Femoral growth plate stresses in children with cerebral palsy compared to typically developing children

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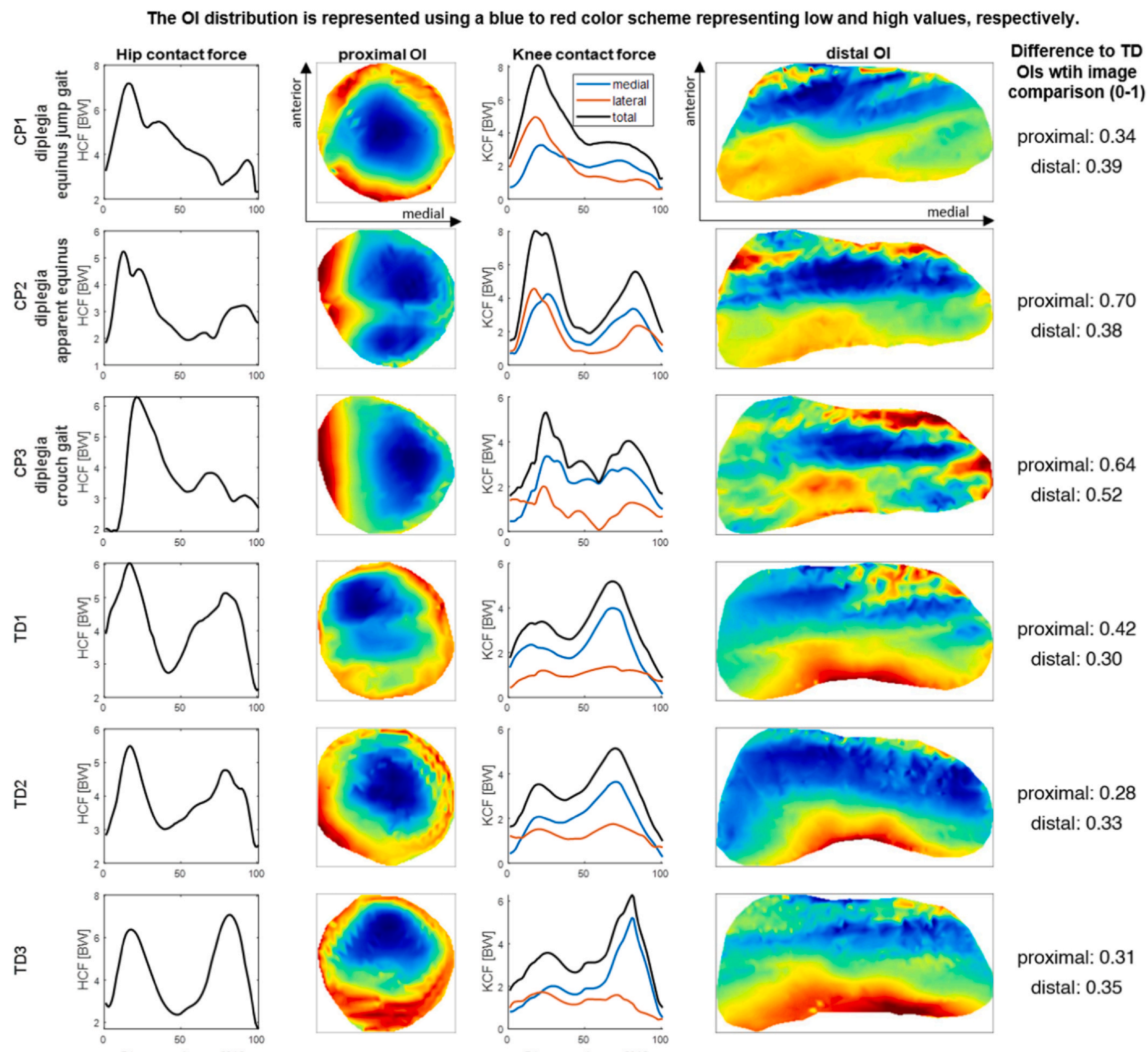
Introduction: Bone growth is partially determined by the mechanical loading of the growth plate. A multi-scale workflow based on gait analysis data, musculoskeletal simulations and mechanobiological finite element (FE) analysis can be used to estimate growth plate loading [1,2]. Previous studies showed severe differences in stress distribution at the proximal growth plate of the femur between individuals with cerebral palsy (CP) compared to typically developing (TD) children [3–5]. Distal epiphysis stresses at the femur have not yet been evaluated in CP children. Imbalanced growth due to pathological stresses could lead to varus/valgus malalignment.

Research question: Do growth plate stresses differ between CP and TD participants?

Methods: Magnetic resonance images (MRI) and gait analysis data of 3 TD and 3 CP children was analyzed. Muscle and knee contact forces were estimated with musculoskeletal simulations based on subject-specific MRI-informed models [6]. A semi-automated workflow was modified to create subject-specific FE models for the distal growth plate including femoral geometry based on MRI



segmentation and loading from musculoskeletal simulations [3]. The growth rate due to mechanical loading was estimated as the osteogenic index (OI) based on the obtained principal stresses from the FE analysis. A color scheme was used to visualize OI. Template matching [3] was performed to quantify variability within groups and the difference of each OI to those of the TD group.

Results: Gait patterns of CP participants resulted in higher maximum knee joint contact forces compared to the TD group with normal gait pattern. Shape and distribution of the OI in the growth plates within the TD group was homogeneous. In the participant with equinus jump gait (CP1) the shape and distribution were similar compared to the TD group in the proximal and distal growth plate. Despite large deviation of the proximal OI the distal OI varied only slightly in the participant with apparent equinus gait (CP2). Crouch gait (CP3) led to the highest differences of the distal OI compared to the TD group (Fig. 1).

Fig. 1: Hip and knee contact force as well as the proximal and distal OI distribution and its mean difference (0 = ident, 1 = no similarity) compared to those of the TD group.

Discussion: The variability of OI shape and distribution in the distal growth plate is lower compared to the proximal growth plate in both groups. Therefore, proximal growth analysis might be more important to predict the development of femoral deformities, e.g. increased anteversion angle, at an early stage. However, severe gait pathologies, i.e. crouch gait, can additionally result in abnormal OI distribution at the distal growth plate which might lead to the development of knee malalignments. The study highlights the importance of assessing growth plate loading in children with CP to aid the development of targeted interventions.

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