Hip Morphology Characterization

Implications in Femoroacetabular Impingement in a Chilean Population

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Background: Femoroacetabular impingement (FAI) is the result of a mechanical conflict in the hip joint, and its diagnosis is based on clinical and radiological parameters. To our knowledge, there are no published studies describing the radiologic characteristics of FAI in Latin American populations.

Purpose: To describe the radiological features associated with FAI in an asymptomatic Chilean population.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: We prospectively recruited asymptomatic patients with no history or symptoms of hip pathology who underwent abdomen-pelvis computed tomography (CT) for a nonorthopaedic indication. The acetabular and femoral parameters related to FAI were measured.

Results: We studied 101 subjects (202 hips) with a mean age of 36.8 ± 14.4 years. The mean center-edge angle was 39.4° ± 7.2°. The crossover sign was present in 34 cases (33.7%). The mean alpha angle was 49.7° ± 8.3°. Depending on the cut points chosen for FAI-related parameters, between 39.6% and 69.3% of an asymptomatic Chilean population were found to have morphological features related to FAI.

Conclusion: Our findings suggest that the proposed pathological threshold values in the literature cannot be extrapolated to a Chilean population, and this must be taken into consideration when evaluating Latin American patients with hip pain.

Keywords: hip morphological characterization; femoroacetabular impingement; computed tomography of hip

Femoroacetabular impingement (FAI) is a disease caused by abnormal mechanical contact between the acetabular rim and the head-neck union of the proximal femur. It is recognized as a common cause of hip pain in the adolescent and young adult patient population and is currently considered as a possible cause of hip osteoarthritis.[2,4,5,18,31] An FAI diagnosis should be based on clinical evaluation and subsequent appropriate radiological confirmation that aims to detect excessive femoral head coverage (pincer type) and/or insufficient femoral head-neck offset (cam type).

Establishing normal radiologic joint anatomy is of paramount importance because the FAI diagnosis, surgical treatment, and subsequent evaluation depend on it. Accordingly, several studies have described the population characteristics and aimed to define normal values for each radiological parameter involved in FAI.[3,6,8,11,12,14,19,29] To our knowledge, there are no published studies regarding the radiologic characteristics of a Latin American population. Therefore, reliable radiographic parameters of hip morphology in this specific population are needed for precise diagnosis and treatment.

The aim of the present study was to describe the radiological morphology associated with FAI in an asymptomatic Chilean cohort. We also used the published threshold values to determine the prevalence of pathological cases in the asymptomatic cohort.

METHODS

Our institutional ethics review board approved this study, and all participants provided informed consent. We designed

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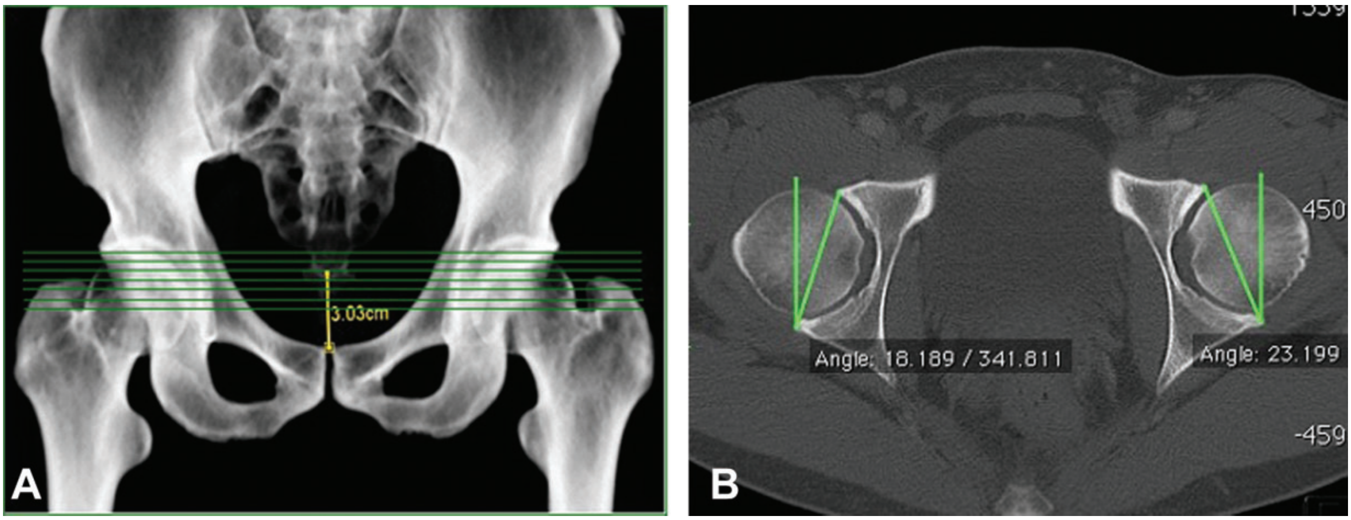

