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Radiographic Parameters of Acetabulum for Dysplasia in Korean Adults

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We analyzed plain radiographs of 591 normal adult hips of various parameters to evaluate the radiological characteristics of the hip joint including the center-edge (CE) angle, acetabular angle, acetabular depth, acetabular roof obliquity and roof angle, and also to verify the rate of acetabular dysplasia. The CE angle was negatively correlated with acetabular angle and acetabular obliquity, but it was positively correlated with acetabular depth and roof angle. The rate of acetabular dysplasia (CE angle<20 degrees) was 1.8%. We concluded that the CE angle and acetabular angle are more useful parameters for the diagnosis of acetabular dysplasia because there was no significant difference with advancing age and gender, as well as relatively small standard deviations.

Key Words: Hip joint, acetabulum, acetabular dysplasia, radiographic measurement

The methods of measuring anatomical morphology of the acetabulum from plain radiographs of the hip joint include the following: CE angle (Fredensborg, 1976; Cooperman *et al.* 1983; Croft *et al.* 1991; Smith *et al.* 1995), acetabular angle (Sharp, 1961; Cooperman *et al.* 1983), acetabular depth (Murray, 1965; Croft *et al.* 1991; Smith *et al.* 1995), acetabular roof obliquity (Massie and Howorth, 1950), and roof angle (Stulberg and Harris, 1974). By applying these methods, we can evaluate the morphology of the acetabulum and degree of the acetabular dysplasia.

The intention of this study was to gather clinical data concerning the normal hip joint from Koreans, to discover the correlation among the measured values and their utilities, and finally to evaluate the rate of acetabular dysplasia in the Korean population compared with those values from other countries.

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MATERIALS AND METHODS

The subject of this study was normal hip joints of 591 Koreans over 20 years old; 143 who were treated with bipolar hemiarthroplasty for fractures of the femoral neck and 448 who had clinically-normal hip joints. They were 54.0% male (319) and 46.0% female (276). The average age was 51.5 years (from 22 to 88); broken down by decades, the twenties - 16.8% (99), the thirties - 15.6% (92), the forties - 8.3% (49), the fifties - 22.7% (134), the sixties - 18.1% (107) and over seventy - 18.6% (110)(Table 1).

Antero-posterior radiograph was used to measure the radiography of a hip joint. To get a constant pelvic radiography, the distance between the X-ray tube and the film was set at 40 inches, and the beam was injected 5cm proximal to the symphysis pubis

Table 1. Age and gender distribution of the subjects

Age(yrs)	No. of males	No. of females	Total no.
20~29	85	14	99
30~39	61	31	92
40~49	35	14	49
50~59	63	71	134
60~69	37	70	107
≥70	38	73	110
Total	349	272	591

(Sharp, 1961). A retrospective study was performed for the radiography of patients treated by bipolar hemiarthroplasty and a prospective study was done for the radiography of clinically-normal hip joints. To measure the morphology of acetabulum, the anatomical structure of hip joints was assessed by measurement of the CE angle, acetabular angle, acetabular depth, acetabular roof obliquity and roof angle (Fig. 1).

The CE angle is formed by the angle between a line connecting the center of the femoral head and lateral margin on the acetabular roof and a perpendicular line joining the center of the two femoral heads (Fig. 1A)(Fredensborg, 1976; Cooperman *et al.* 1983; Croft *et al.* 1991; Smith *et al.* 1995). The center of the femoral head was determined with the aid of a transparent plastic sheet marked with concentric circles. The acetabular angle is formed by the angle between a line connecting the left and right sides of the pelvic tear drop and a line joining the lateral edge of the acetabular roof and the inferior tip of the pelvic tear drop (Fig. 1B)(Sharp, 1961; Cooperman *et al.* 1983). The acetabular depth is the longest vertical distance between a line joining the lateral acetabular margin and upper margin of the symphysis pubis on the same side and the acetabular roof (Fig. 1C)(Murray, 1965; Croft *et al.* 1991; Smith *et al.* 1995). The acetabular roof obliquity is defined as the angle between a line connecting the lateral edge of the acetabular roof and the lower iliac tip of the acetabular surface and a line parallel to the pelvic tear drop (Fig. 1D)(Massie and Howorth, 1950). The roof angle is determined by a line along the lateral side of the ilium on the acetabular surface and a line parallel to the pelvic tear drop (Fig. 1E)

