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Abstract	***Aims*** Femoroacetabular impingement (FAI) has been highlighted and well documented primarily in Western countries and there are few large studies focused on FAI-related morphological assessment in Asian patients. We chose to investigate this subject. ***Patients and Methods*** We assessed the morphology of the hip and the prevalence of radiographic FAI in Japanese patients by measuring predictors of FAI. We reviewed a total of 1178 hips in 695 men and 483 women with a mean age of 58.2 years (20 to 89) using CT images that had been obtained for reasons unrelated to symptoms from the hip. We measured the lateral centre edge angle, acetabular index, cross-over sign, alpha angle, and anterior femoral head-neck offset ratio. ***Results*** A total of 441 hips (37.4%) had pincer-type deformity (41.7% men, 31.3% women) and 534 (45.3%) had cam-type deformity (54.4% men, 32.3% women). Moreover, 773 hips (65.6%) had at least one parameter that predisposes to FAI (74.0% men, 53.6% women) and 424 hips (36.0%) had two or more parameters (43.6% men, 25.0% women). ***Conclusion*** The prevalence of radiographic FAI was common in Japanese patients who are generally considered to have dysplastic hips. Take home message: Radiographic FAI is common even in dysplastic hips. A comprehensive evaluation is essential to predict the development of FAI in clinical practice. Cite this article: *Bone Joint J* 2016;98-B:??-??.
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Femoroacetabular impingement (FAI) has recently been recognised as a cause of pain in the hip.[[1,2]] It is defined as impingement between the head-neck junction of the femur and the acetabular margin due to morphological abnormalities such as a small offset of the femoral head–neck junction or an aspherical femoral head in cam impingement, and acetabular over-coverage in pincer impingement.[[1]] Clinically, establishing the morphological features associated with FAI by radiographic evaluation allows early diagnosis and treatment, which could reduce symptoms and prevent irreversible degenerative changes of the hip joint.[[3,4]]

Since the concept of FAI was first described,[[1]] considerable information has been published on the radiographic characteristics of FAI, [[7]] and many imaging parameters have been suggested and used clinically for its diagnosis. FAI is common in Western countries and most published data on FAI is based on studies of Caucasians. FAI has been proposed as a potential cause of primary osteoarthritis of the hip (OA). [[1,2]] The concept of FAI seems to be acceptable for Westerners because primary OA of the hip is a major problem in Caucasians. In contrast, FAI is relatively less common in Asian countries because acetabular dysplasia is the main cause of OA.[[5]] The morphological features of the hip appear to be different in different ethnic groups and it has been suggested that the Japanese hip is typically shallower than that of Caucasians.[[6]] We have questioned the extent of FAI-related morphological abnormalities in Asians. The aetiology of FAI, particularly in Japanese people who have a higher incidence of dysplasia, [[5,6]] is still unclear.

The aims of this study were twofold: to assess the morphology of the hip in Japanese patients, both the acetabulum and femur, by measuring predictors of FAI using CT scan with consideration of age and gender, and to determine the prevalence of the radiographic features of cam and pincer types of FAI in Japanese patients according to the cut-off values, which were determined to be factors that predispose to FAI in studies from Western countries.

Patients and Methods

We retrospectively reviewed 1200 hips in 600 consecutive Japanese patients (352 men, 248 women) who underwent abdominal and pelvic CT scan for reasons unrelated to symptoms from the hip, between September 2010 and October 2012. Exclusion criteria were: Perthes'-like deformity of the hip, OA of the hip, and a post-operative state such as following arthroplasty, osteosynthesis for femoral fracture, or pelvic osteotomy. OA of the hip was defined as the presence of narrowing of the joint space, sclerosis and osteophytes. After exclusion, 1178 hips in 695 men and 483 women with a mean age of 58.2 years (20 to 89) were studied. We defined the "young" group as patients aged < 40 years and the "elderly" group as those aged ≥ 40 years.

All CT scans had been ordered from the departments of general surgery, urology, or gynecology at our institution. Each was performed using a 16-detector-row scanner (Aquilion 16; Toshiba Medical System, Tokyo, Japan), and 1 mm slice thickness multiplanar reconstruction images were visualised with the Aquarius NET Server (TeraRecon, Inc; San Mateo, California) under standard bone settings for analysis. Two orthopaedic surgeons (KM and TG) blinded to the clinical details evaluated the images and reviewed the radiographic parameters of FAI for both the acetabulum and femur.

