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Differences in anatomical parameters between the affected and unaffected hip in patients with bilateral cam-type deformities

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ABSTRACT

Background: It is still unclear why many individuals with bilateral cam deformities demonstrate only unilateral symptoms of femoroacetabular impingement, thus symptoms may be attributed to additional anatomical parameters. The purpose was to examine patients with bilateral cam deformities, with unilateral symptoms, and compare anatomical hip joint parameters between their affected (symptomatic) hip and their contralateral, unaffected (asymptomatic) hip.
Methods: Twenty participants (n = 20) with unilateral symptoms, but bilateral cam deformities, underwent CT imaging to measure their affected and unaffected hip's: axial and radial alpha angles, femoral head–neck offset, femoral neck-shaft angle, medial proximal femoral angle, femoral torsion, acetabular version, center-edge angle; and a physical examination (hip flexion, straight-leg raise, internal rotation, external rotation) to ascertain clinical signs.
Findings: The affected hips demonstrated limited motions during physical examination, compared with unaffected hips (effect size = 0.550 to 0.955). The affected hips had significantly lower femoral neck-shaft angles (mean 125° (SD 3)) and lower medial proximal femoral angles (mean 79° (SD 4)), compared with the unaffected hips (mean 127° (SD 3), $P = 0.001$, effect size = 0.922; and mean 81° (SD 4), $P = 0.011$, effect size = 0.632; respectively). There were no differences in cam deformity parameters (axial and radial alpha angles, femoral head–neck offset), femoral torsion, acetabular version, and center-edge angle, between affected and unaffected hips.
Interpretation: A decreased femoral neck-shaft angle or medial proximal femoral angle can be implemented as a diagnostic predictor, to determine which hip may be at a greater risk of developing early symptoms.

1. Introduction

The cam deformity is recognized as a predominant morphology of the proximal femur that causes femoroacetabular impingement (FAI) (Beaule et al., 2005; Beck et al., 2005; Ganz et al., 2003; Leunig et al., 2009; Siebenrock et al., 2004). Characterized by a combined aspherical femoral head and reduced offset, the cam deformity induces impingement between the proximal femur and the hip socket, resulting in clinical symptoms of labral damage, groin pain, and reduced pelvic and hip motions (Allen et al., 2009; Chakraverty et al., 2013; Kappe et al., 2012; Lamontagne et al., 2009). The abnormal joint contact loading can result in elevated hip joint stresses (Chegini et al., 2009; Ng et al., 2012; Ng et al., 2016) and a greater risk of developing early osteoarthritis (Agricola et al., 2012; Beaulé et al., 2012; Beaule et al., 2005; Beck et al., 2005; Ganz et al., 2003).

There has been emerging interest to understand why many individuals with cam deformities do not develop early FAI symptoms (i.e. asymptomatic individuals with the cam deformity but do not demonstrate impingement, clinical signs, symptoms, or pain) (Agricola et al., 2014; Hack et al., 2010; Hartofilakidis et al., 2011; Ranawat et al., 2011). The presence of a large cam deformity, indicated by elevated alpha angles, may not be sufficient to characterize FAI symptoms (Barton et al., 2011; Khanna et al., 2014; Lohan et al., 2009; Ng et al., 2015; Sutter et al., 2012), especially when the pathomechanical threat of the asymptomatic cam deformity can remain undetected, but can still onset early subchondral bone adaptation and joint degeneration (McGuffin et al., 2015; Speirs et al., 2013). In addition to the conventional alpha angles, recent studies examined FAI populations and measured additional anatomical parameters from radiographic (Bardakos and Villar, 2009; Hartofilakidis et al., 2011; Ranawat et al., 2011), computed tomography (CT) (Ergen et al., 2014; Kang et al., 2010; Ng et al., 2015), and magnetic resonance imaging (MRI) data (Ejnisman et al., 2013;

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Sutter et al., 2012), to associate various femoral and pelvic structural parameters with the onset of symptoms.

Knowing that many individuals in the FAI population may have bilateral cam deformities (Allen et al., 2009), it is still unclear why symptoms are often experienced only in one hip, while their other contralateral hip remains unaffected. The prevalence of bilateral cam deformities in the same individual provides a unique opportunity to better delineate pathomechanisms leading to FAI and to possibly further predict the progression of symptoms that will require physical therapy or surgical intervention (Allen et al., 2009; Casartelli et al., 2015; Haviv and O'Donnell, 2010; Klingenstein et al., 2013; McGuffin et al., 2015). The purpose of this study was to examine patients with bilateral cam-type deformities, who demonstrate unilateral FAI symptoms, and determine if there are differences in anatomical hip joint parameters between their affected (symptomatic) and their contralateral, unaffected (asymptomatic) hips.

2. Methods

This diagnostic study (Level of Evidence III — STROBE Guidelines) involved anatomical parameters and physical examinations associated with cam-type FAI symptoms. An observational, case–control study was performed for a symptomatic group, where each participant's affected (case) and unaffected (control) hips' anatomical parameters were blinded and measured.

