Reproducibility of in vivo femoro-pelvic joint angle measurements upon repositioning assessed using open MRI imaging under weightbearing conditions with applications to femoroacetabular impingement

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Objective: Femoroacetabular impingement (FAI) is an abnormal bony contact between the femur and acetabulum caused by bony deformities on either the femoral head/neck junction or the acetabulum; this typically leads to pain, reduced range of motion, and soft tissue damage. FAI is an important predisposing factor for the development of hip osteoarthritis (OA) in young adults. Understanding the hip's kinematic function and the associated pathology of hard and soft tissues will assist orthopaedic surgeons in diagnosing and treating FAI. This paper presents a methodology for measuring the femoro-pelvic joint angle based on *in vivo* magnetic resonance imaging (MRI) images taken from healthy subjects under weight-bearing conditions. In this study, we assess the reproducibility of angle measurements acquired when the subject is asked to repeatedly assume a reference position and perform a voluntary movement.

Materials and Methods: We initially scanned a healthy subject in a lying position in a standard clinical 3T MRI scanner in order to obtain high resolution (HR) images of the femur and pelvis. We obtained three images: T1-weighted TSE sequence scans at the pelvis and knee in the transverse plane and a T1-weighted dual sense scan in the sagittal plane at the hip joint. We then scanned the same subject's femur and acetabulum in a weight-bearing configuration in a lower-field-strength open MRI machine (Paramed, 0.5T) to obtain related low resolution (LR) images. Four scan cycles were obtained with the subject being removed and reinserted between cycles in the Open MRI scanner. In each cycle, a block was inserted (up position) and removed (down position) under the subject's foot. Fig. 1a shows a model seated in the Open MRI scanner, Fig.1b shows the HR MRI image of the hip joint, Fig. 1c shows the LR MRI images of the hip joint in the sitting position, and Fig. 1d illustrates the relative femoroacetabular angle in the sagittal plane.

We built standard orthogonal coordinate systems for the pelvis and femur based on six anatomic landmarks identified from MRI images of the pelvis, hip, and knee in the supine position. A fixed hip joint centre of rotation was obtained as the spherically fitted centre of the femoral head.

The rotation angle and translation of the femur were measured relative to the fixed pelvic coordinate system. The femur and acetabulum bone models were manually segmented from the HR and LR hip joint imagesets, respectively, and the models from the LR (sitting) images were registered to the HR (supine) models using the 3D rigid registration method in the ITK toolbox (an intensity-based algorithm). The kinematic angles of the hip joint (flexion/adduction/internal rotation) were then computed.

Results: The femoroacetabular angles relative to the LR scanning plane for four cycles are shown in Fig 1e. The femoral angle relative to the scanner is quite repeatable (SD < 0.9° for all three angles and both up and down positions, not shown in plot), the pelvic angles are less so (SD ~2.6-4.3°). The hip flexion angle ranged from 23°-34° in the down and up positions, respectively, so the block induced a mean angle

change in the flexion direction of approximately 11°, which was more reproducible (SD = 1.7° in flexion/extension) than the pelvic repositioning.