The parameters which were recorded were: the lateral centre edge angle (LCE), [[7,12,13]] acetabular index (AI), [[9,13]] cross-over sign (COS), [[7,8,12,13]] alpha angle (AA), [[10,12,13]] and anterior femoral head-neck offset (FHNO) ratio. [[11,12]] At the time of measurement, the position of the pelvis was standardised using the anterior pelvic plane (Fig. 1). The LCE, AI, and COS were assessed on the coronal 3D model of the pelvis (Figs 2 and 3). A positive COS was defined with the anterior wall being lateral to the posterior wall in the cranial part of the acetabulum and crossing the posterior wall in the distal part (Fig 3).[[7,8]] The AA and FHNO were evaluated in the oblique axial plane through the centre of the femoral neck (Fig. 4). AAs were evaluated in a clockwise manner, with 12 o’clock being the superior aspect, three o’clock being the anterior aspect, and six o’clock being the inferior aspect on radial sequences of the right hip. In addition we measured AAs at three different slices: AA1 at one o’clock (anterosuperior), AA2 at two o’clock (anterosuperior), and AA3 at three o’clock (anterior) (Fig. 5). The FHNO was measured at the anterior part of the femoral head (three o'clock) and the FHNO ratio was calculated by dividing the FHNO by the diameter of the femoral head. We defined the cut-off value of each measurement as LCE > 40°, AI < 0°, AA > 55° and FHNO ratio < 0.15 as previously described.[[7,9-13]] We diagnosed the presence of radiographic pincer-type deformity as at least one abnormal value in LCE, AI, or positive COS, and the cam-type deformity if AA1, 2, 3, or FHNO ratio was abnormal. A diagnosis of acetabular dysplasia was made if LCE ≤ 20°.[[14]]

The study had ethical approval.

[[Fig 1]]

[[FigCap]]The anterior pelvic plane involving the bilateral anterior superior iliac spines and the top of the pubis symphysis was the reference plane. At the time of measurement, the position of the pelvis was aligned to the anterior pelvic plane vertically.

[[Fig 2]]

[[FigCap]]The coronal transparent three-dimensional pelvis model. The lateral centre edge angle (LCE) represents the angle between the vertical axis of the pelvis and a line running through the center of the femoral head and the lateral edge of the acetabulum. Acetabular index (AI) represents the angle between the pelvic horizontal line and a line connecting the medial and lateral edge of the acetabular roof. The line connecting the teardrops is defined as the transverse reference (dotted line).

[[Fig 3]]

[[FigCap]]The coronal transparent three-dimensional pelvic models show the hips with the negative (a) and positive cross-over sign (COS) (b). A white line indicates the posterior wall of the acetabulum and a dotted line indicates the anterior wall.

[[Fig 4]]

[[FigCap]]In measurement of the alpha angle (AA), a best-fit circle was drawn around the femoral head. The first arm was the axis of the femoral neck and the second arm was drawn from the centre of the circle, anteriorly to the point where the femoral head extends beyond the margin of the circle (a). The femoral head-neck offset (FHNO) was measured by assessing the perpendicular distance between a line parallel to the central axis of the neck drawn along the anterior cortex and a parallel line along the anterior outer part of the femoral head (b).

[[Fig 5]]

[[FigCap]]A three-dimensional CT image shows the radial slices for the measurements of alpha angles (a). Each reference plane for reconstruction of the radial angle is indicated by the dotted line. Examples of the alpha angles (AA1, AA2, and AA3) on reformatted radial axial images of the femoral head are shown in (b), (c), and (d), respectively.

Statistical analysis

This was performed using SPSS software, version 22.0 (SPSS Inc., Chicago, Illinois). The Mann-Whitney U test was used to analyse continous variables and the chi-squared test for categorical values. Statistical differences were considered significant if the p-value was < 0.05. The reliability of the radiographic analysis was assessed by determining the inter- and intra-observer reproducibility in 50 randomly selected patients. Measurements of all the parameters were repeated twice, at least two weeks apart, by two independent observers (KM and TG) who were blinded to the results reported by the other, and the intra- and interclass correlation coefficients (ICC) and the Bland-Altman analyses for all the radiographic parameters (LCE, AI, AA1, 2 and 3 and the FHNO ratio) and Kappa statistic for diagnosing COS were evaluated. Intra- and interclass correlation of these measurements and reproducibility in diagnosing COS were substantial or almost perfect (ICC: 0.69 to 0.97, kappa value: 0.74) (Table I).

