

# Prevalence of radiologic acetabular dysplasia in asymptomatic Asian volunteers

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## ABSTRACT

The purpose of this study was to evaluate the prevalence of acetabular dysplasia in an asymptomatic Asian population as one of the most important risk factors of hip osteoarthritis. From December 2014 to March 2015, we investigated the data of 200 asymptomatic volunteers (400 hips) aged 18–50 years recruited from our institution. Pelvic radiographs were taken and reviewed by two experienced orthopaedic surgeons. Lateral centre-edge (LCE) angle, Sharp angle, Tonnis angle and acetabular depth-to-width ratio (AD/WR) were measured. We investigated the mean values and identified the statistical differences between the sexes and evaluated the prevalence and bilaterality of acetabular dysplasia defined by each parameter. Mean LCE angle, Sharp angle, Tonnis angle and AD/WR were 26.2°, 41.3°, 8.5° and 0.28, respectively. All parameters showed more dysplastic results in females than in males and were statistically significantly different, except for AD/WR. When defined acetabular dysplasia as LCE angle <20°, Sharp angle >45°, Tonnis angle >14° or AD/WR <0.25, the prevalence of acetabular dysplasia by each parameter was 15.0%, 12.8%, 13.3% and 12.8%, respectively. There was a higher prevalence in females than in males; however, only Sharp and Tonnis angles showed significant differences. The bilaterality of acetabular dysplasia was 18.6–39.5% for all subjects. There is high prevalence of asymptomatic dysplastic hips in the Asian population.

## INTRODUCTION

Acetabular dysplasia can cause secondary osteoarthritis (OA) by changes in the hip mechanism [1]. Many patients worldwide have undergone hip arthroplasty due to secondary OA caused by acetabular dysplasia, and the incidence has been known to be more frequent in Asia [2, 3].

To date, several demographic studies have evaluated simple radiographic data on the prevalence of acetabular dysplasia in asymptomatic populations; however, the results have not been consistent. Previous studies have reported that the incidence of acetabular dysplasia varies from nearly 1% to 10% worldwide [4–12]. However, to our knowledge, all previous studies involved retrospectively collected data as well as data from tests that were performed due to problems unrelated to the hip joint, and it is unknown whether the study participants were truly asymptomatic. Most

participants were hospital patients and studies relied on only previous medical records.

We retrospectively reviewed prospectively collected data of 200 volunteers with no hip-related symptoms and measured radiographic parameters, including lateral centre-edge (LCE) angle [13], Sharp angle [14], Tonnis angle [15] and acetabular depth-to-width ratio (AD/WR) [16]. We determined the prevalence of acetabular dysplasia and bilaterality in truly asymptomatic Asian volunteers and determined sex-related differences in the patterns of radiographic parameters.

## MATERIALS AND METHODS

We used the same data sources as in our previous study [17]. This study was approved by our institutional review board. Between December 2014 and March 2015, 200

volunteers (400 hips) were recruited from our hospital. The inclusion criteria were age between 18 and 50 years, no history of previous or ongoing hip-related pain and no pain elicited on physical examination of the hip. The exclusion criteria were as follows: (i) previous diagnosis of hip disorders, including Perthes disease, slipped capital femoral epiphysis, developmental hip dysplasia, hip arthritis and hip fracture; (ii) current hip-related pain, such as groin or buttock pain; (iii) previous surgery of the hip or pelvis; and (iv) contraindication to X-ray imaging, such as pregnancy. All participants were physically examined to confirm that they were asymptomatic.

A standing pelvic anteroposterior (AP) radiograph was taken with a tube-to-film distance of 40 inches (102 cm), with the tube perpendicular to the film. The crosshairs of the beam were centred on the point midway between the superior border of the pubic symphysis and a line drawn connecting the anterior superior iliac spines. The pelvic AP view was considered true when the coccyx tip and pubic symphysis were in line and the distance between them was between 1 and 3 cm and both teardrops, the iliac wing and obturator foramen, were symmetrical. Both hips were internally rotated 15–20° to better evaluate femoral neck geometry. Two experienced orthopaedic surgeons measured the radiographic parameters for acetabular dysplasia, including LCE angle, Sharp angle, Tonnis angle and AD/WR. The LCE angle was measured following the Wiberg method [13]. The sourcil-edge LCE angle was measured to the edge of the acetabular sourcil and the bone-edge LCE angle to the bone edge. The Sharp angle was measured as the angle between a line connecting the left and right sides of the acetabular teardrops and a line joining the lateral edge of the acetabular roof and the inferior tip of the teardrops [14]. The Tonnis angle was measured as the angle between a line connecting the medial to lateral edges of the acetabular roof and a line parallel to the pelvic teardrops [15]. AD/WR was measured following the Heyman and Herndon method [16]. The acetabular width was defined as the line joining the lateral edge of the acetabulum to the pelvic teardrop. The acetabular depth was measured as another line perpendicular to this line at the point of the greatest acetabular depth.

