

Impacts of Patient-specific Orientation on Cam-type Impingement: A Computational Study

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INTRODUCTION: Cam-type femoroacetabular impingement syndrome (FAIS) is associated with abnormal osseous morphology on the superior-to-anterior area of the femoral neck which impinges with the labrum, acetabular rim and articular cartilage at varying degrees of motion of the hip joint. The relative orientation of the femur and acetabulum varies between patients with FAIS, and the level of impingement that can be associated with that joint orientation remains unclear. The aim of this work was to assess the effects of patient-specific relative hip orientation on predicted impingement.

METHODS: Five patients (P1-P5) previously diagnosed with cam-type FAIS were chosen for this study. These included 1 male and 4 females, age range 18-38 years. The sex imbalance is due to limited availability of patient cases with all necessary imaging. This study was approved by an ethics committee. The femoral neck shape was extracted from CT data, by categorizing the cam into five cam heights^[2] (+0.35 mm, +1 mm, +2 mm, +3 mm, +4 mm, Figure 1a). Acetabular coverage was also captured. Six joint orientation measures for each patient were extracted from the CT data: acetabular inclination, acetabular version, acetabular tilt, femoral version, femoral neck-shaft angle and tibiofemoral angle (Figure 1b). Pelvic tilt could not be assessed from supine CT scans; a **population average pelvic tilt** was used. To assess impingement, the HipMoSh^[1] model was used, which combined hip shape and orientation measures and applied a set of 126 motions (14 activities by 9 individuals, Figure 2a). Occurrence of interference between the femoral cam and the acetabular rim was recorded, along with the depth of impingement. For each patient, the model was run twice; once with the relative femur and acetabulum positioned using population **average orientation** and **average pelvic tilt** (AOAT) and once using the **patient-specific orientation** data (collected from the CT data) and **average pelvic tilt** (SOAT). Patients were assessed for the predicted occurrence of impingement out of a possible 630 motions (126 motions described previously, for each cam height). Predicted impingement depth (in degrees) and clock-face location within the acetabulum were visualized for each of the patients for each orientation case (Figure 2b).

RESULTS: Predicted impingement depth and location differed in all patients between the population average and patient-specific orientation cases (one example in Figure 2b). In 2/5 patients the location of impingement was different; one patient had predominantly posterior impingement with population average orientation and predominantly anterior impingement with patient-specific orientation (P1). With population average orientation the hips with smaller cams all increased in impingement occurrence when changing to patient-specific orientation (P1, P2 and P5, Figure 2b).

DISCUSSION: The use of patient-specific hip orientation generated substantially different predicted impingement occurrence and location when compared predictions using a population average orientation. Smaller cams (P1, P2 and P5) had the largest change in predicted impingement occurrence and had a higher risk of impinging when changing from population average orientation to patient-specific orientation.

SIGNIFICANCE/CLINICAL RELEVANCE: Efforts to improve cam-type FAIS patient outcomes require an improved understanding of the interplay of joint shape and orientation. The ability to assess the impact of patient-specific orientation on predicted impingement, through systems such as the HipMoSh model, could improve diagnostic and treatment pathways.

REFERENCES: [1] Jones. J Clin Orthop Relat Res. 2023. [2] Rayment. J Biomed Eng Adv. 2024.

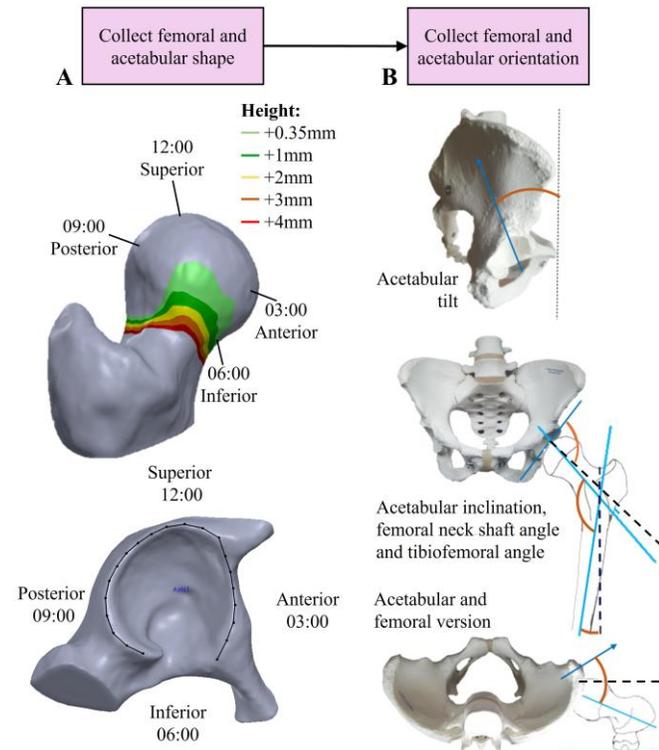


Figure 1. Methods workflow detailing shape (a) and orientation (b) collection.

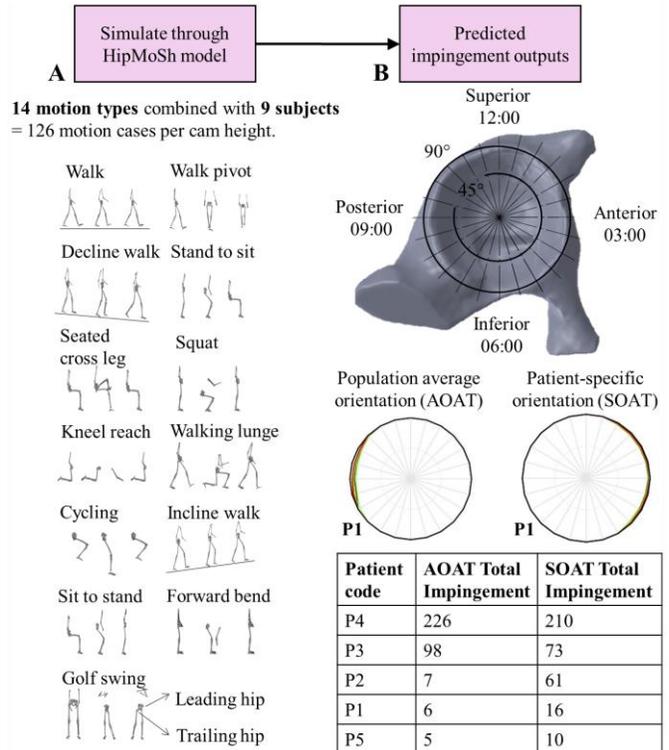


Figure 2. Activities for simulation (a), and acetabular impingement depth and location plots and total impingement metrics (b).