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Combined femoral and acetabular version is sex-related and differs between patients with hip dysplasia and acetabular retroversion

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ABSTRACT

Aims: Frequency of abnormal femoral and acetabular version (AV) and combinations are unclear in patients with developmental dysplasia of the hip (DDH). This study aimed to investigate femoral version (FV), the proportion of increased FV and femoral retroversion, and combined-version (CV, FV+AV) in DDH patients and acetabular-retroversion (AR).

Patients and methods: A retrospective IRB-approved observational study was performed with 78 symptomatic DDH patients (90 hips) and 65 patients with femoroacetabular-impingement (FAI) due to AR (77 hips, diagnosis on AP radiographs). CT/MRI-based measurement of FV (Murphy method) and central AV were compared. Frequency of increased FV($FV > 25°$), severely increased FV ($FV > 35°$) and excessive FV ($FV > 45°$) and of decreased FV ($FV < 10°$) and CV (McKibbin-index/COTAV-index) was analysed.

Results: Mean FV and CV was significantly ($p < 0.001$) increased of DDH patients (mean ± SD of 25 ± 11° and 47 ± 18°) compared to AR (16 ± 11° and 28 ± 13°). Mean FV of female DDH patients (27 ± 16°) and AR (19 ± 12°) was significantly ($p < 0.001$) increased compared to male DDH patients (18 ± 13°) and AR (13 ± 8°). Frequency of increased FV (>25°) was 47% and of severely increased FV (>35°) was 23% for DDH patients.

Proportion of femoral retroversion ($FV < 10°$) was significantly ($p < 0.001$) higher in patients AR (31%) compared to DDH patients (17%). 18% of DDH patients had AV > 25° combined with FV > 25°. Of patients with AR, 12% had FV < 10° combined with AV < 10°.

Conclusion: Patients with DDH and AR have remarkable sex-related differences of FV and CV. Frequency of severely increased FV > 35° (23%) is considerable for patients with DDH, but 17% exhibited decreased FV, that could influence management. The different combinations underline the importance of patient-specific evaluation before open hip preservation surgery (periacetabular osteotomy and femoral derotation osteotomy) and hip-arthroscopy.

1. Introduction

Patients with developmental dysplasia of the hip (DDH) often exhibit combined osseous femoral deformities [1,2] and were investigated previously mainly with regard to planning of total hip arthroplasty. More recently, a high proportion of femoral deformities were reported, such as the valgus deformity [3] or cam-type deformities (in up to 86% [4]) of patients with DDH, but also increased femoral version (FV) was noted in 52% [4]. Femoral deformities even may be more predictive of hip range of motion than severity of DDH [5] and increased FV was associated with earlier onset of hip pain [6]. Abnormalities of FV were observed in patients with DDH and femoroacetabular impingement (FAI) previously [7] but little is known about combined version (CV), the sum of FV and acetabular version(AV). Knowing the exact proportion of increased FV and of CV could influence surgical decision-making. It is unclear, if femoral deformities (especially increased FV) should be

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treated (with femoral derotation osteotomy). The periacetabular osteotomy (PAO) has become an accepted surgical treatment to treat DDH [8,9]. But treatment of patients with DDH and increased FV is unclear. On the other hand, acetabular retroversion is a cause for pincer-type FAI that was initially described as a prominent overgrowth of the anterior acetabular wall [10]. In the last decade there was increasing evidence that acetabular retroversion could be rotational abnormality of the ilium bone [11–13]. Young patients with acetabular retroversion typically present with decreased internal rotation (IR) and with anterior hip pain. This conflict could be worsened by femoral retroversion [14]. Previous studies reported, that a cam-deformity reduces hip IR, typically assessed in 90° of flexion [14,15]. Femoral retroversion also decreases IR [16–18] and thus theoretically can accelerate or worsen anterior FAI. Before the description of FAI, Tönnis and Heinecke investigated abnormalities of FV [16]. Femoral retroversion was described already in 1991, and it was called diminished femoral antetorsion syndrome [19], when they observed that patients with hip pain and early signs of osteoarthritis had femoral retroversion and exhibited decreased hip IR [16,19]. More recently, an important contribution of FV and AV on hip range of motion was reported [18,20]. Femoral retroversion was associated with an extra-articular conflict between the proximal femur and the anterior inferior iliac spine [21,22]. Both increased and decreased FV can impair the patient-related outcomes [23] and severe femoral retroversion was associated with poor outcomes after hip arthroscopy for FAI [23]. But only few studies investigated the effect of FV and of CV. However, different measurement methods of FV exist [24] and different definitions of femoral retroversion [23,25] add confusion.

