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Does Native Combined Anteversion Influence Pain Onset in Patients With Dysplastic Hips?

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Abstract

Background   Combined anteversion is the sum of femoral and acetabular anteversion and represents their morphological relationship in the axial plane. Few studies have investigated the native combined anteversion in patients with symptomatic dysplastic hips.

Questions/purposes   We hypothesized the following: (1) dysplastic hips have two distinct populations, which differ from each other and from normal hips in their combined anteversion; and (2) these populations differ clinically in terms of correlation between age of onset of symptoms and amount of anteversion.

Methods   We measured radiographic parameters by CT of 100 dysplastic hips in 76 patients who were symptomatic enough to undergo periacetabular osteotomy and of 50 normal hips in 44 patients who had CT scans as part of preparation for computer-navigated TKAs; these patients had no visible hip arthritis or dysplasia and no hip symptoms. Dysplastic hips were divided into the anteversion (83 hips) and retroversion groups (17 hips) based on acetabular version. Age at pain onset was determined from their medical charts.

Results   Combined anteversion in the anteversion group was greater than that in the retroversion and control groups: $47° \pm 12°$, $30° \pm 16°$, and $36° \pm 9°$, respectively. In the anteversion group, combined anteversion (r = -0.49; 95% confidence interval [CI], -0.66 to -0.27; p < 0.001) and femoral anteversion (r = -0.41; 95% CI, -0.60 to -0.19; p < 0.001) were associated with an earlier age at pain onset; however, no such relationships were observed in the retroversion group. After controlling for relevant potential confounding variables, we found that combined anteversion (hazard ratio [HR], 1.04; 95% CI, 1.01–1.07; p = 0.006) and Sharp angle (HR, 1.10; 95% CI, 1.02–1.17; p = 0.008) were associated with an earlier age of pain onset in the anteversion group.

Conclusions   These results suggest that not only lateral coverage of the femoral head, but also axial joint morphology is important for the development of pain in the anteversion group. Optimal combined anteversion should be considered during periacetabular osteotomy.

Level of Evidence   Level IV, prognostic study.

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Introduction

Developmental dysplasia of the hip (DDH) is characterized by various morphological abnormalities such as acetabular dysplasia, decreased acetabular coverage of the femoral

head, and excessive femoral anteversion [3, 16, 18]. These features result in abnormal joint stresses, leading to subsequent labral tears, articular cartilage degeneration, and early development of secondary hip osteoarthritis [2, 9, 15, 24, 25]. The severity of hip dysplasia has typically been determined by the degree of subluxation [21] and the extent of acetabular dysplasia.

Although hip deformities in the axial plane are also associated with the pathology of DDH, they have received less attention. We previously reported that, despite relatively better acetabular coverage, dysplastic hips with acetabular retroversion had earlier pain onset than those with acetabular anteversion [7]. This finding suggested a relationship between acetabular version and the pathogenesis of osteoarthritis. Combined anteversion is the sum of femoral and acetabular anteversion in the axial plane, and its role has not to our knowledge been evaluated.

We therefore sought to determine whether (1) dysplastic hips have two distinct populations, which differ from each other and from normal hips in their combined anteversion; and (2) these populations differ clinically in terms of correlation between age of onset of symptoms and amount of anteversion.

Patients and Methods

This retrospective study was approved by our institutional review board. We reviewed standard AP radiographs of the pelvis and pelvic CT images of 218 hips in 197 patients with symptomatic dysplastic hips obtained between January 2006 and June 2014 during preoperative assessment for periacetabular osteotomy. Hip dysplasia was defined as a lateral center-edge (CE) angle of Wiberg $< 20°$ based on measurements using AP radiographs of the pelvis. Forty-nine hips were excluded because either their CT images were unavailable or did not include the knee to allow measurements of femoral anteversion. Forty-one hips that were scored as Grade 2 or worse according to the Tönnis osteoarthritis grading system [21] or that had visible osteophyte formation were excluded, because of concerns regarding the accuracy of measurements to be made. Fifteen hips in 10 patients with severe deformity of the femoral head, 12 hips in six patients with prior surgery, and one hip in one patient with severe pubic symphysis diastasis were excluded. The remaining 100 hips in 76 patients were included in this study. Eleven hips belonged to eight male patients and 89 hips belonged to 64 female patients. The average age of the patients at surgery was 38 years (range, 16–59 years) and all patients were skeletally mature. According to the classification system of Crowe et al. [4], all hips were classified as Type I. Nineteen hips in 15 patients had a history of nonoperative DDH treatment in

childhood. From a review of the medical records, we determined the age at pain onset when the patients had continuous symptoms enough to consider periacetabular osteotomy. When the age at pain onset was unclear from this review, the patients were interviewed by one of us (YN) directly during their hospitalization for periacetabular osteotomy.