2.1. Participants

Twenty-two participants (n = 22; m = 19, f = 3) were initially recruited from the senior orthopaedic surgeon's clinical practice (PB), during a two-year recruitment period at The Ottawa Hospital. All participants presented themselves with primary unilateral hip pain, clinical signs, and symptoms. Pelvic and knee CT images were acquired from each participant, using a clinical CT scanner (Acquilion, Toshiba Medical Systems Corporation, Otawara, Japan; or Discovery CT750, GE Healthcare, Mississauga, Ontario, Canada) and confirmed by a musculoskeletal radiologist (KR) to have a cam deformity on their affected (symptomatic) hip, with elevated axial or radial alpha angles (Barton et al., 2011; Hack et al., 2010; Khanna et al., 2014; Rakhra et al., 2009; Sutter et al., 2012).

Any participant with neurological or musculoskeletal disorders, degenerative diseases, or any previous major lower limb injuries or surgeries was excluded. Participants were excluded if they indicated pain in their contralateral, unaffected (asymptomatic) hip or other areas of their lower limbs. Two participants did not show a cam deformity on their contralateral, unaffected (asymptomatic) hip, thus were excluded for unilateral-only deformities. A total of twenty patients (n = 20; m = 17, f = 3) indicated elevated alpha angles for both affected and unaffected hips, confirming bilateral cam deformities (Table 1). Each participant completed pain questionnaires – Hip Disability and Osteoarthritis Outcome Score (HOOS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC) – to ascertain their level of symptoms. Participants signed and provided informed consent prior to the study. The university and hospital research institute ethics boards approved this study, to ensure that all investigations were conducted ethically in conformity with research principles.

2.2. Anatomical parameters

To remove bias, each participant's CT data were blinded and randomly assigned new filenames. Using an image reading software (Onis 2.4, DigitalCore, Tokyo, Japan), both left and right hips were measured for multiple anatomical CT parameters, which included: axial alpha angle, radial alpha angle, femoral head–neck offset, femoral neck-shaft angle, medial proximal femoral angle, femoral torsion, acetabular version, and lateral centre-edge angle; all corresponding with common anatomical features of the hip joint that may distinguish symptoms (Bedi et al., 2011; Kang et al., 2010; Ng et al., 2015; Ranawat et al., 2011).

Prior to measuring the alpha angles and neck angles, the slice of the femoral head center was located on the oblique-axial, frontal, and sagittal planes. Using the femoral head center as the point of rotation, the frontal plane was corrected to display the widest femoral neck and shaft regions. A circle was traced around the femoral head on each of the three planes, where the longitudinal femoral neck axis was determined as the line from the femoral head center through the narrowest part of the femoral neck, on the oblique-axial and corrected frontal planes. The longitudinal femoral shaft axis was defined as the line from the piriformis fossa through the midpoint of diaphysis on the corrected frontal plane.

The axial alpha angle was measured on the oblique-axial plane of the longitudinal femoral neck axis, observing for an aspherical anterior femoral head (Nötzli et al., 2002; Nouh et al., 2008). With the vertex centered at the femoral head, the angle was formed from the femoral neck axis to the head–neck junction (Fig. 1A). Anterior femoral head–neck offset was also observed on the oblique-axial plane (Chakraverty et al., 2013; Kang et al., 2010), measuring the offset distance between the two tangents of the anterior femoral head and neck (Fig. 1A). The radial alpha angle was obtained by a 1:30 clock-face rotation about the longitudinal femoral neck axis, observing for an anterosuperior asphericity (Rakhra et al., 2009; Sutter et al., 2012) (Fig. 1B). An axial alpha angle, greater than 50.5°, or radial 1:30 alpha angle, greater than 60°, was considered as cam deformity (Hack et al., 2010; Khanna et al., 2014).

The femoral neck-shaft angle was measured on the frontal plane (Hartofilakidis et al., 2011; Ranawat et al., 2011) (Fig. 1C), between the femoral neck and shaft axes, with values below 120° deemed as coxa vara and above 135° as coxa valga. Similarly, the medial proximal femoral angle was measured between the femoral shaft axis and the line joining the center of the femoral head to the superior greater trochanter (Bardakos and Villar, 2009) (Fig. 1C).

Femoral torsion was measured as the difference between the femoral neck horizontal and condyle horizontal angles (Bedi et al., 2011; Ejnisman et al., 2013), each taking the angle with respect to the transverse view's horizontal plane (Fig. 1D). Acetabular version was determined on the transverse plane coincident with the left and right femoral head centers (Chakraverty et al., 2013; Dandachli et al., 2009; Reynolds et al., 1999). This angle was constructed by the line connecting the anterior and posterior acetabular notches and the perpendicular

Table 1
Participant demographics, pain questionnaires, and bilateral cam deformity observations, reporting mean and (SD).

n = 20 (m:f)	Age (years)	BMI (kg/m^2)	HOOS Pain (%)	WOMAC Pain (%)	Axial alpha angle > 50.5° or radial alpha angle > 60°	
					Affected hip	Unaffected hip
17:3	36 (8)	26 (5)	64 (21)	71 (21)	Yes	Yes

HOOS = Hip Disability and Osteoarthritis Outcome Score.
WOMAC = Western Ontario and McMaster Universities Arthritis Index.