ANALYSIS OF LOWER LIMBS FOR CHILDREN WITH CEREBRAL PALSY: GAIT ANALYSIS AND MUSCULO-SKELETAL MODELING

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INTRODUCTION

Pathology of Cerebral Palsy (CP) results in abnormalities of muscle strength and tone (spasticity), and joint movement. Disorders of movement tend to progress with age. Spasticity causes not only contractures but also torsional deformities. Orthopaedic clinical decision-making for children with CP should be based on a global approach regrouping information on gait patterns, skeletal malalignment and muscle-tendon unit deformities. The aim of this study is to assess this information by using gait analysis and specific patient 3D lower limbs reconstruction of bones and muscles.

METHODS

Gait analysis databases, using Plug in Gait® protocol, were collected for 56 healthy children and 45 patients with CP, between 5 and 15 years old (Vicon® devices, with dynamic EMG). 17 healthy subjects performed the exam twice for repeatability study [1]. Parents signed an informed consent prior to the study.

Frontal and lateral X-Rays in standing position using the EOS® low dose biplanar X-Rays system (Biospace Med) of 12 children (6 CP and 6 non CP), between 5 and 15 years, were obtained [2]. Individual 3D reconstructions of lower limbs were realized by selecting points and contours on both X-Rays. Clinical axes and angles were computed on these reconstructions. Matching 3D subject specific bones in gait analysis frames was proposed.

MRI acquisitions were done for 3 healthy children (9, 11 and 14 years old) and 1 CP patient (diplegic, 8 years old). Horizontal slices in T1 were provided from iliac spine to foot. A specific technique [3] was used to obtain specific subject 3D reconstructions in lying position of 19 muscles at left and right lower limbs by selecting contours on few slices. Volumes, Physiological Cross Sectional Areas (PCSA) and Lengths of muscles were calculated. 3D muscle reconstructions in standing position were provided, by applying non linear deformation on 3D muscles in lying position, based on skeletal architecture. Muscle-tendon length ratio was then calculated based on specific subject muscles insertion areas on skeletal segments.

RESULTS AND DISCUSSION

An asymptomatic database for gait parameters was established to allow gait analysis data interpretations of patients with CP. Uncertainties on gait parameters were quantified. Specific subject 3D reconstructions of skeletal lower limbs in standing position were done. Skeletal malalignment was quantified by calculating clinical parameters. Uncertainties were less than 5° for most of them except for tibial torsion. Specific subject lower limbs were matched with gait analysis frames allowing display of bone

movement during walking. Hip center calculated by the gait protocol was behind the femoral head center in static and dynamic trials (3,7cm). Specific subject 3D reconstructions of 19 muscles were obtained for each lower limb side. Volumes, PCSA and lengths were calculated. Losses of muscle volumes were found and evaluated for the CP patient as compared to healthy subjects. Muscles were reconstructed in standing position. Muscle-tendon length ratios were lower for the CP patient as compared to the healthy children

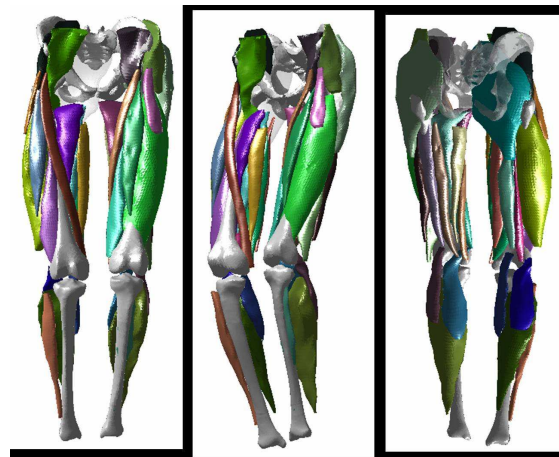


Figure 1: Specific subject 3D musculo-skeletal reconstruction for a CP patient (8 years old).

CONCLUSIONS

Uncertainty on gait parameters was quantified and could therefore be taken into account when comparing a patient's gait pattern to a normal one, or between pre and post treatment. Feasibility of skeletal malalignment and muscular deformities quantification was assessed in 3D and in standing position. The subject specific 3D approach, combining gait analysis and musculo-skeletal reconstructions, provided more accurate data for clinicians and thus could allow a better treatment decision making. These techniques could be integrated together in the future to obtain subject specific dynamic model for various clinical applications.

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