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Femoral anteversion assessment: Comparison of physical examination, gait analysis, and EOS biplanar radiography

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ABSTRACT

Background: Multiple measurement methods are available to assess transverse plane alignment of the lower extremity.

Research question: This study was performed to determine the extent of correlation between femoral anteversion assessment using simultaneous biplanar radiographs and three-dimensional modeling (EOS imaging), clinical hip rotation by physical examination, and dynamic hip rotation assessed by gait analysis.

Methods: Seventy-seven patients with cerebral palsy (GMFCS Level I and II) and 33 neurologically typical children with torsional abnormalities completed a comprehensive gait analysis with same day biplanar anterior-posterior and lateral radiographs and three-dimensional transverse plane assessment of femoral anteversion. Correlations were determined between physical exam of hip rotation, EOS imaging of femoral anteversion, and transverse plane hip kinematics for this retrospective review study.

Results: Linear regression analysis revealed a weak relationship between physical examination measures of hip rotation and biplanar radiographic assessment of femoral anteversion. Similarly, poor correlation was found between clinical evaluation of femoral anteversion and motion assessment of dynamic hip rotation. Correlations were better in neurologically typical children with torsional abnormalities compared to children with gait dysfunction secondary to cerebral palsy.

Significance: Dynamic hip rotation cannot be predicted by physical examination measures of hip range of motion or from three-dimensional assessment of femoral anteversion derived from biplanar radiographs.

1. Introduction

Rotational abnormalities of the lower extremity which lead to in-toeing and out-toeing gait patterns are common in children. An intoeing gait pattern may be caused by foot deformity (metatarsus adductus) and/or transverse malalignment of the long bones (internal tibial torsion and/or increased femoral anteversion) [1,2]. Out-toeing is less common than intoeing, with its etiology related to femoral retroversion (diminished femoral anteversion), external tibial torsion, and/or foot deformity (pes planovalgus). Transverse plane deviations are commonly observed in infants and usually corrected by typical physiologic growth mechanisms [3]. Persistent transverse malalignment may lead to gait dysfunction [4].

In patients with cerebral palsy (CP), intoeing gait patterns are common with a reported prevalence of 64%, mostly related to increased femoral anteversion and internal tibial torsion [5]. Multiple factors including long bone torsional alignment and foot deformity may contribute to an intoeing gait in some patients [2].

Accurate examination and assessment of transverse plane deviations is necessary for appropriate treatment and counsel. Multiple methods are available to measure transverse plane alignment of the lower extremity including physical examination, three-dimensional (3-D) radiography with CT or MRI, and computerized motion analysis [6–9]. Due to the recent availability of EOS (EOS imaging ®, Paris, France), transverse plane geometry of the lower limb (tibial torsion and femoral anteversion) may now be evaluated using 3-D modeling based on biplanar radiographs [10,11]. Previous studies have demonstrated that EOS assessment of the torsional profile is comparable to CT evaluation, with the added benefit of a significant reduction in the amount of radiation required for the exam [12,13]. These studies, performed in both adult and pediatric populations, have shown that EOS assessments of the 3-D anatomy of the lower extremity are equivalent to that of CT [11,14,15]. The clinical utility of this new method of evaluation has not been established.

The goals of the current study were to determine the extent to which measures of femoral skeletal alignment including physical examination