So far, the proportion of absolute femoral retroversion of patients with acetabular retroversion is unclear. In addition, it is unclear if patients with DDH are associated with combined abnormalities of FV and AV.

This study aimed to investigate mean FV, the proportion of increased FV and femoral retroversion, and CV (equals FV+AV) in patients with DDH and acetabular retroversion.

2. Methods

This is an institutional review board (IRB)-approved retrospective observational study of 333 patients (384 hips) seeking to compare abnormalities of FV, AV and CV. Subgroups of DDH and acetabular retroversion were analysed in depth. All symptomatic patients were evaluated for hip preservation surgery that had been referred in a 5-year period to our university hospital (between 01/ 2011 and 12/ 2015). All patients presented with pain at the time of image acquisition. Inclusion criteria included the presence of hip pain, radiographic signs of skeletal maturity, no previous surgery of hip joint altering AV and/or FV, no posttraumatic condition, no avascular necrosis of the femoral head, availability of standard plain radiographs, and the availability of either CT or MRI of the pelvis/hip including the distal femur condyles to allow for measurement of FV according to the method described by Murphy et al [26]. Out of a total of 463 patients (538 hips), the following patients were analyzed in detail: 77 hips in 65 patients with acetabular retroversion and 90 hips (78 patients) with DDH were included in this study (Table 1, Fig. 1). All patients were part of a previous study[7].

Based on the analysis of the conventional radiographs, we subdivided our patient cohort into the following subgroups (Table 1): 1) cam-type FAI, 2) Pincer-type FAI due to overcoverage (LCE-angle 35-39°), 3) Pincer-type FAI due to severe overcoverage (LCE-angle >39°), 4) Pincer FAI due to acetabular retroversion, 5) mixed-type FAI 6) hip dysplasia and 7)Perthes. The allocation to each group was based on previously published reference values for acetabular and femoral morphology (Table 1). [16,27,28] A cam-type deformity was defined as alpha angle >50° (Table 1). Overcoverage was defined as LCE angle between 34 and 39° with an alpha angle below 50° (Table 1). Diagnosis of acetabular retroversion was based on three radiographic signs: Positive cross-over sign [29], positive ischial spine sign [30], positive posterior wall sign [29], and retroversion index >30% [11], independent from alpha angle. Diagnosis of DDH was based on LCE angle <22° (Table 1).

As part of the routine workup, all patients were clinically evaluated by one of our attending hip surgeons (KAS or MT) with several years of experience in hip preservation surgery. This included a thorough acquisition of the patient history, a goniometric measurement of the hip range of motion, the evaluation of the anterior and posterior

Table 1
Definition of study groups. The allocation to a specific group was performed based on the morphological analysis of the conventional anteroposterior pelvic radiograph and the cross-table lateral radiographs of the hip.

Group	Definition	Number of hips (patients)
Total	Symptomatic patients with hip pain	538 (463)
Subgroups	Two subgroups were analyzed.	
Acetabular Retroversion	Positive cross-over sign [29], positive ischial spine sign [13], positive posterior wall sign [29], and retroversion index > 30% [11], independent from alpha angle	77 (65)
Hip Dysplasia	LCE-angle < 22° [28]	90 (78)
Subgroups	Subgroups not analyzed	
Cam-type FAI	Alpha angle > 50° [27] with neck-shaft angle of 125 – 140° and with normal acetabulum (LCE-angle 23 – 33°) [28], not all retroversion signs positive	165 (142)
Mixed FAI*	Alpha angle > 50° [27] and LCE-angle 34 – 39°, not all retroversion signs positive	137 (118)
Overcoverage	LCE-angle 34 – 39° [28] with alpha angle < 50°, not all retroversion signs positive	38 (33)
Severe overcoverage	LCE-angle > 39° [16], and/or protrusio acetabuli (defined as femoral head touching or crossing the ilioischial line)	46 (41)
Perthes	Documented avascular necrosis of femoral head in childhood	30 (25)
No obvious pathology	No obvious acetabular and femoral pathology, normal LCE-angle (22 – 34°), normal alpha angle (<50°),	23 (19)

FAI = Femoroacetabular Impingement; LCE = lateral center edge angle. *the hips in the mixed-type FAI group can overlap with the other subgroups.