The control group included 50 hips of 44 patients with osteoarthritis of the knee. We examined AP pelvic radiographs and CT images of hips and pelvis routinely obtained during planning for TKA using a CT-based navigation system [14]. These individuals had no history of disease or articular symptoms in the hips, as indicated by a medical chart search and radiographic examination. All the subjects were women with an average age of 75 years (range, 52–87 years). Although the average age of the control group was higher than that of the dysplastic hip group, we confirmed that the control subjects had no degenerative changes in the hips or other hip abnormalities.

Pelvic CT (Aquilion; Toshiba, Tochigi, Japan) was performed following methods previously described [6]. Briefly, images were obtained at 2-mm intervals from the anterosuperior iliac spines to the inferior rim of the pelvis in combination with a 200-mm section of the midpoint of the knee. Data of the control subjects were obtained in 2-mm slices from a 100-mm section of the femoral head, a 200-mm section of the midpoint of the knee, and a 100-mm section of the distal part of the tibia in preparation for a CT-based navigation system of TKA [14].

Multiplanar reconstruction of all images was performed using the image analysis software (3D Template; Kyocera Medical, Osaka, Japan). For the measurement of femoral anteversion, the femoral neck axis was defined using the single-slice method described by Sugano et al. [20]. The distal femoral condylar axis was measured using the transepicondylar axis, which is discernible in degenerated knees such as those of our control subjects. We defined the angle between the femoral neck axis and the transepicondylar axis as the femoral anteversion angle (Fig. 1A). On the acetabular side, we used the anterior pelvic plane [13] as a reference plane. We defined the acetabular anteversion angle [17] passing through the femoral head center as the angle created by the intersection of the line connecting the anterior and posterior edges of the acetabulum with a sagittal line (Fig. 1B). Native combined anteversion was calculated as the sum of femoral anteversion and acetabular anteversion. We divided the dysplastic hips into two groups following the method described by Jamali et al. [8] to eliminate the effect of pelvic tilt [23]. In particular, on the axial section 5 mm caudal to the acetabular roof, we measured the cranial anteversion angle to determine the presence of acetabular retroversion. We defined the anteversion group
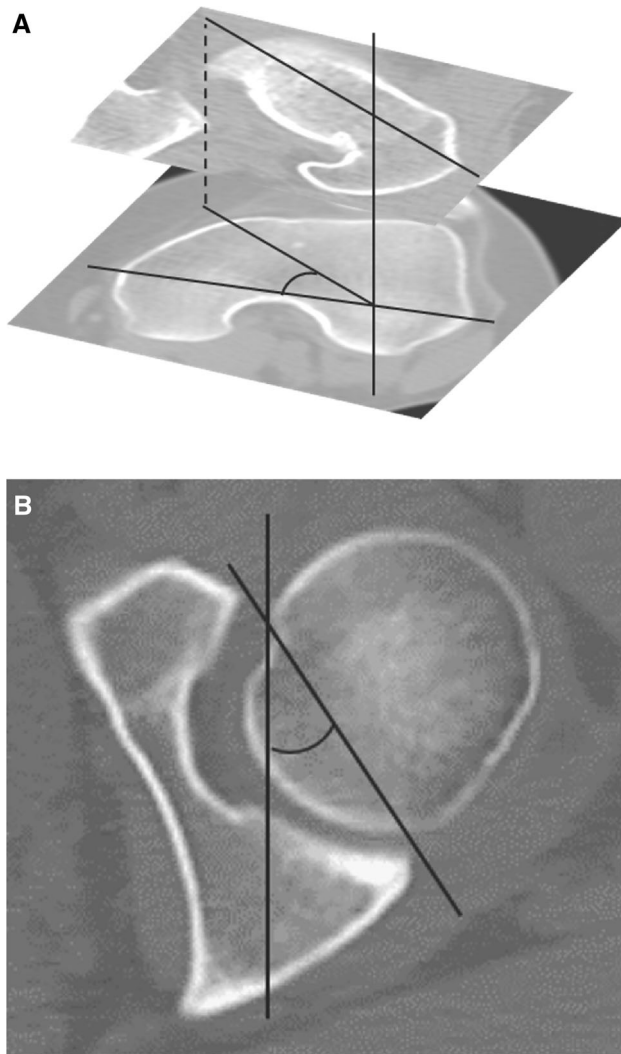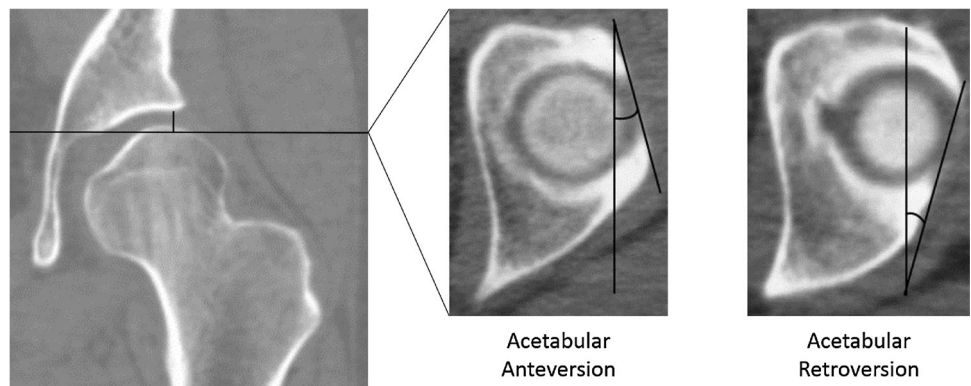
Fig. 1A–B (A) The femoral anteversion angle was measured as an angle between the femoral neck axis and the transepicondylar axis. (B) The acetabular anteversion angle was measured as an angle formed by a line connecting the anterior and posterior edges of the acetabulum and a sagittal line on the axial plane passing through the center of the femoral head.