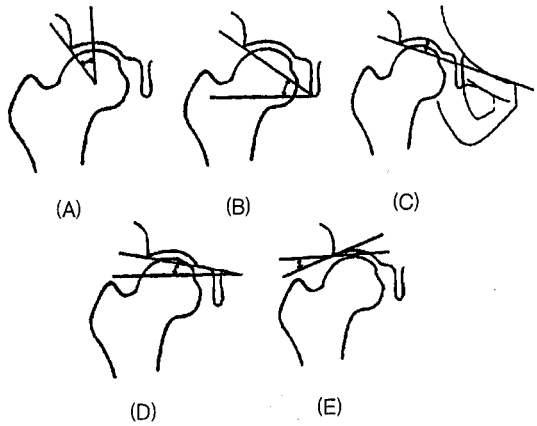

Fig. 1. Measurements of the parameters of the hip joint for acetabular dysplasia. A: CE angle, B: Acetabular angle, C: Acetabular depth, D: Acetabular roof obliquity, E: Roof angle

(Stulberg and Harris, 1974). We analyzed these values for age and gender by ANOVA test and evaluated the relationship between these values by Pearson correlation coefficient using SAS/STAT software, release 6.12 for Windows 95 and NT (SAS institute Inc., Cary, North Carolina, U.S.A.).

RESULTS

The CE angle was 31.9±5.4° in the twenties, 32.4±6.4° in the thirties, 31.2±6.8° in the forties, 32.8±7.1° in the fifties, 31.8±6.2° in the sixties and 33.9±5.5° over 70. The mean CE angle was 32.5±6.4° (32.6±5.7° in male, 32.3±6.8° in female). The acetabular angle was 37.3±3.5° in the twenties, 37.0±3.3° in the thirties, 36.8±5.4° in the forties, 37.0±4.4° in the fifties, 37.5±3.1° in the sixties and 36.0±2.6° over 70. The average was 37.0±3.7° (36.5±3.5° in male, 37.5±3.8° in female). The acetabular depth was 11.8±2.5 mm in the twenties, 11.4±2.5 mm in the thirties, 10.9±2.6 mm in the forties, 10.6±2.7 mm in the fifties, 10.1 ±2.5 mm in the sixties and 10.7±3.0 mm over 70. The average was 10.9±2.7 mm (11.5±2.6 mm in male, 10.2±2.6 mm in female). The acetabular roof obliquity was 4.5±4.3° in the twenties, 5.9±5.6° in the thirties, 7.2±5.4° in the forties, 7.1±5.9° in the

Table 2. Value of each parameter of the hip joint by decades in subjects

Age	20~29	30~39	40~49	50~59	60~69	≥70	p value
CE Angle	31.9±5.4	32.4±6.4	31.2±6.8	32.8±7.1	31.8±6.2	33.9±5.5	>0.05
AA	37.3±3.5	37.0±3.3	36.8±5.4	37.0±4.4	37.5±3.1	36.0±2.6	>0.05
AD	11.8±2.5	11.4±2.5	10.9±2.6	10.6±2.7	10.1±2.5	10.7±3.0	<0.01
ARO	4.5±4.3	5.9±5.6	7.2±5.4	7.1±5.9	8.3±5.9	6.3±5.3	<0.01
RA	17.5±8.0	19.3±9.4	15.9±8.9	17.0±9.0	14.9±8.1	19.4±8.5	<0.01

The values are mean±one standard deviation.
CE angle: Center-edge angle (degree), AA: Acetabular angle (degree), AD: Acetabular depth (mm), ARO: Acetabular roof obliquity (degree), RA: Roof angle (degree)

fifties, 8.3±5.9° in the sixties and 6.3±5.3° over 70. The average was 6.6±5.6° (5.2±4.8° in male, 8.0±5.9° in female). The roof angle was 17.5±8.0° in the twenties, 19.3±9.4° in the thirties, 15.9±8.9° in the forties, 17.0±9.0° in the fifties, 14.9±8.1° in the sixties, and 19.4±8.5° over 70. The average was 17.4±9.0° (18.6±8.4° in male, 16.1±9.4° in female).