[[TblCap]]Table I. Reliability of the radiographic parameters examined in this study

Table I. Reliability of the radiographic parameters examined in this study

Parameters	Examiner	Intra-observer reliability ICC (1.2) (95%CI)	Inter-observer reliability ICC (2.1) (95%CI)
LCE	KM	0.90 (0.85–0.94)	0.94 (0.90–0.96)
	TG	0.96 (0.94–0.98)	
AI	KM	0.96 (0.94–0.98)	0.97 (0.95–0.98)
	TG	0.97 (0.95–0.98)	
AA3	KM	0.77 (0.65–0.86)	0.71 (0.60–0.82)
	TG	0.78 (0.65–0.86)	
AA2	KM	0.77 (0.68–0.89)	0.86 (0.79–0.92)
	TG	0.80 (0.71–0.89)	
AA1	KM	0.86 (0.80–0.92)	0.84 (0.78–0.90)
	TG	0.69 (0.58–0.80)	
FHNO ratio	KM	0.95 (0.91–0.97)	0.78 (0.70–0.87)
	TG	0.78 (0.69–0.87)	

[[TblNote]]LCE: lateral centre edge angle, AI: acetabular index, AV: anteversion angle, AA3: alpha angle at three o'clock, AA2: alpha angle at two o'clock, AA1: alpha angle at one o'clock, FHNO: head-neck offset; ICC, intraclass correlation coefficient; CI, confidence interval

Results

The value of each parameter in all patients in relation to age and gender is shown in Table II. Statistically significant differences in all parameters except the anterior FHNO were seen between the genders. Men tended to have greater acetabular cover than women as they had a greater LCE and lower AI. Asphericity of the femoral head in men was also revealed by the greater AA1, 2 and 3 and a lower FHNO ratio. As for the differences between the ages, the elderly group showed a significantly greater LCE and lower AI than the young group. Among the young patients, there were lower AIs and FHNO ratios and greater AAs, which are predisposing factors for FAI in men (Table III).

[[TblCap]]Table II. Measurement value of each parameter in all hips according to age and gender

	Age (years)	**LCE (°)**	**AI (°)**	**AA3 (°)**	**AA2 (°)**	**AA1 (°)**	**FHNO ratio**	**FHNO (mm)**
Total (N = 1178)	58.2 ± 14.8 (20 to 89)	33.6 ± 7.6 (5.2 to 62.8)	4.1 ± 6.8 (−18.9 to 36.6)	44.2 ± 8.0 (21.6 to 73.0)	50.6 ± 6.6 (31.7 to 71.8)	49.7 ± 7.4 (25.7 to 70.4)	0.18 ± 0.05 (0.03 to 0.32)	8.0 ± 2.2 (1.6 to 14.5)
Men (N = 695)	59.5 ± 14.4 (22 to 89)	34.1 ± 4.1 (5.2 to 62.8)	3.1 ± 6.5 (−18.9 to 36.6)	45.3 ± 8.1 (26.5 to 73.0)	51.7 ± 6.6 (31.7 to 71.8)	50.7 ± 6.9 (29.1 to 70.4)	0.17 ± 0.05 (0.03 to 0.31)	8.0 ± 2.3 (1.6 to 14.5)
Women (N = 483)	56.4 ± 15.2 (20 to 88)	32.9 ± 7.5 (13.0 to 55.2)	5.6 ± 7.0 (−15.0 to 25.9)	42.6 ± 7.6 (21.6 to 69.4)	49.0 ± 6.4 (32.3 to 69.0)	48.3 ± 7.7 (25.7 to 68.5)	0.19 ± 0.05 (0.05 to 0.32)	8.1 ± 1.9 (2.2 to 13.2)
p value	p < 0.001	p = 0.030	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p = 0.109
Young (N = 154)	30.7 ± 9.5 (20 to 39)	31.3 ± 6.3 (17.2 to 50.6)	6.1 ± 5.4 (−11.5 to 21.2)	46.7 ± 8.2 (30.7 to 67.5)	52.6 ± 6.4 (38.9 to 68.5)	52.6 ± 5.5 (40.4 to 65.5)	0.18 ± 0.05 (0.04 to 0.28)	8.0 ± 2.0 (2.2 to 12.6)
Elderly (N = 1024)	62.4 ± 10.8 (40 to 89)	34.0 ± 7.8 (5.2 to 62.8)	3.8 ± 7.0 (−18.9 to 36.6)	43.8 ± 7.9 (21.6 to 73.0)	50.3 ± 6.6 (31.7 to 71.8)	49.3 ± 7.5 (25.7 to 70.4)	0.17 ± 0.05 (0.06 to 0.32)	8.0 ± 2.2 (1.6 to 14.5)
p-value	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p = 0.384	p = 0.948

[[TblNote]]LCE: lateral centre edge angle, AI: acetabular index, AA3: alpha angle at three o'clock, AA2: alpha angle at two o'clock, AA1: alpha angle at one o'clock, FHNO: head-neck offset. All data are shown as mean ± standard deviation (range). The p-values were calculated by Mann-Whitney U tests.