Acetabular dysplasia was defined as LCE angle <20°, Sharp angle >45°, Tonnis angle >14° or AD/WR <0.25 [18]. We analysed the radiographic prevalence of acetabular dysplasia, bilaterality and sex-related differences of each radiographic parameter. An independent *t*-test and the Mann–Whitney *U*-test were used to analyse sex-related differences of radiographic parameters. The  $\chi^2$  test and the Fisher's exact test were used for the prevalence of acetabular dysplasia as well as the bilaterality using SPSS Version

18 (SPSS, Inc., Chicago, IL, USA). The intra-class correlation coefficient (ICC) with 96% confidence interval was used to measure the inter-observer and intra-observer agreements. The observer agreement was considered slight, fair, moderate, substantial and almost perfect if ICC was <0.21, 0.21–0.40, 0.41–0.60, 0.61–0.80 and >0.80, respectively [19, 20]. In our study, the inter-observer and intra-observer agreements were substantial for the LCE angle, AD/WR and Tonnis angle and almost perfect for the Sharp angle.

## RESULTS

A total of 400 asymptomatic hips (146 male and 254 female hips) were evaluated. Table I shows the mean age, body mass index (BMI) and all radiographic parameters of the participants. The mean age was significantly lesser in males than in females, and BMI was substantially lower in females than in males. There were significant sex-related differences in the mean values of LCE, Sharp and Tonnis angles.

Table II shows the prevalence of acetabular dysplasia and bilaterality defined by each parameter. The prevalence of acetabular dysplasia for all subjects was 15.0%, 7.3%, 12.8%, 13.3% and 12.8% by sourcil-edge LCE, bone-edge LCE, Sharp and Tonnis angles and AD/WR, respectively. Male and females differed in terms of their Sharp ( $P < 0.001$ ) and Tonnis angles ( $P = 0.024$ ) but not the other radiographic indicators of acetabular dysplasia. Across all subjects, the bilaterality of acetabular dysplasia varied from 18.6% to 39.5%, depending on the specific radiographic parameter identifying dysplasia. When acetabular dysplasia was defined by two positive parameters, including the sourcil-edge LCE angle, the prevalence was 5.5% (LCE angle <20° and Sharp angle >45°), 6.0% (LCE angle <20° and Tonnis angle >14°) and 4.8% (LCE angle <20° and AD/WR <0.25). When acetabular dysplasia was defined by three positive parameters including the sourcil-edge LCE angle, the prevalence was 2.8% (LCE angle <20°, Sharp angle >45° and Tonnis angle >14°), 1.5% (LCE angle <20°, Sharp angle >45° and AD/WR <0.25) and 3.5% (LCE angle <20°, Tonnis angle >14° and AD/WR <0.25). With all positive parameters, the prevalence of acetabular dysplasia was 1.0% (LCE angle <20°, Sharp angle >45°, Tonnis angle >14° and AD/WR <0.25).

## DISCUSSION

In this study, the prevalence of acetabular dysplasia varied between 12.8% and 15.0% depending on the different radiographic parameters. Various results have been reported on sex-related differences, and the prevalence of