as comprising hips with a positive cranial anteversion angle and the retroversion group as those in which this angle was negative (Fig. 2). In the coronal plane passing through the femoral head center, we measured the lateral CE angle (Fig. 3A), Sharp angle (Fig. 3B), and acetabular roof obliquity (Fig. 3C).

All measurements were performed by two observers (YK, MA) and were repeated in a blind manner at least 1 month after the first measurements. According to the standards for the kappa statistic proposed by Landis and Koch [10], intraobserver reliabilities of the femoral anteversion, acetabular anteversion, and combined anteversion, evaluated by using the intraclass correlation coefficient, were excellent (range, 0.92–0.97). Interobserver measurement reliabilities were also excellent (range, 0.88–0.91).

Statistical analysis was performed using JMP 9.0.2 (SAS Institute Inc, Cary, NC, USA). The Steel-Dwass test was used to compare the clinical data and radiographic parameters among the anteversion, retroversion, and control groups. Only one hip was randomly selected from each of the 24 patients who had bilateral hip pain in the same version group so that the statistical assumption of independent observation was fulfilled. To analyze the factors affecting age of onset of symptoms, we used the Spearman rank correlation coefficient with age at pain onset as the endpoint in each group. The Cox proportional hazard model was then applied to determine these factors contributing to age at pain onset. For all statistical analyses, p values < 0.05 were considered significant.

Results

Of the 100 dysplastic hips, 83 hips (83% [83 of 100]) had positive cranial anteversion angles (anteversion group) and the remaining 17 hips (17% [17 of 100]) had negative cranial anteversion angles (retroversion group). The anteversion

Fig. 2 The cranial anteversion angle was measured as an angle formed by a line connecting the anterior and posterior edges of the acetabulum and a sagittal line on the axial plane 5 mm caudal to the acetabular roof. The anteversion group was defined as comprising hips with a positive cranial anteversion angle. The retroversion group was defined as those in which this angle was negative.