There were no significant differences in the CE angle and acetabular angle related to age ($p>0.05$), whereas significant differences were found in the acetabular depth, acetabular roof obliquity and roof angle ($p<0.01$). No significant differences were observed in the CE angle related to gender. However, the acetabular angle, acetabular depth, acetabular roof obliquity and roof angle differed significantly by gender (Table 2, 3).

To understand the relationship between the CE angle, acetabular depth, acetabular angle, acetabular roof obliquity and roof angle, we compared the data using the Pearson correlation coefficient. Therefore, the acetabular depth ($r=0.60$, $p<0.01$) and roof angle ($r=0.59$, $p<0.01$) were significantly increased compared with CE angle, whereas the acetabular angle ($r=-0.65$, $p<0.01$) and acetabular roof obliquity ($r=-0.66$, $p<0.01$) were significantly decreased. The values between two standard deviation from the mean represented a normal range (95% confidence). Therefore, the critical values for the diagnosis of acetabular dysplasia were defined as a CE angle of less than 20° or an acetabular angle of more than 45° (44° in male, 45° in female). The proportion of acetabular dysplasia was 1.8% overall (1.3% in male, 2.2% in female).

Table 3. Values of each parameter of the hip joint by gender of subjects

	Gender		p value	Total
	Male	Female		
CE angle	32.6±5.7	32.3±6.8	>0.05	32.5±6.4
AA	36.5±3.5	37.5±3.8	<0.01	37.0±3.7
AD	11.5±2.6	10.2±2.6	<0.01	10.9±2.7
ARO	5.2±4.8	8.0±5.9	<0.01	6.6±5.6
RA	18.6±8.4	16.1±9.4	<0.01	17.4±9.0

The values are mean±one standard deviation.
CE angle: Center-edge angle (degree), AA: Acetabular angle (degree), AD: Acetabular depth (mm), ARO: Acetabular roof obliquity (degree), RA: Roof angle (degree)

DISCUSSION

Acetabular dysplasia is the underdevelopment of the acetabular roof; consequently the surface available for weight bearing is smaller than normal and is therefore subject to greater pressure proportionally (Sharp, 1961). The CE angle, acetabular angle, acetabular depth, acetabular roof obliquity and roof angle have been used to examine the anatomical structure of the acetabulum and to diagnose acetabular dysplasia.

The concept of the CE angle was developed by Wiberg (Fredensborg, 1976) as a measurement of the degree of acetabular development and dislocation of the femoral head. A CE angle of more than 25° is regarded as normal, whereas a value less of than 20° is abnormal. Fredensborg showed that there were no differences in CE angles between hip joints.

He reported that CE angles increased slowly until age 15 and then maintained a constant value with no differences between sexes (Fredensborg, 1976). Nakamura *et al.* reported the average CE angle in Japan was 32.2±6.4° (32.2±6.9° in male, 32.1±6.0° in female) and Yoshimura *et al.* reported 30.9±6.4° in male and 31.5±7.9° in female (Nakamura *et al.* 1989; Yoshimura *et al. 1994).* Lau *et al.* reported the average CE angle in Chinese was 35.5±6.4° and Croft *et al.* reported the average in England was 36.2±6.9° (Croft *et al.* 1991; Lau *et al. 1995).* In Stulberg and Harris's report, the white male average was 37° while the white female was 35° (Stulberg and Harris, 1974). Our study showed the average CE angle was 32.5±6.3° (32.6±5.7° in male, 32.3±6.8° in female). Therefore, we found that the degree of acetabular dysplasia in our study was similar to that of Japan and different from those of China and England.