**Table I. Basic characteristics of study population and value of each parameters of acetabular dysplasia**

Characteristics	All volunteers	Male	Female	P value
Age (years)	34.7 ± 7.3 (21–49)	32.4 ± 6.4 (21–49)	36.0 ± 7.4 (23–49)	<0.001
BMI (kg/m <sup>2</sup> )	22.5 ± 3.1 (16.9–32.7)	25.1 ± 2.8 (20.3–32.7)	21.0 ± 2.3 (16.9–30.1)	<0.001
LCE angle (°) (to sourcil)	26.2 ± 6.0 (11.8–49.5)	27.3 ± 6.2(11.8–49.5)	25.6 ± 5.9 (11.9–43.2)	0.003
LCE angle (°) (to bony tip)	28.1 ± 5.5 (15.1–48.2)	29.0 ± 5.6 (15.9–48.2)	27.6 ± 5.4 (15.1–42.3)	0.013
Bony tip–sourcil (°)	2.0 ± 1.6 (0–11.9)	2.0 ± 1.6 (0–11.9)	2.1 ± 1.5 (0–8.3)	0.512
Sharp angle (°)	41.3 ± 3.3 (33.0–51.0)	39.6 ± 2.7 (33.0–46.0)	42.3 ± 3.2 (35.0–51.0)	<0.001
Tonnis angle (°)	8.5 ± 4.3 (–5.8 to 22.1)	7.4 ± 3.8 (0–21.1)	9.1 ± 4.5 (–5.8 to 22.1)	<0.001
AD/WR	0.28 ± 0.3 (0.21–0.38)	0.29 ± 0.3 (0.21–0.36)	0.28 ± 0.3 (0.21–0.38)	0.102

Each result shows mean values ± standard deviation (SD) with 95% CI. Range is shown in parenthesis.  
BMI, body mass index; LCE angle; lateral centre-edge angle, AD/WR, acetabular depth-to-width ratio.

**Table II. Prevalence of acetabular dysplasia and bilaterality by each parameter**

Parameters	Total (n = 400)	Male (n = 146)	Female (n = 254)	P value
LCE angle <20° (to sourcil)	15.0% (n = 60)	11.6% (n = 17)	16.9% (n = 43)	0.154
Bilaterality	20.0% (10/50 pts.)	13.3% (2/15 pts.)	22.9% (8/35 pts.)	0.702
LCE angle <20° (to bony tip)	7.3% (n = 29)	6.8% (n = 10)	7.5% (n = 19)	0.815
Bilaterality	31.8% (7/22 pts.)	25.0% (2/8 pts.)	35.7% (5/14 pts.)	1.000
Sharp angle >45°	12.8% (n = 51)	1.4% (n = 2)	19.3% (n = 49)	<0.001
Bilaterality	27.5% (11/40 pts.)	0% (0/0 pts.)	27.5% (11/40 pts.)	0.404
Tonnis angle >14°	13.3% (n = 53)	8.2% (n = 12)	16.1% (n = 41)	0.024
Bilaterality	39.5% (15/38 pts.)	50% (4/8 pts.)	36.7% (11/30 pts.)	0.687
AD/WR <0.25	12.8% (n = 51)	9.6% (n = 14)	14.6% (n = 37)	0.260
Bilaterality	18.6% (8/43 pts.)	27.3% (3/11 pts.)	15.6% (5/32 pts.)	0.401

LCE angle, lateral centre-edge angle; Pts., patients number; AD/WR, acetabular depth-to-width ratio.

acetabular dysplasia has been reported to be more frequent in females than in males [6, 12, 21, 22]. In our study, the prevalence of acetabular dysplasia was significantly higher in females than in males when determined by only Sharp and Tonnis angles. In our cohort, 15.0% had a sourcil-edge LCE angle <20° and 7.3% had a bone-edge LCE angle <20°. Using a sourcil-edge LCE angle with a cut-off of <20°, our prevalence was markedly more frequent than that reported in most previous studies (Table III); however, it was comparable to the 11.5% reported by Mimura *et al.* [18] using the same cut-off on computed tomography (CT) scan. It was also similar to the results of studies in a

Japanese population, which showed a prevalence of 11.6% for females using a cut-off of 25° [21].

Although it has been known that the prevalence of acetabular dysplasia is higher in Asian than Caucasian populations, previous studies have reported various results using the same radiographic parameters, such as Wiberg's LCE angle. These variances may be due to the different measuring methods (Table III). First, cut-off values of 20° or 25° were used to define acetabular dysplasia in the previous studies. Second, the lateral edge for measuring Wiberg's LCE angle was the sourcil edge or bone edge. Originally, Wiberg [13] described the LCE angle as the lateral aspect

