Characterizing three dimensional alignment of the hip, knee, and ankle and foot under physiological upright load. A weightbearing computed topography study in arthritic joints and healthy controls

Grayson M. Talaski; Eli Schmidt, BS[1]; Andrew Behrens, BS[1]; Albert Anastasio, MD[2]; Don Anderson, PhD[1]; Jacob Elkins, MD, PhD[1], Kevin Wu, BS[2], Emily Luo, BS[2], Kepler Carvalho, MD[2], Cesar de Cesar Netto, MD, PhD[2]
[1]Department of Orthopedics and Rehabilitation, University of Iowa, Iowa City, Iowa, USA
[2]Department of Orthopedic Surgery, Duke University, Durham, North Carolina, USA
gtalaski@uiowa.edu

Disclosures: Grayson M. Talaski (N); Eli Schmidt (N); Andrew Behrens (N); Albert Anastasio (QPIX); Don Anderson (N); Jacob Elkins (Depuy); Kevin Wu (N); Emily Luo (N); Kepler Carvalho (N); Cesar de Cesar Netto (Paragon28, Curvebeam, Stryker, Zimmer Biomet)

INTRODUCTION: Lower limb alignment assessment is commonly performed using two-dimensional (2D) conventional- radiographs. However, this image modality does not account for three-dimensional factors such as rotation. Furthermore, the alignment with the respect to the weightbearing tripod of the foot is not capable, thus limiting proper pre-operative planning when using lower limb alignment to assess arthroplasty. Recently, Weight-Bearing Computed-Tomography (WBCT) has allowed for concomitant 3D imaging of the hip, knee, ankle, and foot, a more complete and multidimensional assessment of the entire overall lower limb alignment is now possible.
Foot and ankle offset (FAO), the relationship between the weightbearing tripod and the center of the ankle joint, has grown in popularity when assessing ankle and hindfoot conditions. However, the center of the hip and knee in relation to the foot tripod have yet to be described, particularly for conditions of the knee and hip. Therefore, the aims of this study were: (1) to characterize the normal relative 3D alignment of the center of the hip, knee, and ankle joints in relation to the weight bearing foot tripod in a cohort of healthy control volunteers with no lower extremity pathologies, (2) to perform the same 3D WBCT assessment in a cohort of patients with either hip osteoarthritis (HOA), knee osteoarthritis (KOA) or ankle osteoarthritis (AOA), and to compare the results between arthritic cases and controls.

METHODS: In this prospective comparative and controlled cohort-study, 7 HOA limbs (4 patients), 17 KOA limbs (10 patients), 7 AOA limbs (4 patients) and 10 control limbs (5 patients) received bilateral WBCT imaging of the full lower extremity. Using multiplanar reconstruction WBCT images, 3D landmark coordinates (on X, Y, and Z planes) were manually measured by two observers. The utilized software (CubeVue®) generated an automatic calculation of the Foot-Hip Offset (FHO), Foot-Knee Offset (FKO) and Foot and Ankle Offset (FAO). The relationship between the center of the hip, knee and ankle joints and the bisecting line of the foot tripod was assessed and compared between HOA, KOA, AOA patients and controls. Examples of measurements for arthritic patients and controls is presented in Figure 1. Continuous data was assessed for normality with the Shapiro-Wilk test, and variables were compared using ANOVA or Kruskal-Wallis Rank Sum. P-Values of less than 0.05 were considered significant.

RESULTS SECTION: The average FAO and 95%-Confidence-intervals-(CI) for HOA, KOA, AOA and controls were: 3.62% (0.4 to 6.8)(neutral), 2.8% (0.78 to 4.9)(neutral), -4.68% (-7.8 to -1.4)(varus), and 2.12% (-0.5 to 4.8)(neutral), respectively. The FAO-differences were found to be significant between the groups (p=0.0077), with AOA patients being significantly different than all the other groups (Figure 2). Similarly, the HFO was found to be significantly different-between the groups (p=0.002), with the following average values and 95%CI for respectively HOA, KOA, AOA and controls: 0.7% (-6.4 to 7.8), 2.3% (-2.3 to 6.8), -10.1% (-17.2 to -3.0), and 5.3% (-0.6 to 11.3). Again, the AOA patients were found to be significantly different than the other groups. No significant differences were found between the groups when assessing the KFO (p=0.37).

DISCUSSION: In this WBCT study, the baseline 3D lower limb alignment and relative position of the hip, knee, ankle and foot was assessed and established for the first time in the literature. When comparing 3D alignment in arthritic patients with hip, knee or ankle OA and controls, we observed that AOA was found to be the one affecting more the overall 3D alignment of the lower extremity, with no complete compensation of the deformity through the other joints, resulting in significantly different values of HFO, KFO and FAO in patients with ankle OA. Additional prospective studies with longer cohorts of patients are needed.

SIGNIFICANCE/CLINICAL RELEVANCE: This study is of great clinical interest as it demonstrates significant results related to how arthritis of hip, knee, and ankle effect their respective joints, but also how they may impact the alignment of the entire limb. With this data and measurement technique, surgeons may be able to form a more comprehensive and detailed pre-operative plan when assessing anthric joints.

IMAGES AND TABLES:

Figure 1: The center of the hip was measured at the 3D center of the femoral head and the center of the knee was measured as the center of an oval-shaped structure positioned in the most proximal full axial cut of the proximal tibia. The center of the ankle joint was defined as the most proximal and centered voxel of the talar body, and the center of the foot was defined as the bisecting line of the foot tripod point. The relationship between the center of the hip, knee and ankle joints and the bisecting line of the foot tripod was assessed and compared between HOA, KOA, AOA patients and controls. Examples of measurements for arthritic patients and controls is presented.
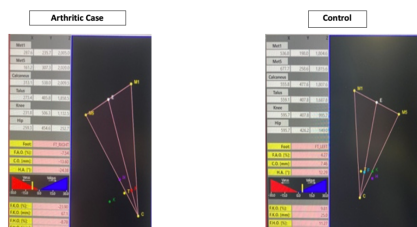

Figure 2: The Foot Ankle Offset differences were found to be significant between the groups (p=0.0077), with AOA patients being significantly different than all the other groups.