# Evaluation of Synthetic Computed Topography Data as a Radiation-Reducing Approach for Hip Joint Reconstruction and Model-Based Markerless Tracking of Biplane Radiography Data

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INTRODUCTION**:** Model-based markerless tracking of biplanar radiography (BR) has been shown to be an accurate method to measure in vivo hip joint kinematics. A major limitation of this technique is that it requires a radiation exposing computed topography (CT) scan of the participant's pelvis and femur, to provide the basis to generate 3D models and digitally reconstructed radiographs (DRRs) that are required for tracking BR data. Elimination of the CT scan would substantially reduce the radiation exposure associated with BR imaging of the hip joint (by ~50% for our hip protocol, which assumes a total of 60 seconds of BR imaging time). Herein, we evaluated the use of a synthetic CT (sCT) scan generated from a magnetic resonance imaging (MRI) sequence and machine learning algorithm to generate the 3D reconstructions and DRRs necessary to track in vivo hip motion from BR data.

METHODS: Two asymptomatic participants were recruited under IRB approval. Each participant walked on an instrumented treadmill at their preferred speed while BR was acquired. Pelvis and knee CT scans were obtained, along with two MRI sequences, including a Dixon-like sequence to generate a sCT of the pelvis and proximal femur using a commercial machine learning algorithm (MRIguidance) and a generic Volumetric Interpolated Breath-hold Examination (VIBE) to visualize distal knee anatomy. The sCT and CT images of the pelvis and proximal femur, along with the VIBE images of the distal femur, were semi-automatically segmented with Corview and Amira. Surface reconstructions were registered, and the root mean squared (RMS) difference between surfaces were calculated. Motion of the proximal femur and pelvis were tracked using the CT and sCT data (MTWtesla), following previous methods [1]. The distal femur reconstruction was not tracked as it was not visible with our BR configuration; it was only used to define the femoral anatomical coordinate system. Hip kinematics were calculated from landmark locations with MATLAB, using landmarks/tracked solutions for (1) CT pelvis with CT femur, (2) sCT pelvis with sCT femur, (3) CT pelvis with sCT femur, and (4) sCT pelvis with CT femur. The kinematic curves and average maximum error were compared between conditions (2-4) and (1), the latter serving as the reference standard.

RESULTS SECTION: The average surface-to-surface RMS errors (**Table 1**) showed that sCT and the VIBE MRI were reconstructed within a millimeter of the CT surfaces. The distal femur reconstruction had the largest RMS error for both participants. Hip kinematics, including flexion, abduction, and external rotation angles agreed well with the CT-tracked solution (**Figure 1**). Still, max (average) error, for both participants, was 1.82(0.83), 0.89(0.31), and 1.95(0.76)°, respectively, exceeding the 0.6° rotational error previously observed for BR derived hip kinematics from CT [2]. However, evaluating error between conditions (1) and (4) yielded max (average) error of 0.58(0.23), 0.48(0.11), and 0.57(0.25)°, respectively.

DISCUSSION: Our results suggest that sCT can be used in lieu of traditional CT for model-based markerless tracking of BR images of the hip. Variability in the distal femur landmarks was likely the primary source of kinematic differences, as error between conditions (1) and (4) was within expected model-based markerless tracking error (0.6°), for each participant. The VIBE sequence was chosen to reconstruct the distal femur because a sCT is not yet available for the knee/distal femur. Future work will optimize an MRI sequence to image the bone of the distal femur to reduce errors.

| | Participant #1 | Participant #2 |
|---|---|---|
| Left Pelvis RMS (mm) | **0.2993** | **0.3811** |
| Right Pelvis RMS (mm) | **0.4440** | **0.4289** |
| Prox. Femur RMS (mm) | **0.3059** | **0.3726** |
| Distal Femur RMS (mm) | **0.6815** | **0.5359** |

***Table 1*** *Global RMS errors demonstrating the difference between CT- and MRI-based surface. The relative RMS stopping criteria was set to 1e-7 mm.*

SIGNIFICANCE: These findings demonstrate that a sCT can be used to generate the 3D anatomy reconstructions and DRRs needed for model-based markerless tracking of BR images. This approach substantially reduces radiation exposure associated with BR and could expand the use of BR to monitor musculoskeletal disorders and evaluate the effects of treatment longitudinally.

REFERENCES: [1] Atkins, P. *J Orthop Res,* 2020, 38(4): 823-833. [2] Kapron, A. *J Appl Biomech*, 2014, 30(3): 461-70.

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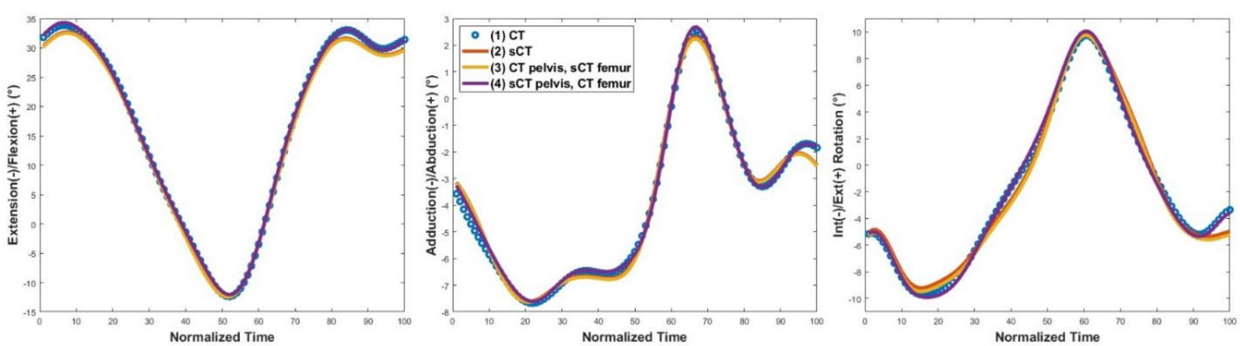


***Figure 1*** *Kinematic curves for Participant 1 across one normalized gait cycle. Max (average) error between (1) and (2) were 1.64 (0.682), 0.662 (0.186), and 1.61 (0.488)°, for flexion/extension, ab/adduction, and int/external rotation, respectively.*