Figure 1. Acetabular version angle measurement. (A) The 7 levels are shown in a 3-dimensional reconstruction of a computed tomography (CT) scan. (B) The measurement is shown for level 6 in an axial CT reconstruction corrected on 3 planes.

a cross-sectional study and included patients with an indication of abdomen and pelvis computed tomography (CT) for nonorthopaedic causes who agreed to participate voluntarily without compensation. The inclusion criteria were patients aged between 15 and 85 years who were asymptomatic and with no history of hip pathology. Patients who had a history of hip pathology, pain attributed to the hip (current or historical), surgical history of the pelvis and/or hip, or imaging findings consistent with arthritis or other local disease were excluded. Patients were prospectively recruited and asked to complete a form approving a request to release their personal and medical histories. Participants were not exposed to additional radiation for the purpose of the study because we only added a bone pelvic CT to the abdominal and pelvis CT.

The images were obtained using a Multi-Slice CT scanner (Somaton Sensation 64; Siemens). The images were acquired using a protocol with 1.5-mm slices taken every 0.3 mm. The information was subsequently processed to multiplanar reconstructions of 3 mm in bone window and 3-dimensional (3D) reconstructions, which were processed with 3D and Inspace software (both Siemens), respectively. Multiplanar reconstructions included pelvis axial planes and axial oblique planes of the femoral neck. Because the pelvis has a 3D spatial arrangement, we considered pelvis position deviations in relation to the CT-scanner table, and axial and 3D reconstructions were corrected in 3 planes (axial rotation, lateral bending, and pelvic tilt).[23,28,30] Then, differences in the distance between the sacrococcygeal junction and the upper edge of the pubis were considered between sexes, as described in previous studies.[20,26]

The following morphological parameters were measured in both hips. In the acetabulum, the center-edge angle of Wiberg, the version angle as measured, and the presence of the crossover sign was assessed.[25] On the femoral side, the alpha angle and femoral head-neck offset were measured. The evaluations of images and measurements were performed by musculoskeletal radiologists using the OsiriX v4.0 program.

The center-edge angle and the crossover sign were measured in a 3D transparent reconstruction, emulating a posterior anterior pelvis radiograph. The acetabular version was measured in axial cuts in the deepest part of the acetabulum, previously corrected in 3 planes (Figure 1).[12,29] The alpha angle and the femoral neck offset were evaluated in axial oblique neck cuts.[21] Three levels were determined (cephalic, medium, and caudal neck), and measurements were performed in the center of each level. This method allowed evaluation of the anterior-superior zone, which is considered a cornerstone in FAI (Figure 2). The femoral head-neck offset is the distance between the anterior margin femoral neck and the anterior margin of the femoral head and was evaluated in the same 3 zones as the alpha angle.

The threshold values used to determine the prevalence of individuals that could be labeled as pathological were as follows: (1) pincer type, Wiberg angle >40° and/or presence of crossover sign[27]; (2) cam type, alpha angle >50° at mid level[21]; and (3) mixed type, coexisting pincer and cam types.