Table 2
Radiographic parameters and surgical treatment of all patients and of the subgroups are shown.

Parameter	Hip Dysplasia	Acetabular Retroversion
Number of hips (patients)	90 (78)	77 (65)
Age at imaging (years)	29 ± 9	27 ± 9
Sex (% women of all hips)	73%	48%
Height (cm)	168 ± 8	171 ± 7
Weight (kg)	71 ± 14	73 ± 18
BMI (kg/cm^2)	25 ± 4	25 ± 5
LCE-angle (°)	17 ± 5	35 ± 7
Acetabular index (%)	12 ± 6	0 ± 5
Extrusion index (%)	32 ± 6	16 ± 7
Retroversion index (%)	7 ± 9	43 ± 16
Neck-shaft angle (°)	135 ± 7	131 ± 7
Alpha angle (°)	56 ± 13	58 ± 12
Cross over sign pos. (%)	81%	100%
Posterior wall sign pos. (%)	60%	100%
Ischial spine sign pos. (%)	62%	100%
COS, PWS and ISS and RI > 30%	36%	100%
Surgical treatment		
SHD	6%	30%
HAS	9%	8%
PAO	46%	16%

Continuous values are expressed as mean ± SD, LCE = lateral center edge angle; COS = Cross over sign; ISS = Ischial spine sign; PWS = Posterior wall sign; RI = Retroversion index. SHD = surgical hip dislocation, PAO = periacetabular osteotomy; HAS = hip arthroscopy.

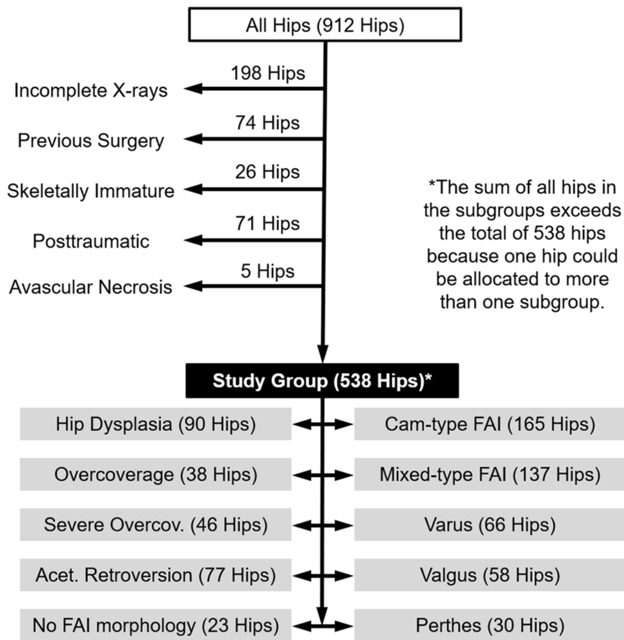

Fig. 1. Inclusion and exclusion criteria are shown. The subgroups hip dysplasia and acetabular retroversion were evaluated. The patients (hips) in the mixed-type FAI group can overlap with the other subgroups. Figure reprinted with permission from.

impingement tests, [14] the assessment of hip instability (using the apprehension/the FABER tests), the assessment of abductor strength and general joint laxity.

Routine radiographic evaluation generally consisted of a supine anteroposterior (AP) pelvic radiograph taken with a standardized technique [14] and a cross-table lateral radiograph of the hip. The AP pelvic radiograph was then assessed with a previously described and validated computer software (Hip2Norm, University of Bern). This software allows accurate and reliable measurement of radiographic parameters of the hip. The alpha angle was measured as a measure of femoral asphericity on the axial cross table radiograph. All radiographic measurements were performed by two independent observers.

