INTRODUCTION

Developmental dysplasia of the hip (DDH) is an important disease leading to osteoarthritis (OA), as it is well established that high stress concentrations during weight-bearing ambulation cause osteoarthritis. Historically, static geometric factors, e.g., center-edge (CE) angle, Sharp angle, Acetabular roof obliquity (ARO), and acetabular head index (AHI), have been used to quantify risk of OA in hips with DDH. Recently, researchers have focused on hip instability as a potentially important dynamic factor for OA, but the detailed kinematics of DDH hips during weight-bearing gait have not been reported. We considered two hypotheses: First, because the DDH hip has less geometric coverage, we assumed femoral head translations in DDH hips would be larger than in normal hips. Second, we assumed the direction of femoral translation would be superolateral during stance-phase and inferoposterior during swing-phase due to the net joint forces during those phases of gait. The purpose of this research is to contrast femoral translation in normal and DDH hips during weight-bearing stepping.

METHODS

Twelve DDH subjects, including ten females, gave informed consent to participate in this IRB approved study. Their mean age was 34 years (range: 19 to 44 years). Five subjects had bilateral dysplastic hips and seven had unilateral dysplastic hips. Diagnosis of DDH was based on anteroposterior radiography with a CE angle less than 20°. The Sharp angle, ARO and AHI also were measured by anteroposterior radiography. Exclusion criteria included pregnancy, history of systemic disease, hip injury, hip operation, any hip disease except DDH, radiographical evidence of osteoarthritis, or deformed femoral head. After exclusions, 11 dysplastic hips and 7 healthy hips were available for study.

Pelvic and femoral geometry models were developed from CT images of each hip (Aquilion, Toshiba Medical Systems, Japan; 1 mm slice thickness, 512 x 512 acquisition matrix, 0.732mm pixel spacing). 3D mesh models were created using open-source software (tk-SNAP, Penn Image Computing and Science Laboratory, Philadelphia, PA.) Standard coordinate systems were placed in the femoral and pelvic models following published conventions (Geomagic studio 9, Geomagic Inc.). The femoral head center was determined as the center of a best fit sphere. The acetabular center was defined coincident with the femoral head center in the CT images.

Each hip was imaged using A-P fluoroscopy (ARCADIS Avantic, Siemens AG, German) at 15 frames/sec while the subject walked in place. Subjects repeatedly simulated a gait motion, including full weight-bearing and swing phases, without forward progression. Hip joint kinematics was quantified using 3D-to-2D model-image registration. Motions were expressed as the femur moving with respect to the pelvis, with reference to the posture in the CT scan. Femoral translation, a potential measure of instability, was quantified as the displacement of the femoral head center relative to the acetabular center in each image, and as the maximum displacement of the femoral head between any two images. Group averaging was performed by resampling each subject’s data at each 5% increment of the gait cycle using linear interpolation.

Kinematic results from DDH and healthy hips were compared using two-way repeated-measures ANOVA with post hoc Tukey tests for pair-wise comparisons (p=0.05). Regression analysis was performed to compare the hip translations (instability) with standard static geometric parameters: CE angle, Sharp angle, ARO and AHI.

RESULTS

Femoral head translations were significantly different between DDH and normal hips (Fig.1). Maximum mean translation was 1.0mm in DDH hips and 0.5mm in normal hips during swing-phase. Translations were predominantly in the superior/inferior direction, with average anteroposterior translations of 0.3mm in each group (p>0.05).

Regression analysis showed high inverse correlations between the CE angle and femoral translations (Fig. 2). Each correlations between translation and AHI, translation and ARO were also high (P=0.002; R²=0.448) (P=0.006; R²=0.379). Correlation between translation and Sharp angle was low(P=0.17).

DISCUSSION:

Consistent with our hypothesis, we observed greater femoral translations in DDH hips than in normal hips. However, our motion hypothesis was only partially supported: we did not observe significant translation during stance-phase, instead observing the majority of femoral translation during swing-phase.

Many in vivo and in vitro studies showed the hip joint force during gait was directed superoposterior at heel strike, and we expected to observe corresponding femoral translations. It would appear that both DDH and normal hips have sufficient conformity to support these loads without significant translation at heel strike and during stance-phase. One can speculate superior instability will accompany advancing arthritis. We did observe inferior translations during swing phase, greater in DDH hips, which will result in moving areas of high pressure, especially as the joint load increases prior to heel-strike. These translations may contribute and predispose the hip to degenerative changes.

SIGNIFICANCE:

DDH hips exhibit greater than normal swing-phase femoral translations during simulated walking. These excess motions may be predictive of future degenerative changes. We found relatively high correlations between hip geometry (CE angle, AHI, ARO) and dynamic femoral head translations.