

Epiphyseal Tubercle Morphology is Similar in SCFE and cam-type FAI: Evidence for a Shared Morphological Precursor?

David S Liu, Mahdi Aghaalkhani, Shanika De Silva, Yi-Meng Yen, Young-Jo Kim, Mohammedreza Movahhedi, Ata M Kiapour
 Department of Orthopedics and Sports Medicine, Boston Children's Hospital, Harvard Medical School, Boston, MA
David.Liu2@childrens.harvard.edu

DISCLOSURE: Y.J. Kim: 4; Cytex, Imagen. 3C; Orthopediatrics. 8; Journal of Hip Preservation Surgery, Orthopedics Review, Osteoarthritis and Cartilage. M. Movahhedi: 4; BonePixel. A.M. Kiapour: 3B; MIACH Orthopaedics, 4; BonePixel, 8; BMC Musculoskeletal Disorders and American Journal of Sports Medicine. All other authors: None.

INTRODUCTION: Cam-type femoroacetabular impingement (FAI) and slipped capital femoral epiphysis (SCFE) both exhibit alteration in proximal femoral epiphysis-metaphysis morphology. Prior reports independently associate cam deformity and SCFE to smaller epiphyseal tubercles, yet a comparison of epiphyseal tubercle morphology between cam FAI and SCFE has not been reported. While some theories exist to suggest a relationship between the epiphyseal cupping seen in cam FAI and SCFE, no direct link between the two conditions have been established. We hypothesized that epiphyseal tubercle morphology in SCFE and cam FAI is similar, with both pathologically smaller than epiphyseal tubercles in normal hips.

METHODS: Following IRB approval, a retrospective analysis was performed on 54 patients with cam-type FAI and 56 patients with SCFE. 80 asymptomatic hips without radiographic pathology served as controls. CT scans that included the pelvis and femur were obtained for each patient. A custom-developed and validated program (VirtualHip, Boston Children's Hospital) was used to automatically segment bones, identify landmarks, define anatomical coordinate system based on ISB recommendations, and then measure anatomical features of the hip joint. Primary epiphyseal outcomes were tubercle height, tubercle width, and tubercle length. For each continuous outcome, we fit an ANCOVA (ordinary least squares) with Group (Control, FAI, SCFE) as the categorical factor, and age and sex as covariates. From each model, pairwise comparisons were evaluated using Dunn tests, with significance levels corrected for multiple testing using the Bonferroni-Holm procedure.

RESULTS: After adjusting for age and sex, both SCFE and cam-type FAI groups differed from controls for epiphyseal tubercle height and length, whereas no difference was found in tubercle width among the three groups. Tubercle height and width were similar between SCFE and cam-type FAI (Figure 1). For tubercle height, adjusted contrasts showed smaller values in FAI and SCFE versus controls (FAI-control -4.21, 95% CI -6.39 -- -2.02, $p < 0.001$; SCFE-control -3.69, 95% CI -5.46 -- -1.93, $p < 0.001$). Tubercle length was likewise reduced in both pathology groups relative to controls (FAI-control -20.35, 95% CI -24.19 -- -16.52, $p < 0.001$; SCFE-control -13.39, 95% CI -16.49 -- -10.29, $p < 0.001$). Tubercle width did not differ significantly. Adjusted mean differences in epiphyseal height and width were not significantly different between FAI and SCFE (Figure 2).

DISCUSSION: Epiphyseal tubercle morphology (height and length) is similarly reduced in SCFE and cam-type FAI relative to normal hips, supporting the theory of a shared epiphyseal morphologic substrate. The diminutive nature of the epiphyseal tubercle in both conditions may predispose the hip to increased physical stress and micro-instability. A delicate balance between biomechanical loading and peri-physeal remodeling may bias towards slip (SCFE) when remodeling is insufficient, or toward cam morphology when remodeling counters load without slip. Further studies are necessary to better understand the developmental etiologies of SCFE and cam-type FAI.

SIGNIFICANCE/CLINICALRELEVANCE: Our data supports a common epiphyseal morphology in SCFE and cam-type FAI, which may help elucidate the etiologies of these conditions and motivate longitudinal studies in at-risk adolescents.

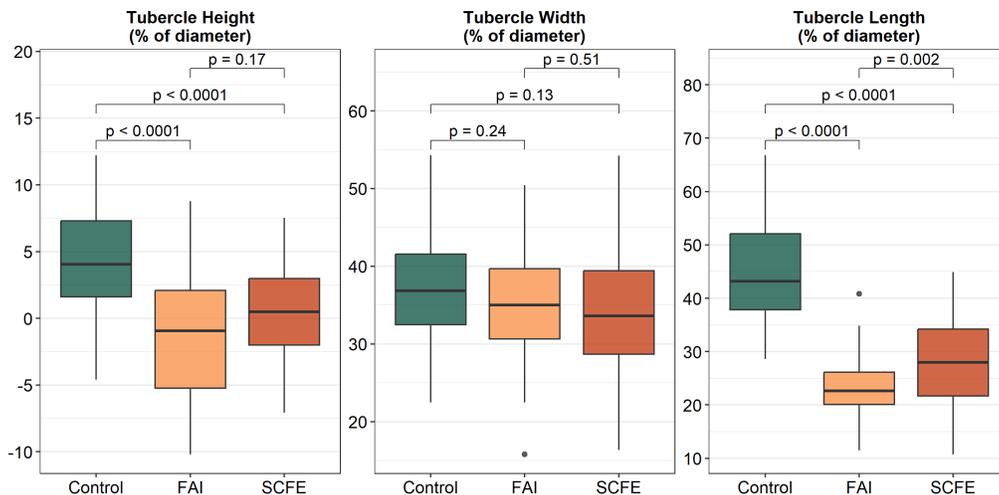


Figure 1: Distribution of epiphyseal tubercle morphologic features stratified by condition.

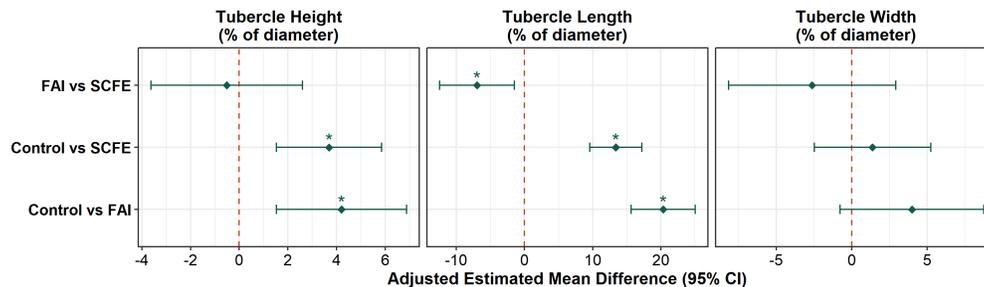


Figure 2: Adjusted mean differences (95% CI) in epiphyseal tubercle dimensions across conditions from multivariable linear regression models adjusting for age, sex, and BMI percentile. Asterisks indicate statistically significant pairwise differences after Bonferroni-Holm correction.