Pediatric sagittal imbalance contributes to proximal femoral physis mechanical shear in slipped capital femoral epiphysis

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INTRODUCTION: Slipped capital femoral epiphysis (SCFE) is a multifactorial pathology of the hip which most commonly affects children between the ages of 8 and 15. The incidence of SCFE has been estimated to be between 0.33/100,000 and 24.58/100,000 [1]. Given the highly acute nature of SCFE, it is essential to study risk factors to identify high-risk patients and initiate prophylactic measures to mitigate slippage at the proximal femoral physis. Many risk factors are known to contribute to SCFE such as obesity, endocrinopathies, and acetabular version. Sagittal balance refers to the physiologic alignment of the spine which maximizes kinetic efficiency and minimizes mechanical stress and consists of four parameters that constitute it's makeup; pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS) and lumbar lordosis (LL) [2, 3]. Recently, the role of pelvic incidence (PI) has been suggested to contribute to shear stresses on the pediatric growth plate which lead to slippage in SCFE [4, 5]. To elucidate this phenomenon, the authors in the current study employed the use of the finite element (FE) method and created semi-patient specific pediatric models to simulate the effects of imbalanced spinopelvic parameters on the proximal femoral physis. We hypothesize that severely imbalanced pediatric spinopelvic complexes contribute to shear stress on the pediatric growth plate which may suggest a higher likelihood of slippage in these patients.

METHODS: A non-linear ligamentous, validated finite element (FE) model was developed from computed tomographic (CT) scans of a healthy lumbar spine, pelvis, and femurs with no abnormalities, deformities, or severe degeneration. Pediatric models were created by utilizing a scaling factor on the original model, modelling an idealized growth plate on the femurs, and applying rotational boundary conditions to create various sagittal alignments (Figure 1) (Table 1). Various activities were simulated such as two leg stance (2LS), one leg stance (1LS), walking heal strike (WHS), ascending stairs heal strike (AHS), and descending stairs heal strike (DHS). Maximum Tresca (shear) stresses on the growth plate were recorded for each alignment and activity.

RESULTS SECTION: The 2LS simulation reported decreases in the high PT (posterior tilted pelvi) variants compared to low PT (anterior tilted pelvi), however a combination of high PI and high PT indicated larger Tresca stresses on the growth plate. 1LS indicated higher Tresca stresses on the growth plate in high PT variants compared to lower PT, with a combination of high PT and high PI resulting in the largest value. The heal strike simulations reported the largest Tresca stresses on the growth plate with AHS resulting in the largest values overall. Overall, high PT cases indicated larger stresses compared to the low PT variants except in 2LS. A combination of high PT and high PI resulted in the largest Tresca stress on the growth plate for each simulated case (Figure 2).

DISCUSSION: Results in the current study are the first to quantify a relationship between spinopelvic parameters and their contribution to shear stresses on the pediatric growth plate, especially in pediatric cases with high pelvic incidence and posterior pelvic tilt. The study indicated that pediatric patients with posterior tilted pelvi in any pelvic incidence may experience higher shear stress on the growth plate. Additionally, patients with a combination of high pelvic incidence and tilt may be more prone to slip due to the higher shear stress values. Various activities such as walking, ascending and descending stairs and even sports activities that cause large biomechanical loads at the hip joint suggest contribution to shear stresses on the growth plate compared to more static activities such as one and two leg stances. Future studies will employ large patient cohorts to determine if patients with SCFE exhibit imbalanced spinopelvic parameters.

CLINICAL RELEVANCE: Results found in this study allow clinicians to understand the hip-spine relationship in the pediatric population and to consider spinopelvic sagittal imbalance as a potential risk factor in SCFE etiology.

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IMAGES AND TABLES:

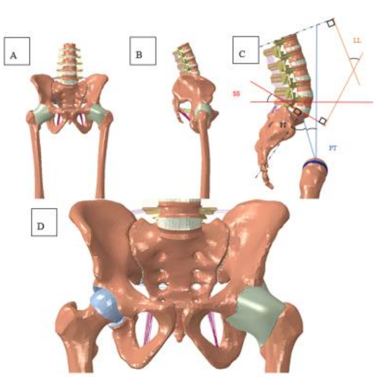

Figure 1: Pediatric finite element model

Model	Sacral Slope (SS°)	Pelvic Tilt (PT°)	Lumbar Lordosis (LL°)
PI 36° Low PT	26.7	9.5	41
PI 36° High PT	16.7	19.5	41
PI 41° Low PT	31.7	9.8	46
PI 41° High PT	21.7	19.8	46
PI 46° Low PT	36.7	10	51
PI 46° High PT	26.7	20	51
PI 52° Low PT	41.7	10.4	56
PI 52° High PT	31.7	20.4	56

Table 1: Spinopelvic parameters of FE model

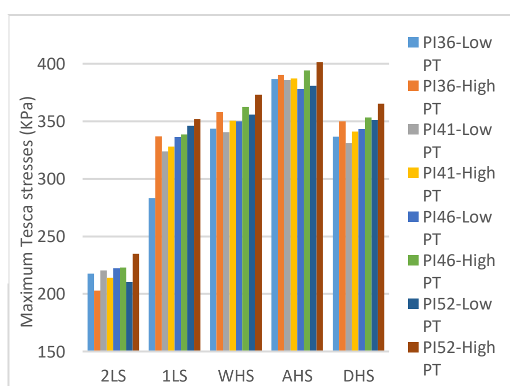

Figure 2: Maximum Tresca stresses on the growth plate