[[TblCap]]Table III. Values of CT measurement of hips in young patients based on gender

	Age (years)	LCE (°)	AI (°)	AA3 (°)	AA2 (°)	AA1 (°)	FHNO ratio	FHNO (mm)

Men (N = 78)	30.7 ± 5.0 (22 to 39)	31.5 ± 5.5 (17.7 to 44.8)	5.3 ± 4.9 (−8.3 to 15.5)	48.9 ± 8.1 (30.7 to 67.5)	54.4 ± 5.8 (40.8 to 68.5)	54.0 ± 5.3 (44.7 to 65.5)	0.17 ± 0.04 (0.06 to 0.26)	8.1 ± 2.1 (2.8 to 12.6)
Women (N = 76)	30.7 ± 5.0 (20 to 39)	31.1 ± 7.1 (17.2 to 50.6)	7.0 ± 5.7 (−11.5 to 21.2)	44.3 ± 7.7 (31.9 to 66.6)	50.6 ± 6.4 (38.9 to 67.1)	51.1 ± 5.4 (40.4 to 65.0)	0.19 ± 0.04 (0.05 to 0.28)	7.9 ± 1.9 (2.2 to 12.0)
p-value	p = 0.966	p = 0.724	p = 0.049	p < 0.001	p < 0.001	p = 0.001	p = 0.001	p = 0.603

[[TblNote]]LCE: lateral centre edge angle, AI: acetabular index, AV: anteversion angle, AA3: alpha angle at three o’clock, AA2: alpha angle at two o’clock, AA1: alpha angle at one o’clock, FHNO: head-neck offset. All data are shown as mean ± standard deviation (range). The p-values were calculated by Mann-Whitney U tests.

The prevalence of abnormal values for each parameter in all patients is shown in Tables IV and V. Abnormal AI, AA1, AA2, and FHNO ratios were relatively more common than abnormal LCEs in all subjects. Abnormal AI, AA 1,2 and 3, and FHNO ratios were more prevalent in men than in women. Moreover, there were greater abnormal rates of AA1 and 2 in young men than in young women (Table V). Overall, 441 hips (37.4%) showed evidence of pincer-type deformity and 378 (45.3%) showed cam-type deformity. All types of impingement were more common in men than in women. A total of 773 patients (65.6%) had at least one abnormal parameter, and 424 (36.0%) had two or more abnormal parameters. Moreover, 136 hips (11.5%) had acetabular dysplasia and the prevalence of cam-type deformity in these patients was similar to that in the whole cohort. (Table VI). Although the prevalence of cam-type deformity in young men was slightly higher than that in all patients, relatively lower rates of abnormal parameters were mostly seen in young patients (Table VII).

[[TblCap]] Table IV. Prevalence of abnormal value in each parameter based on gender

	LCE (°)	AI (°)	AA3 (°)	AA2 (°)	AA1 (°)	FHNO ratio	FHNO (mm)	COS
Cut-off value	> 40°	< 0°	> 55°	> 55°	> 55°	< 0.15	< 8 mm	positive
Total (n = 1178)	7.0% (82 hips)	23.2% (273 hips)	9.3% (109 hips)	25.0% (295 hips)	22.5% (265 hips)	29.7% (350 hips)	47.2% (556 hips)	17.2% (203 hips)
Men (n = 695)	7.3% (51 hips)	26.5% (184 hips)	11.4% (79 hips)	30.2% (210 hips)	26.0% (181 hips)	38.0% (264 hips)	49.9% (347 hips)	19.0% (132 hips)
Women (n = 483)	6.4% (31 hips)	18.4% (89 hips)	6.2% (30 hips)	17.6% (85 hips)	17.4% (84 hips)	17.8% (86 hips)	43.3% (209 hips)	14.7% (71 hips)
p-value gender comparison	p = 0.563	p = 0.001	p = 0.003	p < 0.001	p < 0.001	p < 0.001	p = 0.024	p = 0.055

[[TblNote]]LCE: lateral centre edge angle, AI: acetabular index, AA3: alpha angle at three o'clock, AA2: alpha angle at two o'clock, AA1: alpha angle at one o'clock, FHNO: head-neck offset, COS: cross-over sign. The p-values were calculated by chi-squared tests.