In order to calculate FV and AV, all symptomatic patients either underwent standardized protocol-specific magnetic resonance imaging and/or CT of the hip. The use of each of these imaging modalities for this purpose has been validated by previous studies that compared the measurement of FV [31] and AV [32] on MRI and on CT showed comparable results. MR arthrography [11,33] was obtained according to a standardized technique. In brief, the scans were performed using a Siemens TRIO 3.0-T high field scanner (Erlangen, Germany). The patients were positioned supine, and the feet were fixed in neutral position to prevent motion during scanning. A radial proton density sequence was acquired for evaluation of chondrolabral lesions. Sagittal and coronal proton density-weighted and axial T1-weighted were acquired of which the axial slices were used for measurements of FV and AV. A second axial T1-weighted sequence of the femoral condyles was used for measurements of FV [7,24]. These sequences were taken immediately after the original axial T1-weighted sequences and the patient was instructed not to move the leg to ensure accurate measurement. If needed, CT was acquired according to a previously validated protocol [22]. A slice thickness of 2 mm and an interval of reconstruction of 1.7 mm were chosen.

FV was measured according to Murphy et al [26] (Fig. 2) by two different independent observers (TDL and FS) using three reference points on transverse slices at different femoral locations: the femoral head center, the center of the base of the femoral neck, and the condylar axis. No summation image was used. The method described by Murphy et al is performed by superimposing the center of the femoral head on the CT section through the base of the femoral neck [26] and showed good reproducibility between two readers [24]. Because of the good reproducibility [24] and the similarity to method of a summation image described by Tönnis et al [16], we have chosen this method. Normal FV was 10–25° according to Tönnis et al [16]. Femoral retroversion was defined as FV < 10° and absolute femoral retroversion was defined as FV < 0°. Increased FV was defined as FV > 25°, severely increased FV as FV > 35° and excessively increased FV as FV > 45°.

Central AV was measured on 3o'clock (equator level) according to Hetsroni [37] and was defined as the angle between a sagittal line and a line connecting the anterior and posterior acetabular rim. A normal central AV and FV was defined from 10 to 25 [16]. Decreased AV was defined as AV < 10°. Increased AV was characterized as >25°. Abnormal AV was defined as <10° or >25°. CV was calculated as the sum of AV and FV. Combined version was considered normal between 20 and 50°. Decreased CV was <20° [17].

Two different observers (TDL and FS) with 3 years of experience in musculoskeletal radiology measured FV and AV independently at two different time points on a random sample of 50 hips taken from our patient cohort. A good agreement (defined as interclass correlation coefficient [ICC] > 0.8 [38]) was found for both reproducibility and reliability of FV (intraobserver ICC of observer 1 of 0.93, ranging from 0.87 to 0.96 and intraobserver ICC of observer 2 of 0.97, ranging from 0.95 to 0.98). A substantial agreement (defined as ICC > 0.6 [38]) was found for reproducibility and reliability of central AV (ICC of observer 1 0.8 ranging from 0.65 to 0.89 and ICC of observer 2 of 0.78 ranging from 0.61 to 0.87). Interobserver agreement for FV was 0.96 (0.94 – 0.97) and for AV was 0.75 (0.62–0.83).

2.1. Statistical analysis

A normal distribution was present for all continuous parameters, which were confirmed using the Kolmogorov-Smirnov test. Continuous variables among the two groups were compared using independent unpaired *t*-test. A p-value below 0.05 was considered significant (significance level). Categorical variables were compared between the two groups using the Chi square test.

3. Results

Mean FV and CV was significantly ($p < 0.001$) increased of patients with DDH (mean ± SD of 25 ± 11° and 47 ± 18°) compared to patients with acetabular retroversion (16 ± 11° and 28 ± 13°, Table 3). Mean FV of female patients with DDH (27 ± 16°) and acetabular retroversion (19 ± 12°) was significantly ($p < 0.001$) increased compared to male patients with DDH (18 ± 13°) and acetabular retroversion (13 ± 8°, Table 3).

Frequency of increased FV (>25°) was 47%, of severely increased FV (>35°) was 23% and excessive FV (>45°) was 8% for patients with DDH (Table 4). Interestingly, normal FV (10-25°) was prevalent in>50% of patients with acetabular retroversion (Fig. 2).

