Changes in Acetabular Coverage between Standing vs. Supine Positions: An Exploratory 3D Simulation

Joshua Wright-Chisem[1], Jordan H. Larson[1,2], Omair Kazi[1], Kyleen Jan[1], Philip Malloy[1,3], Joel Williams[1], Shane J. Nho[1] Alejandro A. Espinoza Orías[1]
[1]Dept. of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, [2]Rosalind Franklin University School of Medicine, North Chicago, IL,
[3]Arcadia University, Glenside, PA
Email of Presenting Author: *Alejandro_Espinoza@rush.edu*

Disclosures: Joshua Wright-Chisem (N), Jordan H Larson (N), Omair Kazi (N), Kyleen Jan (N), Philip Malloy (N), Joel Williams (N), Shane J. Nho (Allosource, Am J Orthop, AOSSM, Arthrex, Inc, AANA, Athletico, DJ Orthopaedics, Linvatec, Miomed, Ossur, Smith & Nephew, Springer, Stryker), Alejandro A. Espinoza Orías (NIH, Stryker, PLoS One)

INTRODUCTION: Variations in acetabular coverage of the femoral head may lead to impingement, labral tears, and early development of osteoarthritis. For many years, acetabular morphology has commonly been assessed using two-dimensional (2D) radiographs. However, these images provide a limited view and are subject to variation based on pelvic tilt and malrotation. The use of three-dimensional (3D) models for determining acetabular coverage can mitigate these concerns due to the ability to standardize pelvic orientation. However, a majority of imaging studies, notwithstanding the modality, acquire the image with the patient in supine position. If hip pain is suspected in standing position, the resulting images will not provide an interpretation that is representative of the pathology to the clinician. Therefore, the purpose of this pilot study was to 1) provide proof-of-concept of a novel methodology to simulate the standing position using a 3D model derived from supine images and 2) demonstrate the changes in acetabular coverage with alterations to pelvic tilt that occur when going form supine to standing.

METHODS: A retrospective review from an IRB-approved, prospectively maintained repository consisting of patients who underwent hip arthroscopy from a large orthopedic practice between August 2017 to October 2021 was performed. For this pilot study, six patients (4F/2M, age range 19-34, mean 29.7 y.o.) were included since they had a preoperative computerized tomography (CT) scan available for review. Three-dimensional (3D) osseous models were constructed from CT scans (Materialise Mimics, v. 24, Leuven, Belgium). Acetabular coverage was determined by superimposing the acetabular rim onto the superior surface of the femoral head as we have demonstrated before [1]. 3D models of the femur, pelvis, and sacrum were oriented to neutral by aligning the anterior superior iliac spine (ASIS) on both sides to a normal vertical axis (Materialise 3-matic 17.0. Leuven, Belgium). The procedure to orient to standing position is outlined in **Figure 1** and is performed as follows: The distance from the pubic symphysis to sacrococcygeal joint (PS-SC) on standing 2D radiographs was measured to determine pelvic tilt. The 3D pelvis was rotated to match PS-SC distance as determined on the 2D radiograph to simulate pelvic tilt on the model. The posterior aspects of the bilateral condyles are aligned to a horizontal axis that crosses through the center of the femoral head. Then, the bilateral ASISs were oriented to be in the same plane. Measures of acetabular coverage, pelvic inclination, and degrees of pelvic tilt were measured on neutral, supine, and standing positions for 6 available 3D models. Data is presented as mean±SD. Paired t-tests were conducted to evaluate the comparisons, with $p < 0.05$ deeming significance.