The statistical workup consisted of an exploratory analysis of the variables in the study. The total mean of a parameter (ie, alpha angle) was calculated by averaging the right and left hip of each individual, and this value was used to report the mean of the sample. For statistical inference, the analysis was based on each patient and joint laterality to avoid violating the independence of measures principle.[10] If a normal distribution was confirmed by a Shapiro-Wilk test ($P > .15$), a Student t-test was used; otherwise, a nonparametric Wilcoxon test was used. A proportions test was used to compare frequencies. Also calculated were an overall mean for the alpha angle and Wiberg angle, including the right and left hip, using the following equations:

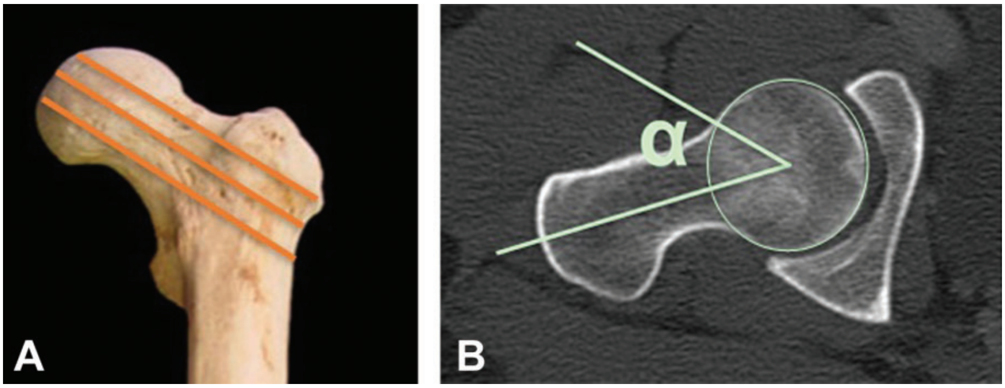

Figure 2. Alpha angle measurement. (A) The 3 cephalic, medium, and caudal neck levels were determined. (B) Measurement in the second level in an oblique axial computed tomography of the femoral neck.

$$\frac{\sum([\text{alpha angle right hip}\,(i) + \text{alpha angle left hip}\,(i)]/2)}{101}$$

and

$$\frac{\sum([\text{Wiberg angle right hip}\,(i) + \text{Wiberg angle left hip}\,(i)]/2)}{101}$$

where i stands for each observation ($i = 0, 1, 2, \ldots, 101$).

We set the significance at .05. Data were analyzed using the statistical program STATA v.11.1 (Stata Corp).

RESULTS

Exploratory Analysis Sample

We studied 202 hips in 101 subjects, with a mean age ± SD of 36.8 ± 14.4 years. Of these, 60 (59.4%) were males and 41 (40.6%) were females, and their respective body mass indices were 25.8 ± 2.7 kg/m^2 and 24.70 ± 4.0 kg/m^2. The mean weight and height of the total group were 71.6 ± 13.0 kg and 1.68 ± 0.09 cm, respectively.

Center-Edge Angle (Wiberg)

The mean center-edge angle was 39.2° ± 7.7° on the right side and 39.8° ± 7.5° on the left. The overall mean center-edge angle was 39.4° ± 7.2°. The mean value for all subjects was 39.5° ± 7.2°. The center-edge angle values by sex and laterality are shown in Table 1. There was a positive correlation between the center-edge angle that was significant in both hips, with r values of 0.49 in the right hip ($P = .00$) and 0.42 in the left hip ($P = .00$).

Crossover Sign

The crossover sign was present in 34 cases (33.7%), with 24 bilateral cases (23.8%), right side only in 7 cases (6.9 %), and left side only in 3 cases (2.9 %). When analyzed by sex, it was negative in 42 males (70.0%), positive on the right in 5 subjects (8.3%), on the left in 2 cases (3.3%), and bilaterally in 11 cases (18.3%). Among females, 25 (61%) showed no crossover signs, while it was present bilaterally in 13 subjects (31.7%). In 2 cases (4.9%) it was on the right side, and in 1 case on the left (2.4%). There were no significant differences in the proportion of crossover sign segregated by sex ($P = .35$).

TABLE 1
Wiberg Angle Values by Sex and Laterality[a]

	Wiberg Angle, deg		Difference
	Male	Female	(P Value[b])
Right side	39.57 ± 7.98	38.54 ± 7.27	.73
Left side	39.71 ± 7.89	39.97 ± 7.05	.82

[a]Values are reported as mean ± SD.
[b]Wilcoxon test.

TABLE 2
Acetabular Version Angle Values Corrected in 3 Planes by Sex and Laterality[a]

	Acetabular Version Angle, deg		Difference
	Male	Female	(P Value[b])
Right side	15.23 ± 5.00	15.94 ± 6.38	.55
Left side	15.83 ± 4.44	16.00 ± 6.03	.88

[a]Values are reported as mean ± SD.
[b]t-test with Welch approximation.