The advantages of the CE angle are its simplicity and its consistency over age and between sexes (Fredensborg, 1976). However, the CE angle may not provide an accurate measurement for the following reasons; 1) the center point of a deformed femoral head cannot be located accurately; 2) subluxation, or simple loss of joint space alter the CE angle; and 3) subluxation of the contralateral hip affects the CE angle (Sharp, 1961). Therefore, the acetabular angle (Sharp, 1961) and acetabular depth (Murray, 1965) were used for the diagnosis of acetabular dysplasia to compensate for the limitation of the CE angle. Sharp reported a new measurement, acetabular angle, which can measure the degree of acetabular development (Sharp, 1961). This method can diagnose the acetabular dysplasia if the angle is above 42°. Based on Nakamura's report, the average acetabular angle in Japan was 38.0±3.6° (37.3±3.7° in male, 38.6±3.4° in female) (Nakamura *et al.* 1989). Stulberg and Harris reported the average acetabular angle was 32.2° in white males and 32.1° in white females, whereas the average in our study was 37.0±3.7° (36.5±3.5° in male, 37.5±3.8° in female). No significant differences in age and gender were observed (Stulberg and Harris, 1974).

Murray reported another method, acetabular depth, to compensate for the inaccuracy of the CE angle which was caused by formation of a bony spur of lateral margin of the acetabulum and displacement of the femoral head (Murray, 1965). It is considered acetabular dysplasia if the acetabular depth is less than 9 mm (Murray, 1965; Croft *et al.* 1991; Lau *et al.* 1995). Lau *et al.* reported the average acetabular depth in the Chinese population was 11.8 mm and Croft *et al.* reported that it was 14.4mm in the English (Croft *et al.* 1991; Lau *et al.* 1995). The depth value of our study was 10.9±2.7 mm (11.5±2.6 mm in male, 10.2±2.6 mm in female). Lau *et al.* showed a correlation between CE angle and acetabular depth (r=0.75) and our study also showed a correlation (r=0.60, $p<0.0001$) (Lau *et al.* 1995). However, since the value of acetabular depth decreased with an increase in age, and the value for females was less than that of males, acetabular depth may not be a good measure of acetabular dysplasia.

Massie and Howorth reported acetabular roof obliquity was normal if the angle was less than 30° under one year of age, if the angle was less than 25° between age 1 and 3, and if the angle was less than 20° from age 3 to adult (Massie and Howorth, 1950). The report of Nakamura *et al.* showed the Japanese average was 4.4±5.1° (4.6±4.1° in male, 5.4±4.5° in female), whereas our study indicated the average was 6.6±5.6° (5.2±4.8° in male, 8.0±5.9° in female)(Nakamura *et al.* 1989). Interestingly, we observed the values of males were significantly lower than those of females and a discrepancy was observed between ages. Also, there was a correlation between the CE angle and acetabular roof obliquity ($r=-0.66$, $p<0.001$). However, it may not be a good diagnostic method for acetabular dysplasia because of the differences between ages and sexes and its high standard deviation.

In 1974, Stalburg and Harris reported the roof angle showed a decrease in value with severe acetabular dysplasia. Nakamura *et al.* reported the roof angle was 19.3±10.3° (20.9±10.1° in male, 17.9±10.2° in female) in Japan (Nakamura *et al.* 1989). Our study's average was 17.4±9.0° (18.6±8.4° in male, 16.1±9.4° in female). There was a significant difference in the values of females compared to those of males as well as between ages. However, it also showed a large contrast among ages and sexes and high standard deviation. Thus, it is not possible to use roof angle as a diagnostic method for acetabular dysplasia. Therefore, the CE angle

was considered useful as a diagnostic method for acetabular dysplasia. In cases to which CE angle could not be applied, acetabular dysplasia could be determined by acetabular angle according to the sex of patients and by other parameters according to sex and age of patients. The prevalence of acetabular dysplasia was 1.1% in Hong Kong (Lau *et al.* 1995) and 1.0% in England (Croft *et al.* 1991). In our study the prevalence was 1.8% (1.3% in male, 2.2% in female). This suggests the prevalence of acetabular dysplasia is higher in Asia than in Western countries (Nakamura *et al.* 1989; Croft *et al.* 1990; Lau *et al.* 1995).

In summary, we analyzed the radiological characteristics of the CE angle, acetabular angle, acetabular depth, acetabular roof obliquity, and roof angle and their correlation to acetabular dysplasia. Our data suggested that the prevalence of acetabular dysplasia in Asia is higher than in Western countries. We also concluded that the CE angle and acetabular angle are considered useful as a diagnostic method for acetabular dysplasia.

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