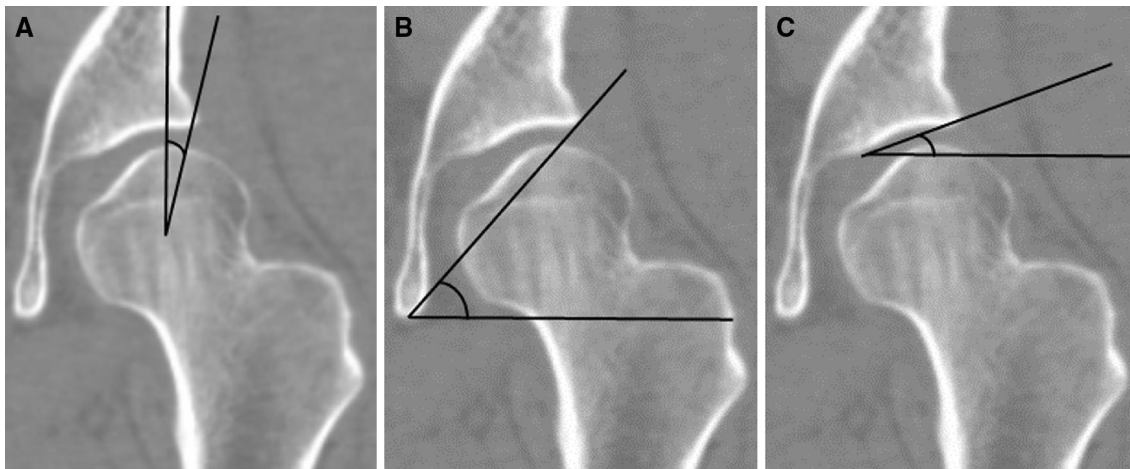Acetabular Anteversion

Acetabular Retroversion

Fig. 3A–C (**A**) The lateral CE angle was measured as an angle formed by a line connecting the center of the femoral head and the lateral edge of the acetabulum and a sagittal line on the coronal plane passing through the center of the femoral head. (**B**) The Sharp angle was measured as an angle formed by a line connecting the lateral and inferior edges of the acetabulum and a horizontal line. (**C**) The acetabular roof obliquity was measured as an angle formed by a line connecting the medial edge of the sourcil and the lateral edge of the acetabulum and a horizontal line.

Table 1. Radiographic and clinical parameters in the anteversion, retroversion, and control groups

Parameter	Dysplastic hip group (100 hips)		Control group (50 hips)
	Anteversion group (83 hips)	Retroversion group (17 hips)	
Femoral anteversion (°) (range)	22 (−2 to 53)[†]	16 (−11 to 40)	14 (0–37)
Acetabular anteversion (°) (range)	25 (12–37)[*,†]	17 (6–25)[†]	22 (8–35)
Combined anteversion (°) (range)	47 (22–77)[*,†]	30 (4–61)	36 (19–67)
Lateral CE angle (°) (range)	9 (−24 to 20)[†]	13 (1–19)[†]	39 (25–55)
Sharp angle (°) (range)	49 (41–59)[†]	47 (42–51)[†]	36 (29–44)
Acetabular roof obliquity (°) (range)	26 (10–44)[*,†]	21 (15–31)[†]	2 (−6 to 11)
BMI (kg/m^2) (range)	24 (17–31)	23 (19–35)[†]	25 (18–37)
Sex (male/female)	10/73	1/16	0/50
History of DDH treatment (yes/no)	18/65	1/16	0/50

Values are expressed as mean with range in parentheses; *significant compared with retroversion group; †significant compared with control group; CE = center-edge; BMI = body mass index; DDH = developmental dysplasia of the hip.

group showed greater combined anteversion than the retroversion group (47° ± 12° versus 30° ± 16°; p < 0.001) and control group (47° ± 12° versus 36° ± 9°; p < 0.001), whereas no difference was noted between the retroversion and control groups (30° ± 16° versus 36° ± 9°; p = 0.24) (Table 1).

In the anteversion group, increased combined anteversion (r = −0.49; 95% confidence interval [CI], −0.66 to −0.27; p < 0.001) and femoral anteversion (r = −0.41; 95% CI, −0.60 to −0.19; p < 0.001) were associated with an earlier age at onset of pain (Table 2; Fig. 4); however, no such relationships were observed in the retroversion

Table 2. Correlation of age at pain onset with radiographic and clinical parameters in the anteversion group

Parameter	Correlation coefficient	p value
Femoral anteversion	−0.41	< 0.001
Acetabular anteversion	−0.24	0.060
Combined anteversion	−0.49	< 0.001
Lateral CE angle	0.33	0.0090
Sharp angle	−0.33	0.0098
Acetabular roof obliquity	−0.24	0.060
BMI	0.25	0.051

CE = center-edge; BMI = body mass index.