Acetabular Version

The 101 patients had a mean value of 15.5° ± 5.6° on the right side and 15.9° ± 5.1° on the left. The acetabular version values by sex and laterality are shown in Table 2. The sides were not significantly different between sexes.

Alpha Angle

The mean alpha angles obtained at each level are shown in Table 3. The overall mean alpha angle in the mid level was 49.7° ± 8.3°. Notably, the angle decreased caudally.

TABLE 3
Alpha Angle Values by Cutoff Level and Laterality[a]

	Alpha Angle, deg	
	Right Side	Left Side
Level 1	50.44 ± 10.22	49.02 ± 8.67
Level 2	47.32 ± 6.79	48.30 ± 6.06
Level 3	38.00 ± 5.15	39.75 ± 4.68

[a]Values are reported as mean ± SD.

TABLE 4
Femoral Offset Values by Cutoff Level and Laterality[a]

	Femoral Offset, mm	
	Right Side	Left Side
Level 1	6.11 ± 1.67	6.91 ± 1.56
Level 2	7.95 ± 1.32	7.65 ± 1.34
Level 3	9.18 ± 1.56	8.44 ± 1.30

[a]Values are reported as mean ± SD.

Femoral Offset

The mean offset values obtained at each level are shown in Table 4. The mean alpha angle was 49.7° ± 8.3°.

The measurements show that the offset value increased caudally. In the total joint sample, the mean femoral offset measured at the superior level was 6.1 ± 1.7 mm on the right side and 6.9 ± 1.6 mm on the left side.

Pincer Type

When a Wiberg angle greater than 40° was considered for pincer-type impingement, there were 50 cases (49.5%) with a normal Wiberg angle (<40°). Eleven patients (10.9%) showed values considered unilaterally pathological, and 40 patients (39.6%) showed bilaterally pathological values.

When Wiberg angle greater than 40° and/or positive crossover sign is considered, there were 31 cases (30.7%) that were considered normal. Eleven (10.9%) and 59 (58.4%) subjects had values considered unilaterally and bilaterally pathological, respectively.

Cam Type

Considering the alpha angle at level 2, there were 61 subjects (60.4%) with alpha angle values within the normal range (<50°). Nine (8.9%), 18 (17.8%), and 13 (12.9%) subjects presented values within the pathological range on the right, left, and bilaterally, respectively.

DISCUSSION

Femoroacetabular impingement is a dynamic disorder caused by pathological contact between the femoral head-neck junctions and the acetabular rim.[2,4] Clinically, it presents as pain and variable decrement in the articular range of motion, which is associated with intra-articular labrum and/or cartilage damage. Some reports have linked radiological FAI changes to osteoarthritis development. Current treatment aims to reduce pain and regain an individual's baseline functional status by correcting the morphoradiological abnormality involved in this pathology.[16-18]

Morphological studies have been important in understanding this disease. Several studies have been carried out to define a normal radiological evaluation of hip anatomy. However, the use of these parameters is controversial, and in many cases, no diagnosis cutoff points have been determined.[9,14,21,25]

This is the first report describing the radiological characteristics of the Chilean population using CT. The strength of this study is that individuals were recruited prospectively and none of them had current hip pathology or complaints related to the hip, such as pubalgia. CT can adequately characterize the joint morphology and correct the errors associated with poor positioning on the table and pelvis rotation. Unlike conventional radiography, which is the most commonly used method, CT can better define conflict areas.[1,7,22]

Conversely, we did not perform a physical examination, so we were unable to define a normal range of motion. Because the study was cross-sectional, we cannot assert that individuals will not become symptomatic in the future. Another limitation of our study is that we did not assess intra- or interobserver concordance.

Regarding acetabular parameters, the Wiberg center-edge angle, classically described for evaluating acetabular dysplasia and used as an index of acetabular coverage, shows a mean value greater than other published series.[7,12,13] The wide age range of our sample and the positive correlation with age could explain this observation. Thus, we believe that age should be considered in future research to establish normal Wiberg angle values.