Proportion of decreased FV < 10° was significantly($p < 0.001$) higher in patients acetabular retroversion(31%) compared to patients with DDH(17%). Absolute femoral retroversion was prevalent in 2% of DDH and 3% of patients with acetabular retroversion (Table 4).

CV of female patients with DDH (51 ± 17°) was significantly ($p < 0.001$) increased compared to male patients with DDH (37 ± 14°, Table 3). Proportion of increased CV (>50°) was 40% in DDH patients (Fig. 2). Of patients with DDH, 18% (Table 5) had AV > 25° combined with FV > 25° (Fig. 3). Of patients with acetabular retroversion, 12% had FV < 10° combined with AV < 10° (Fig. 4).

4. Discussion

Most importantly, we found that mean FV and CV was significantly

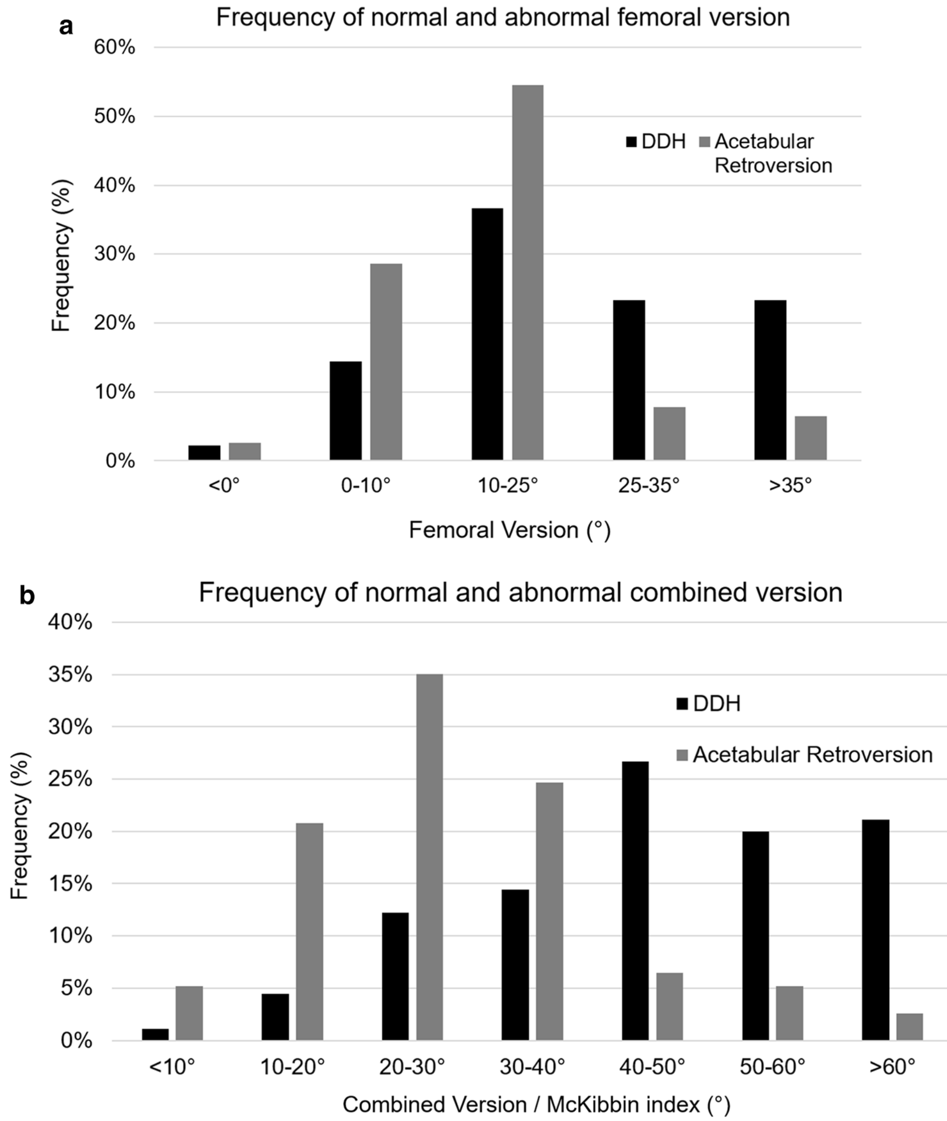

Fig. 2. A and B. Frequency of normal and abnormal femoral version (A) and combined version (B) is shown for patients with hip dysplasia and with acetabular retroversion. Combined version was also called McKibbin index or COTAV index.