RESULTS: Changes to pelvic tilt and acetabular coverage are illustrated in **Figure 2**. For supine vs standing, respectively, pelvic inclination (60.2° ± 8.2°, 62.9° ± 7.8°, p = 0.572) and tilt (13.7° ± 3.9°, 15.5° ± 10.1°, p = 0.692) increased slightly when standing. Acetabular coverage (%) either did not change or slightly increased when going from supine vs standing orientation across coverage measurements: Global: 62.4 ± 2.1 vs. 62.5 ± 2.6, p = 0.943; Anterior: 53.5 ± 3.5 vs. 53.7 ± 1.9, p = 0.905; Posterior: 71.5 ± 2.1 vs. 71.6 ± 4.9, p = 0.964; Anteromedial: 81.7 ± 4.1 vs. 82.0 ± 2.1, p = 0.876; Anterolateral: 15.3 ± 3.1 vs. 15.6 ± 4.5, p = 0.896; Posteromedial: 100.0 ± 0.0 vs. 100.0 ± 0.0, p = 1.000; Posterolateral: 30.9 ± 2.9, vs. 31.4 ± 8.0, p = 0.888, respectively. In summary, standing position is associated with a slight increase in anterior pelvic tilt, which resulted in only minor increases in acetabular coverage of the femoral head.

DISCUSSION: Virtually all CT and MRI scans are produced with patients in the supine position. Older, upright MRI scanners yield poor resolution data, and are not commonly used in musculoskeletal applications. While the resulting images and 3D models are useful, obtaining information on how the hip morphology changes when shifting to a weight-bearing position may be more applicable to the patient's pathology. Pelvic tilt is a critical factor that influences dynamic anteversion of the acetabulum, which is associated with motions such as sitting to standing [2]. In a previous study with plain radiographs, changes were shown between these positions together with decreases in pelvic tilt resulting in lower incidence and degree of crossover sign. However, that study did not evaluate 3D coverage due to the nature of the 2D images [3]. Our preliminary study demonstrates that when going from supine to standing, there is an increase in anterior tilt and only a slight increase in acetabular coverage of the femoral head. Future studies should explore the role of acetabular coverage on functional status and patient outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: Weight-bearing positions are better representations of real-world conditions and activities such as walking and standing that may aggravate symptoms due to increased joint contact. These observations on the changes that occur to joint morphology during weight-bearing can assist in more accurate diagnostics and a personalized approach in determining effective interventions.

REFERENCES: [1] Larson JH *et al*., Proceedings ORS Annual Meeting vol. 48:1580 [2] Ross JR, *et al*., Am J Sports Med. 2014 Oct;42(10):2402-9. [3] Jackson TJ, *et al*. Clin Orthop Relat Res. 2016 Jul;474(7):1692-6.

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IMAGES AND TABLES:

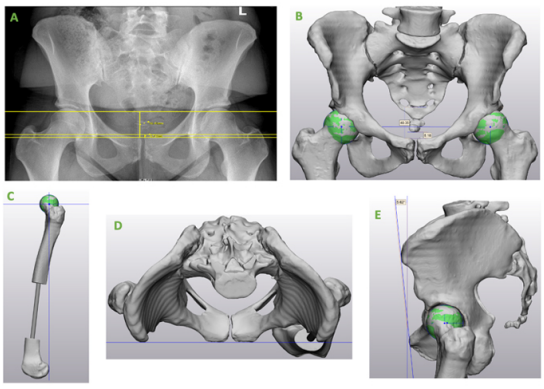

Figure 1: Establishing 3D standing orientation through A) PS-SC on 2D standing radiograph, B) Superimposing 2D standing PS-SC to 3D supine pelvis, C) Aligning the femur, D) Aligning the pelvis, E) Change in tilt with reorientation.

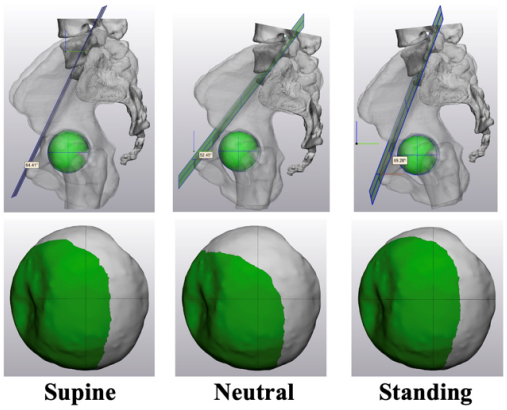

Figure 2: Visual illustration of pelvic orientation and acetabular coverage for supine, neutral, and standing positions.