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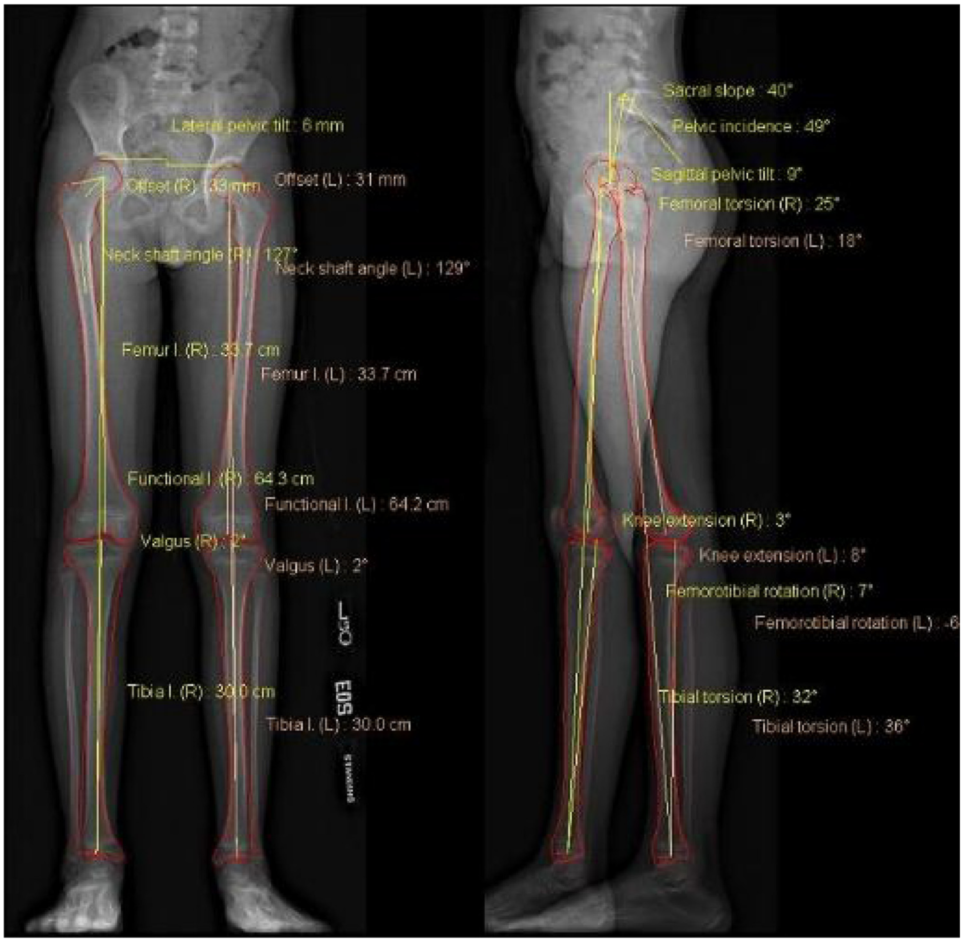

Fig. 1. The sterEOS 3-D parametric model representing the patient's lower extremity.

of hip rotation and EOS assessment of femoral anteversion are correlated. Additionally, we sought to determine the extent to which these measures of femoral skeletal alignment correlate with dynamic hip rotation as assessed by quantitative motion analysis in cohorts of neurologically typical children (NT) with torsional abnormalities and children with CP.

2. Methods

The study design was a retrospective review, approved by our hospital's Institutional Review Committee. Patients were identified by searching a computerized database of health information for children who had been evaluated in our institution's Motion Analysis Laboratory between January 2014 and June 2015. As part of the comprehensive motion analysis evaluation, biplanar radiographs of the lower extremities were obtained on the same day as the motion studies. Patients categorized as GMFCS levels I or II were selected for study and compared with a cohort of neurologically typical children with torsional abnormalities evaluated during the same time period. Patients categorized as GMFCS levels III or higher were excluded from the study in order to investigate populations of children with similar walking patterns and walking ability.

2.1. Clinical measures

Measurement variability was minimized by having the same examiners perform the physical exam. The physical exam was performed by trained kinesiologists during a comprehensive motion analysis study. The examination was done by a single examiner manipulating the limb, with another utilizing a gravity referenced inclinometer for specific measurement. Clinical hip rotation was used as a proxy for femoral anteversion and was assessed with the patient in the prone position, hips extended, and knees flexed [16]. Maximum internal and maximum external hip rotation were recorded. The trochanteric prominence angle test as a measure for femoral anteversion was not utilized in this study [17].

2.2. Gait analysis

For the assessment of dynamic (walking) kinematics and static (standing) posture, retro-reflective markers were placed over key anatomical landmarks associated with the Newington gait model [18]. The gait model produced anatomical axes associated with the pelvis, thigh, and lower leg that quantified the transverse plane alignment of the lower extremity. Specifically, hip transverse rotation reflected the angular displacement of the femoral condylar axis relative to the line from the right-to-left anterior superior iliac spines about the longitudinal axis of the femur. The hip rotation angle was computed in this way for both static (standing) and dynamic (walking) motion capture trials. An internal hip rotation angle was assigned a positive value, and an external hip rotation angle assigned a negative value. The mean hip transverse rotation angles over the single-stance phase of the gait cycle were reported for the dynamic (walking) trial along with the hip rotation value from the static (standing) trial [19].

2.3. Radiographic measures

Digital radiographs of lower extremities, from the pelvis to the feet