[[TblCap]]Table V. Prevalence of abnormal value in the hips of young patients based on gender

	LCE (°)	AI (°)	AA3 (°)	AA2 (°)	AA1 (°)	FHNO ratio	FHNO (mm)	COS
Cut-off value	> 40°	< 0°	> 55°	> 55°	> 55°	< 0.15	< 8 mm	positive
Young total (N=154)	9.1% (14 hips)	9.1% (14 hips)	15.6% (24 hips)	37.0% (57 hips)	26.6% (41 hips)	19.5% (30 hips)	41.6% (64 hips)	23.4% (36 hips)
Young men (N=78)	7.7% (6 hips)	12.8% (10 hips)	20.5% (16 hips)	48.7% (38 hips)	38.5% (30 hips)	24.4% (19 hips)	38.5% (30 hips)	29.5% (23 hips)
Young women (N=76)	10.5% (8 hips)	5.3% (4 hips)	10.5% (8 hips)	23.7% (18 hips)	14.5% (11 hips)	14.5% (11 hips)	44.7% (34 hips)	15.8% (12 hips)
p-value gender comparison	p = 0.586	p = 0.160	p = 0.120	p = 0.001	p = 0.001	p = 0.155	p = 0.513	p = 0.054

[[TblNote]]LCE: lateral centre edge angle, AI: acetabular index, AA3: alpha angle at three o'clock, AA2: alpha angle at two o'clock, AA1: alpha angle at one o'clock, FHNO: head-neck offset, COS: cross-over sign. The p-values were calculated by chi-squared tests.

[[TblCap]]Table VI. Prevalence of findings associated with femoroacetabular impingement (FAI) in the hips of all patients

	Prevalence of pincer type	**Prevalence of cam type**	**Prevalence of combined type**	**All types of FAI**	
Definition	Abnormal value in LCE, AI, or COS	Abnormal value in AAs or FHNO ratio		At least one abnormal parameter	Two or more abnormal parameters
Total (N = 1178)	37.4% (441 hips)	45.3% (534 hips)	17.1% (202 hips)	65.6% (773 hips)	36.0% (424 hips)
Men (N = 695)	41.7% (290 hips)	54.4% (378 hips)	22.2% (154 hips)	74.0% (514 hips)	43.6% (303 hips)
Women (N = 483)	31.3% (151 hips)	32.3% (156 hips)	9.9% (48 hips)	53.6% (259 hips)	25.0% (121 hips)
p-value gender comparison	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
Dysplasia total (N=136)	7.4% (10 hips)	40.4% (55 hips)	14.7% (20 hips)	62.5% (85 hips)	35.3% (48 hips)

[[TblNote]] LCE: lateral centre edge angle, AI: acetabular index, COS: cross-over sign, AAs: alpha angles (AA1, AA2, or AA3), FHNO: head-neck offset. The p-values were calculated by chi-squared tests.

[[TblCap]]Table VII. Prevalence of findings associated with femoroacetabular impingement (FAI) in the hips of young patients based on gender

	Prevalence of pincer type	**Prevalence of cam type**	**Prevalence of combined type**	**All types of FAI**	
Definition	Abnormal value in LCE, AI, or COS	Abnormal value in AAs or FHNO ratio		At least one abnormal parameter	Two or more abnormal parameters

Young total (N = 154)	29.9% (46 hips)	44.8% (69 hips)	16.2% (25 hips)	59.7% (92 hips)	33.8% (52 hips)
Young men (N = 78)	37.2% (29 hips)	62.8% (42 hips)	24.4% (19 hips)	69.2% (54 hips)	48.7% (38 hips)
Young women (N = 76)	22.4% (17 hips)	35.5% (27 hips)	7.9% (6 hips)	50.0% (38 hips)	18.4% (14 hips)
p-value	p = 0.053	p = 0.001	p = 0.008	p = 0.001	p < 0.001

[[TblNote]] LCE: lateral centre edge angle, AI: acetabular index, COS: cross-over sign, AAs: alpha angles (AA1, AA2, or AA3), FHNO: head-neck offset. The p-values were calculated by chi-squared tests.

Discussion

In this study, we retrospectively reviewed 1178 CT scans of Japanese hips which had been acquired for non-orthopaedic conditions. These provided substantial data on the morphology of the hip and the prevalence of FAI-related abnormalities in Japanese patients. Most of the bony abnormalities related to FAI have been traditionally assessed on plain radiographs. However, this evaluation has several disadvantages including poor reproducibility and that it is greatly affected by the positioning of the patient and the imaging conditions such as film-focus distance or X-ray incident angle.[[15]] In contrast, the morphology can be assessed using CT scans independent of the position of the patient using post-processing techniques. It can also evaluate many planes in detail and with high accuracy.[[16]] The number of patients we studied is one of the largest among reports of FAI-related morphological assessment using CT in the literature (Table VIII).