Table 3. Correlation of age at pain onset with radiographic and clinical parameters in the retroversion group

Parameter	Correlation coefficient	p value
Femoral anteversion	−0.36	0.25
Acetabular anteversion	0.086	0.79
Combined anteversion	−0.11	0.74
Lateral CE angle	−0.61	0.035
Sharp angle	0.11	0.74
Acetabular roof obliquity	0.77	0.0037
BMI	−0.17	0.59

CE = center-edge; BMI = body mass index.

Table 4. Association between age at pain onset and potentially relevant risk factors in the anteversion group

Parameter	HR	95% CI	p value
Combined anteversion	1.04	1.01–1.07	0.006
Sharp angle	1.10	1.02–1.17	0.008
BMI	0.93	0.84–1.01	0.096
Sex (male/female)	0.90	0.44–1.69	0.72
History of DDH treatment (yes/no)	0.83	0.29–2.15	0.76

HR = hazard ratio; CI = confident interval; BMI = body mass index; DDH = developmental dysplasia of the hip.

group (Table 3). After controlling for relevant potential confounding variables such as combined anteversion, Sharp angle, body mass index (BMI), and history of DDH treatment, we found that combined anteversion (hazard ratio [HR], 1.04; 95% CI, 1.01–1.07; p = 0.006) and Sharp angle (HR, 1.10; 95% CI, 1.02–1.17; p = 0.008) were associated with an earlier age of pain onset in the anteversion group (Table 4).

Discussion

Combined anteversion is the sum of femoral and acetabular anteversion and represents their morphological relationship in the axial plane. Although hip deformities in the axial plane are considered to be associated with the pathology of DDH, they have received less attention. We therefore sought to determine whether (1) dysplastic hips have two distinct populations, which differ from each other and from normal hips in their combined anteversion; and (2) these populations differ clinically in terms of correlation between age of onset of symptoms and amount of anteversion.
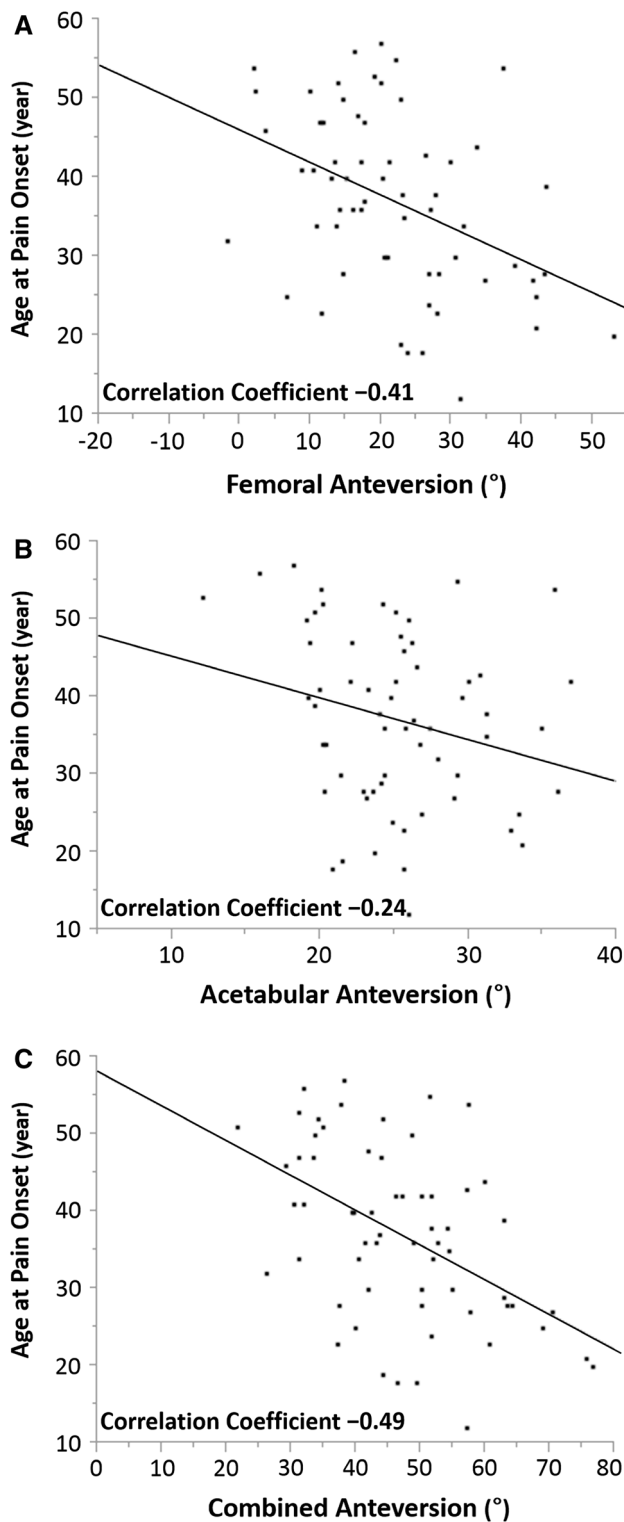
Fig. 4A–C Graphs showing the correlation between age at pain onset and (**A**) femoral anteversion (r = −0.41, p < 0.001), (**B**) acetabular anteversion (r = −0.24, p = 0.060), and (**C**) combined anteversion (r = −0.49, p < 0.001) in the anteversion group.