($p < 0.001$) increased of patients with DDH compared to acetabular retroversion (Table 3). The proportion of increased FV > 25° was significantly ($p < 0.001$) higher in patients with DDH compared to acetabular retroversion. Overall, almost one out of five DDH patients (23%) had severely increased FV > 35°, these patients could be at risk for posterior extraarticular ischiofemoral impingement [39]. Interestingly, 17% of DDH patients had FV < 10°. In addition, mean FV of female patients with DDH (27 ± 16°) and acetabular retroversion (19 ± 12°) was significantly ($p < 0.001$) increased compared to male patients with DDH (18 ± 13°) and acetabular retroversion (13 ± 8°, Table 3). Analysing combined abnormalities of FV and AV, we found that 12% of the patients with acetabular retroversion had decreased FV < 10° combined with decreased AV (Table 5 and Fig. 4). Theoretically, these patients could be at risk for anterior intra- and extraarticular subspine hip impingement [22,40]. This analysis confirms that each patient requires a careful personalised evaluation.

Comparing our results with the literature, we found similar measurements of mean FV in symptomatic patients with DDH [6,45,46]. Some studies found a higher mean FV for DDH patients [47–52] using different measurement methods for FV. The reason for this discrepancy could be the different measurement methods used for FV measurement and different inclusion criteria in other studies. A recent study found similar mean FV for DDH and for patients with acetabular retroversion [50] using the same method (Murphy method) for FV measurement. Few studies investigated FV in patients with acetabular retroversion, while studies evaluating cam- and pincer-type FAI patients found comparable values for FV [51,52].

For patients with DDH, the reported proportion of patients with abnormal FV ranged from 57% [46] to 64% [50], for patients with FV < 5° from 10% [46] to 16% [4] and for patients with FV > 20° from 22% [16] to 52% [4]. In comparison to two recent studies [46,50], we found a similar proportion of patients with abnormal FV for patients with DDH (63%, Table 4).

The literature remains sparse regarding analysis of FAI patients with femoral retroversion [50,55] and a recent study found a slightly lower proportion of decreased FV < 10° for patients with acetabular retroversion [50]. Definitions and categories for femoral retroversion or femoral anteversion vary in the literature. Reported thresholds for categorizing FV in femoral retroversion were < 25° [35], <10° [16], <5° [36], and < 0° [34]. In addition, further definitions of femoral retroversion exist, some authors defined it using FV < 10° [7] or FV < −2° [25]. Some authors reported a similar proportion of femoral retroversion of 27% [36] for patients with mixed-type FAI (compared to patients with acetabular retroversion in the current study) and other reported a

Table 3
Results of mean FV and AV and McKibbin index (combined version) are shown.

Parameter	Hip Dysplasia	Acetabular Retroversion
Number of hips (patients)	90 (73)	77 (65)
Femoral version, Murphy method (°)	25 ± 15 (-9 – 84)	16 ± 11(-4 – 48) *
Femoral version females (°)	27 ± 16 (-9 – 84)	19 ± 12 (-3 – 48)
Femoral version males (°)	18 ± 13(-2 – 44) †	13 ± 8(-4 – 35) †
Central Acetabular version, 3o'clock version (°)	22 ± 7 (5 – 38)	13 ± 6(-1 – 26) *
Central Acetabular version females (°)	24 ± 6 (10 – 38)	13 ± 6 (1 – 26)
Central Acetabular version males (°)	19 ± 6(5 – 34) †	12 ± 6 (-1 – 25)
Combined version, McKibbin index, COTAV index (°)	47 ± 18 (8 – 110)	28 ± 13(-1 – 72) *
Combined version females (°)	51 ± 17 (8 – 110)	32 ± 15 (7 – 72)
Combined version males (°)	37 ± 14(15 – 76) †	25 ± 10(-1 – 45) †

Continuous values are expressed as mean ± SD with range in parentheses, FV = femoral version; *significant difference compared to patients with hip dysplasia. † significant difference compared to female patients of the same subgroup.