The morphological parameters associated with FAI have been previously investigated in several studies using similar methods of measurement based on CT scans (Table VIII). Lepage-Saucier et al[[4]] and Kang et al[[12]] reported greater mean LCE angles in men (35° and 36.1°, respectively) than in women (32° and 33°, respectively), whereas Ergen et al[[17]] showed a mean LCE angle of 37.3° with no gender differences. In the current study, the LCE angles were larger in men and in the elderly patients, and these angles in each cohort, especially in young patients, were relatively lower than those in previous reports.[[4,12,17]] Lepage-Saucier et al[[4]] also reported a mean AI of 6° without gender differences,[[4]] and Chakraverty et al[[3]] found a mean AI of 4.4° in young asymptomatic men and women. We found lower mean AIs in men and in elderly patients. Although the AIs in men did not differ much from those in previous reports, young women had greater AIs in our study. The COS was used to evaluate acetabular version. An accurate assessment of the COS can be obtained by adjusting pelvic tilt using post-processing techniques of CT images.[[8]] Kang et al[[12]] reported that 20% (20 of 100 hips) of asymptomatic patients had a positive COS, with 71% sensitivity and 88% specificity, with the position of the pelvis being standardised. We found that the COS was positive in 17.2% of patients. Although there was no statistically significant difference ($p = 0.06$), a positive COS was more common in men

(19%) than in women (14.7%). These results reflect the fact that the Japanese acetabulum, especially in young women, has been considered to be dysplastic.

[[TblCap]]Table VIII. Previous reports of morphology associated with femoroacetabular impingement (FAI) using CT images

	Number of hips	Mean age (yrs)	Symptoms	LCE (°)	AI (°)	AA3 (°)	FHNO (mm)
Lepage-Saucier et al.[4]	188	49	Asymptomatic	Male: 35 Female: 32	Male: 6 Female: 6	Male: 50 Female: 50	Male: 9 Female: 8
Ergen et al.[17]	131	32.9	Asymptomatic	37.3 (no sex difference)	NA	41.6° (male > female)	9.0 (no gender difference)
Chakraverty et al.[3]	100	30.8	Asymptomatic	31.5	4.4	46	9
Kang et al.[12]	100	< 40	Asymptomatic	Male: 36.1 Female: 33	NA	Male: 44 Female: 46.9	Male: 10 Female: 9
Current study	1178	58.2	None selected	Male: 34.1 Female: 32.9	Male: 3.1 Female: 5.6	Male: 45.3 Female: 42.6	Male: 8.0 Female: 8.1
Current study (young group)	154	< 40	None selected	Male: 31.5 Female: 31.1	Male: 5.3 Female: 7.0	Male: 48.9 Female: 44.3	Male: 8.1 Female: 7.9

[[TblNote]]FAI:, LCE: lateral center edge angle, AI: acetabular index, AA3: alpha angle at three o'clock, FHNO: head-neck offset, NA: not applicable

We identified the mean value of AA in Japanese patients at the anterior (AA3) and anterosuperior (AA1 and 2) segments. It has been reported that the AA at the anterosuperior segment using radial images is relatively large and shows the best discrimination between normal and abnormal hips.[[3,12,18-22]] Khan and Witt[[22]] evaluated the size and location of measurements of the AA using multi-planner CT scans in 42 patients with cam-type FAI and showed that the greatest AA was found at the two o'clock position, followed by the one o'clock position. Our results also revealed similar tendencies: greater values of AA and higher abnormal rates in the one and two o'clock positions than in the three o'clock position. The difference between the anterior and the anterosuperior AA values was approximately 5° in all patients. Furthermore, all AAs in men were greater than those in women. Most recent reports have suggested greater AAs in men, and our results support this.[[3,18,19]] The threshold value for an abnormal AA should be reconsidered based on gender and the location where it is measured.

Ergen et al[[17]] reported a mean FHNO of 9 mm with a rate of abnormality of 25.8% without differences between genders. Kang et al[[12]] also reported a mean FHNO of 9.49 mm (10 mm in men, 9 mm in women) with a rate of abnormality of 12%.The current study revealed a mean FHNO of 8 mm and mean FHNO ratio of 0.18. When FHNO < 8 mm was considered the cut-off value for abnormal FHNO, the prevalence of an abnormal anterior FHNO was nearly 50% (556 of 1178 hips), whereas the abnormal FHNO ratio was 29.7% (350 of 1178 hips) (Table IV). Since Japanese people have a relatively small skeleton, absolute measurements such as FHNO are inadequate for evaluation and result in a higher rate of abnormal findings. Therefore, the FHNO ratio, which is corrected using the diameter of the femoral head, seems to be a more suitable evaluation.