**Table III. Review of previous studies on prevalence of dysplasia in asymptomatic hips by lateral centre-edge angle**

Author	Cut-off	Modality	No. of hips	Race	Margin	Position	Prevalence
Lau <i>et al.</i> [5]	25°	X-ray	678	Chinese man	Sourcil	Supine	4.5%
Ali-Gombe <i>et al.</i> [8]	25°	X-ray	126	Nigerian men	Sourcil	Supine	3.3%
Lane <i>et al.</i> [7]	25°	X-ray	414	British woman	Sourcil	Supine	3.4%
Umer <i>et al.</i> [12]	25°	X-ray	500	Pakistan	Bone	Supine	1.4%
Yoshimura <i>et al.</i> [11]	25°	X-ray	2603/390	Britain/Japanese	Sourcil	Supine	M: 4%, F: 4%/M: 16%, F: 19%
Inoue <i>et al.</i> [21]	25°	X-ray	401/782	French/Japanese	Bone	Supine	M: 1.8%, F: 5.6%/M: 5.1%, F: 11.6%
Croft <i>et al.</i> [10]	25°/20°	X-ray	759	British man	Sourcil	Supine	3.6%/1.0%
Engesaeter <i>et al.</i> [22]	25°/20°	X-ray	2072	Norwegian	Bone	Standing	20%/3.3%
Han <i>et al.</i> [6]	20°	X-ray	591	Korean	Sourcil	Supine	1.8%
Umer <i>et al.</i> [4]	20°	X-ray	522	Singaporean	Bone	Supine	7.3%
Mimura <i>et al.</i> [18]	20°	CT	104	Japanese	Sourcil	Supine	11.5%
Current study	20°	X-ray	400	Korean	BoneSourcil	Standing	7.3%15%

M, male; F, female.

of the bony support for the femoral head or sourcil. However, others have interpreted this as the most lateral aspect of the acetabular bone [4, 21, 22]. Wylie *et al.* [23] showed that the bone-edge LCE angle was a mean 4.7° greater than the sourcil-edge LCE angle, and that the sourcil-edge LCE angle represents antero-superior acetabular coverage, whereas the bone-edge LCE angle represents superio-lateral acetabular coverage. There was a mean 2.0° difference between the bone-edge and sourcil-edge LCE angles in our study. Third, most researchers have measured LCE angle on supine AP radiographs [6, 7, 10, 11, 21], whereas some, including us, have measured it on standing AP radiographs [22]. Theoretically, a higher prevalence may be expected when acetabular dysplasia is defined by the LCE angle using a cut-off value of 25° to the sourcil-edge of the acetabulum on standing AP radiographs [24, 25]. For example, in a Norwegian cohort study, 20% of hips had a bone-edge LCE angle of <25° on standing AP radiographs and this is the most prevalent finding among other studies, followed by our results which showed a 15.0% prevalence using a sourcil-edge LCE angle of <20° on standing AP radiographs. Using the same criterion (bone-edge LCE angle <20° on standing AP radiographs) our prevalence of acetabular dysplasia (7.3%) was higher than the Norwegian study prevalence (3.3%). However, it

was comparable to the study of Umer *et al.* [4], which showed a 7.3% prevalence of acetabular dysplasia in a Singaporean population by measuring the LCE angle on supine AP radiographs.

The incidence of bilateral developmental dysplasia of hip (DDH) in children ranges from 12% to 20% and that of bilateral acetabular dysplasia in adults is 40% with varying severity on either side [26]. Okano *et al.* [27] reported 65% bilaterality of acetabular dysplasia among patients with prearthrosis or early-stage OA caused by acetabular dysplasia who had no history of DDH. In our asymptomatic adult cohort, the bilaterality of acetabular dysplasia, as defined by the Tonnis angle alone, was 39.5%.

Our study has some limitations. First, all radiographic parameters were measured on AP view only. Acetabular dysplasia is characterized by multiplanar insufficient femoral head coverage; therefore, multiplanar evaluation should be performed to obtain correct information. Mimura *et al.* [18] reported a prevalence of acetabular dysplasia in Asians that was more than twice as high as previously reported when they investigated its prevalence using multiplanar CT images. Second, our cohort consisted of only Koreans and was too small to represent the entire Asian population.

In conclusion, our study showed a high prevalence of acetabular dysplasia in asymptomatic Asian volunteers; however, the incidence of bilateral acetabular dysplasia was relatively uncommon compared with that of previous results. A longitudinal study using our cohort can provide meaningful data to establish whether an association exists between acetabular dysplasia and development of hip OA in the Asian population.

#### CONFLICT OF INTEREST STATEMENT

None declared.

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