This study has several limitations. First, the normal subjects in the control group were older than the patients with dysplastic hips. However, because the normal subjects were asymptomatic and without morphological abnormalities that would suggest progression toward osteoarthritis, we considered them to be appropriate for the purpose of this study. There is also a view that only hips that remain asymptomatic in old age should be considered healthy [12]. Because the pelvis tends to tilt backward as a result of lumbar kyphosis in elderly patients, acetabular version may change. Thus, we also adjusted the pelvic tilt in reference to the anterior pelvic plane. Second, we retrospectively determined age at pain onset. In particular, we interviewed the patient regarding his or her history; however, this method depends on the patient's subjective recollection and thus raises the possibility of inaccuracy. The onset of pain may be affected by not only hip morphology, but also other factors such as BMI or the levels of daily activity. Third, our results are representative only of Asian patients and therefore further studies are needed for patients of other ethnicities. Fourth, our patients are symptomatic enough to undergo major pelvic surgery. There may be many individuals with similar radiographs but no symptoms who never come to the attention of surgeons performing hip procedures. Thus, there may be a selection bias; however, it was difficult to justify taking CT of asymptomatic patients with dysplastic hips, and screening radiographs of the population at large would not be feasible.

We divided dysplastic hips into two groups based on the cranial acetabular version. The anteversion group included the majority of the patients (83%) and showed greater femoral anteversion compared with the retroversion group. We previously reported that the more acetabular anteversion was accompanied by the more femoral anteversion in this group [1]. The resultant combined anteversion in the anteversion group was greater than those in the retroversion and control groups; 47°, 30°, and 36°, respectively. In contrast, the acetabular retroversion was observed in 17% of the dysplastic hips in accordance with the previous studies: 17.2% by Li and Ganz [11] and 18% by Ezoe et al. [5]. Femoral anteversion and combined anteversion in this group were equivalent to those in the control group, and no correlation between acetabular and femoral anteversion was noted. Despite the less severe acetabular dysplasia compared with the anteversion group, age at pain onset in the retroversion group was earlier than that of the anteversion group. These findings support our hypothesis that the dysplastic hips have two distinct populations.

Tönnis and Heinecke [22] described the role of acetabular and femoral version (instability index) on the development of hip osteoarthritis. They mentioned that when decreased acetabular anteversion was combined with increased femoral anteversion or vice versa, the pathological consequences were compensated or diminished. In practice, however, increased femoral anteversion was often combined with the increased acetabular anteversion in our studies. Synergistically, increased combined anteversion was associated with an earlier age at onset of pain in the anteversion group. Sharp angle was also associated with an earlier age of pain onset, suggesting the important roles of both lateral coverage and combined anteversion on the pain onset in the anteversion group. In the retroversion group, earlier pain onset was observed regardless of the femoral anteversion. An earlier biomechanical study demonstrated the concentration of joint stress in the posterior region of the acetabulum during activities of daily living [19], and another found the peak pressures during postural change (standing up and sitting down) were located at the edge of the posterior wall of the acetabulum [26]. When posterolateral acetabular coverage is decreased as seen in the retroversion group, the increased stress concentrations at the same site during dynamic hip movement may contribute to the pain onset.

In conclusion, increased combined anteversion and Sharp angle were associated with an earlier age of pain onset in the anteversion group. These results suggest that not only lateral coverage of the femoral head, but also axial joint morphology (combined anteversion) is important for the development of pain in the anteversion group. Optimal combined anteversion should be considered during periacetabular osteotomy.

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