We found that 37.4% (41.7% in men, 31.3% in women) of all patients had pincer-type deformity and 45.3% (54.4% in men, 32.3% in women) had cam-type deformity among seven radiographic features associated with FAI. Moreover, 65.6% of all hips had at least one parameter that predisposes to FAI (74.0% in men, 53.6% in women), and 36.0% had two or more parameters (43.6% in men, 25.0% in women). A similar prevalence of cam-type deformity was observed in patients with dysplasia, indicating that acetabular dysplasia may be associated with a relatively high rate of FAI-related deformities on the femoral side. In the study by Kang et al[[12]] on the prevalence of predisposing factors for FAI (LCE, AV, AA, and FHNO) in 50 asymptomatic patients, 52% of men and 33% of women had at least one abnormal parameter. Chakraverty et al[[3]] reported that 66% (66 of 100 hips) had at least one abnormal parameter (71.7% in men, 57.5% in women) and 29% had two or more abnormal parameters (31.7% in men, 25% in women) among eight radiographic features associated with FAI in asymptomatic patients. Although the study was based on plain radiographs, Laborie et al[[23]] reported that most patients showed morphological features of FAI. In regards to previous reports on the morphology of the hip in Japanese patients, Takeyama et al[[24]] reviewed 946 hips of patients with OA and found that only 0.6% had evidence of FAI.[[24]] Fukushima et al[[14]] reported that the prevalence of radiographic FAI in 87 patients who had undergone total hip arthroplasty (THA) was 27.6%.Mori et al[[25]] reported evidence of radiographic FAI in 29.7% (60 of 202 hips) of patients with early-stage hip OA. Miura et al[[21]] found that 56.3% (58 of 103 hips) of asymptomatic Japanese patients had an abnormal angle of femoral head asphericity in the oblique axial plane and AV on CT scans. They also suggested that the abnormal rate of radiographic FAI increased to 71.8% if a LCE > 39° and AI < 0° were used as criteria for diagnosing FAI.[[21]] Although we could not directly compare our results with those in previous reports because of the different parameters used for evaluation and the different conditions of the patients (most of the cited studies were based on asymptomatic patients and ours were based on patients without knowledge of their background), our results were similar to those in reports from Western countries, with a similar or higher frequency of radiographic FAI compared with previous reports from Japan. Our patients tended to have a shallow hip and there was also an abnormally high incidence of FAI-related deformities, which seems to be contradictory. We used seven parameters which is a relatively large number compared with other reports. A large number of parameters may increase the number that are abnormal. Furthermore, in our results, the shallower hips were observed mainly in young patients and in women, and the numbers of these were relatively small among the total number of patients (154 hips of young patients and 483 hips of women) whereas the number of elderly patients (1024 hips) with greater acetabular cover was substantial. The gender dimorphism, with women having a shallower hip, seems to reflect the ethnic characteristic of Japanese patients. A multi-institutional study in Japan revealed that 89% of patients with OA of the hip presenting to an orthopaedic clinic were female and 84% of them had dysplasia.[[5]]

The study had several limitations. First, we had no information about the condition of the hip in the patients. Therefore, we defined the presence of FAI based on radiographic cut-off values without reference to symptoms or physical examination. Our aim was to make all assessments independent of the morphological data from the imaging study and without any biases, so that our study was exclusively based on osseous morphological features in Japanese patients. When we take into account the prevalence of pain in the hip in the Japanese population, which has been reported to be 1.86% in a large prospective cohort study,[[26]] most of our patients are likely to have been asymptomatic. Secondly, we used a single cut-off value for each parameter based on previous reports. Although several alternative cut-off values for predictors of FAI have been reported, a clear consensus has not been reached. We used cut-off values that have been widely accepted by many authors. Thirdly, there were a relatively large number of elderly patients in our study. Our intention was to evaluate morphological features in patients of all ages, but there are several considerations in the evaluation of elderly patients. FAI presents in young patients, and evaluation of the CT images of elderly patients might be influenced by degenerative changes. Moreover, the patients with obvious dysplasia may develop OA in old age and they might have been excluded from the study as OA of the hip was an exclusion criterion. This may have resulted in some bias in the analysis of acetabular cover between young and elderly patients. Therefore, we separately analysed young patients aged < 40 years as previous major reports focused on the morphology FAI in young patients.[[3,12]] Fourth, although all of our subjects are purely Japanese patients because our country, Japan, is racially homogeneous nation, the previous studies from western countries may involve various races (any of the previous reports did not mentioned about races of the subjects in detail). Therefore, when we compared between our data and previous reports from Western countries, it would not be compared between Japanese and Caucasian.