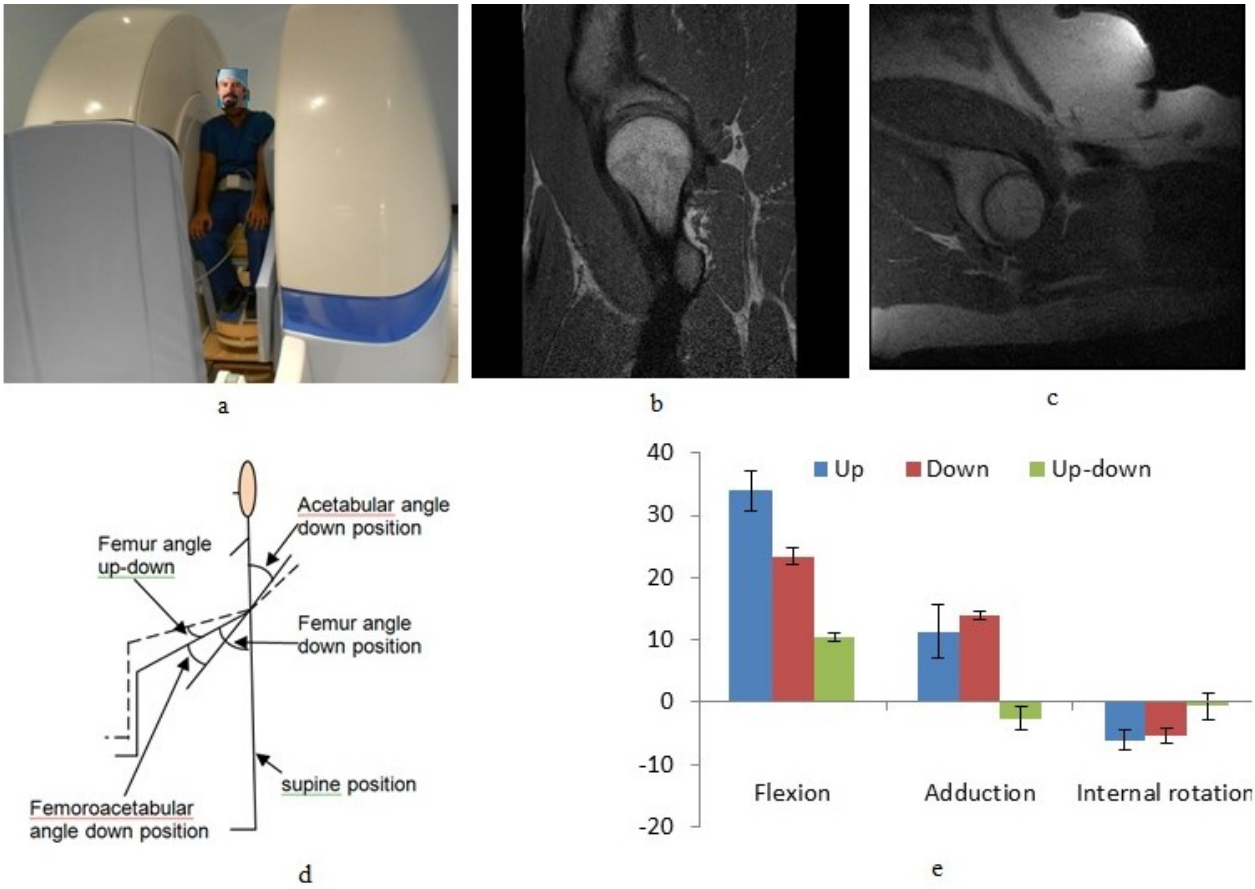

Fig. 1: (a) Open MRI configuration for sitting position; (b) high resolution and (c) low resolution MRI images of the hip joint; (d) the hip joint angle in the sitting position; (e) measurement of the relative femoroacetabular angles (degrees in flexion/adduction/internal rotation) between the up and down positions of the leg.

Conclusions: We found that the femoral position could be accurately re-acquired upon repositioning, while the pelvic position was notably more variable. Limb position changes induced by inserting a block under the subject's foot were consistent, with standard deviations in the relative attitude angles under 1.7°. Our results differed somewhat from those found by Yamamura et al. [1] in which the mean hip flexion in a kneeling position (approximating a seated posture at the hip, though obviously different at the knee) averaged about 55°, which was approximately 20-30° more flexed than what we found, though these differences could be attributed to differences in the overall sitting task. In particular, in our test, there was no direct support for the back, so the pelvis tends to lean backwards, which could explain the smaller flexion angles in this study. Overall, our measurement method produces plausible measures of both the femoroacetabular angles and the changes induced by the block, and the reproducibility of relative joint changes is good.

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References

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