The crossover sign as an index of focal acetabular retroversion was identified in 70 subjects (69.3%), which is consistent with another series.[12] When comparing by sex, females were found to present this sign more frequently, but the difference was not significant. This observation is also consistent with a previous series.[20]

When axial CT images are analyzed, several studies have reported errors when determining the acetabular version in axial cuts.[23,29,30] An anterior tilt in the sagittal plane will decrease the acetabular anteversion, while a posterior tilt increases it. Our measurements were performed on pelvis images previously corrected in all 3 planes considering published sex differences, and axial slices were made from the most proximal acetabular portion every 2 mm distal to the deepest zone. Classically, acetabular anteversion measurement is performed in the deepest part of the acetabulum. The mean acetabular version and the higher angle seen in females in our study are consistent with other published series.[20,23]

Cam-type impingement was determined using the alpha angle as described by Notzli et al.[21] This is important to take into account because the literature reports different ways and radiologic projections suitable for its evaluation.

In fact, the alpha angle has been described in anterior-posterior and axial cross-table hip radiography, as well as frog lateral plain radiography, but these modalities are not as reliable as CT.[15] The CT-based measurement is described in axial oblique cuts to the femoral neck, as well as radial neck cuts. As a practical approach to clinical setting and considering that, in most cases, the femoral "bump" is located in an anterior-lateral position rather than purely anterior, we decided to perform measurements in the middle of the proximal, central, and distal femoral neck thirds as previously described.[29] The mean alpha angle was higher in the upper level and decreased in the lower levels, so we believe that its measurement should not be limited to the central or anterior level, to avoid missing small femoral abnormalities. Although there is controversy over the angle that defines this abnormality, if we consider 50° as pathological, as defined by Notzli et al,[21] our population showed a very high prevalence of this anomaly: 57.4% and 39.6% at levels 1 and 2, respectively. This indicates that alpha angle interpretation is complex; therefore, the value alone is not sufficient to establish pathology. Previous series reported different values; Kang et al[12] showed 45.57° on average, and Kapron et al[13] described an alpha angle average of 52°. One possible explanation is that these studies were performed in collegiate male football players who were evaluated with frog-leg lateral radiography, and the value was even higher (55°) when an anteroposterior radiographic view was used. The study of Hack et al[8] reported that 14% of patients exhibited cam morphology (50.5°). Similar to our series, Hack et al[8] reported a higher prevalence of cam pathology in males than in females.

In a recent large retrospective series using anteroposterior CT scout views, Jung et al[11] determined that the prevalence of cam-type deformity defined as pathological in asymptomatic males was 13.95%, and 14.88% of males have borderline values. In female hips, the mean alpha angle was 45.47°, with 5.56% and 6.11% of hips defined as pathological and borderline, respectively. Our results revealed a higher prevalence of cam deformity than previous reports, but we also observed a higher frequency in males compared with females.

The measurement of the femoral neck offset corresponds with the alpha angle findings; that is, the lowest value is in the center of the upper third and increases distally, confirming the importance of measuring the femoral neck offset on several levels. By comparing these values with other reports, we noticed a high number of patients in the pathological group. Wenger et al[31] used a femoral neck offset measurement method to assess lateral cross-table radiographs and defined a pathological value as <7.2 mm compared with a higher previously published value of 11.6 mm. In a study by Kang et al,[12] the mean femoral offset in axial slices through the center neck using CT was 9.49 mm, with <8 mm considered pathological. This again indicates that these values should be considered in the context of the studied population while taking the measurement method into account.

As previously stated,[9,24] we consider it essential that alpha angle and femoral neck offset measurements for cam-type disorders be performed in several areas where there is a greater possibility of alteration and not only in areas depicted by conventional projections on plain radiography.

CONCLUSION

Our results show that if the published thresholds[22] are used, a high prevalence of "abnormal" morphological features compatible with FAI are present in an asymptomatic Chilean population. The incidences are between 39.6% and 69.3% depending on parameters used to establish FAI. Thus, we believe that the mere presence of these "morphological alterations" does not necessarily indicate the existence of FAI. Conversely, normal values must be weighed in relation to the patient's age, sex, and ethnicity. It is important to remember that the dynamic behavior of the hip joint is not evaluated in imaging. Future studies are needed to establish the discriminatory capacity and threshold of these measurements.

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