In conclusion, we have described the morphological features of Japanese hips, which tend to be dysplastic in young patients and in women. We have also reported the prevalence of a FAI-related deformity based on reliable radiographic parameters that are described in current Western literature. We found that this deformity was common in Japanese patients with a similar rate as in the Western population. Further consideration of the cut-off value for each radiographic parameter is needed, especially with absolute values such as FHNO that are affected by the size of skeleton. We should be aware that radiographic features are only one of many factors that predict the development of FAI in clinical practice. A comprehensive evaluation, including clinical history and physical examination, is essential to making a precise diagnosis and to establish the appropriate therapeutic strategy for FAI. Larger prospective studies in various ethnic groups are required to establish the definite diagnostic criteria of FAI.

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Figure 1

Figure 2

Figure 3

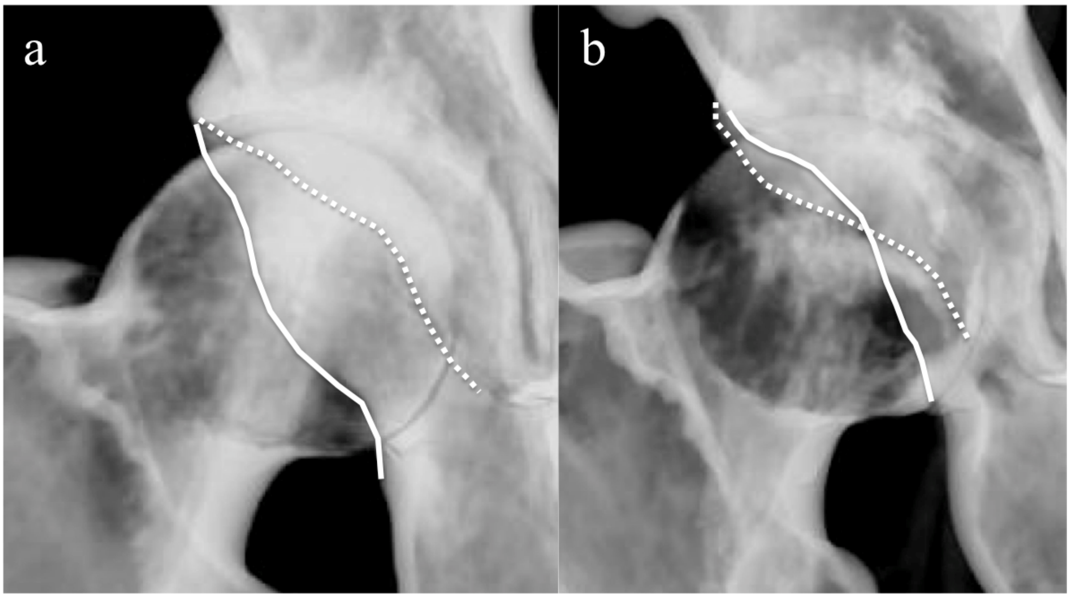

Figure 4

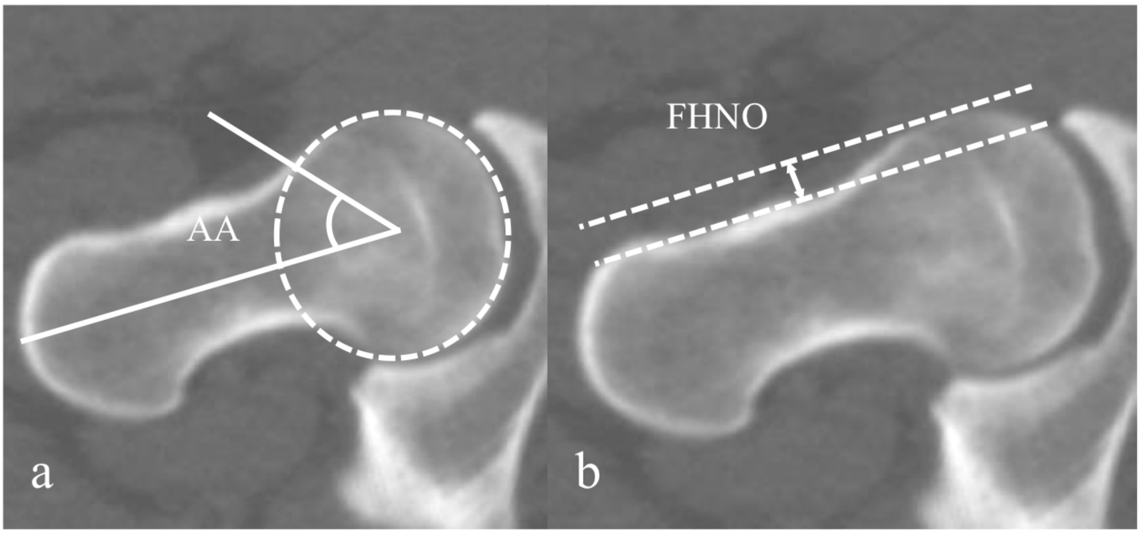

Figure 5