Table 4
Proportion of increased and decreased FV are shown.

Definitions	Hip Dysplasia	Acetabular Retroversion
Excessively increased FV > 45°	8%	1%
Severely increased FV > 35°	23%	6%
Increased FV > 25°	47%	14%*
Abnormal FV (<10° or > 25°)	63%	45%*
Normal FV (10-25°)	37%	55%*
Femoral retroversion FV < 10°	17%	31%*
Absolute Femoral retroversion FV < 0°	2%	3%

FV = femoral version; *significant difference compared to patients with hip dysplasia.

lower proportion of femoral retroversion of 15% [23] and of 9% [25].

Analysing combined deformities has implications for patients with DDH and supports patient-specific evaluation of FV and CV because 17% of patients with DDH had FV < 10°. This combination was not expected and is somewhat atypical. This means that the expected typical combination was DDH combined with increased FV. Both combinations could influence IR and hip impingement. The various possible combinations underline the importance of patient-specific evaluation of FV and CV. Based on the results of this study, routine measurement of FV and AV could be recommended.

Analysing sex differences, previous studies also found sex differences for FV up to 5° [53], others found 2° or 3° of difference [37,54]. Comparing the results for CV, few studies evaluated CV for patients with DDH [6,46,49]. One study reported a mean of 42° [46] and another a mean of 47° [6] for patients with DDH, similar to the results of the current study (Table 4) but lower compared to female patients with DDH. A previous study evaluating FAI patients used the same definition for decreased CV(<20°) [17] and defined increased CV (>45°) slightly different.

Analysing measurement methods, a large heterogeneity of measurement techniques for FV and imaging modalities were described. For most of the measurement methods, FV was measured on transverse images [7] but others used oblique axial images [23,25].

It was reported, that quantification of FV depend on the measurement method [24]. Differences in FV measurements up to 20° between measurement methods were described [24]. For better reproducibility of our results, an example with the measurement method for FV used in the Lisbon agreement was created, the Reikeras method [56]. Example: Assuming that FV of −9° is measured with the Reikeras methods, this corresponds to FV of 0° measured with the method used in our study, the Murphy method (assuming a difference of 9° between Murphy and Reikeras method [24]). Therefore, we propose to use the definition of below −9° or −10° of FV (to avoid false positive results) for absolute femoral retroversion when using the Reikeras method [56] (and < 0° of FV for absolute femoral retroversion using Murphy method). Interpretation of the results in the current study is based on the Murphy method and the applied method should be considered when reporting FV. A recent study reported equivalent usage of CT and MRI for measurement of FV [32] and so FV measurements could be made without additional radiation exposure [57].

This study has clinical implications. FV has been studied since decades [16,19] but the clinical impact for FAI patients and hip preservation surgery [17,23] is controversial. FAI is a known cause for hip pain and precursor to hip osteoarthritis in young patients [15]. Hip arthroscopy is increasingly being used for treatment of FAI [43]. While use of hip arthroscopy for treatment of FAI continues to rise, the effect of FV and femoral retroversion is discussed controversially. Severe femoral retroversion was discussed as a potential contraindication for hip arthroscopy [23], while others reported good patient reported outcomes after hip arthroscopy for patients with femoral retroversion [25] and found no difference compared to patients with normal FV [44]. Femoral retroversion was observed in patients with slipped capital femoral epiphysis [41,42]. Femoral retroversion was associated with out-toeing of the foot and with anterior extraarticular subspine hip impingement [22]. In addition, femoral retroversion was reported to be a negative outcome predictor of patients with acetabular retroversion [50]. Anterior extraarticular subspine impingement was also described for patients with pincer-type FAI due to acetabular retroversion [40]. On the other hand, increased FV combined with valgus deformity has been

Table 5
Distribution of nine combinations of femoral version and acetabular version are displayed. Visualization of the nine combinations are shown in Fig. 3 for patients with hip dysplasia, in Fig. 4 for patients with acetabular retroversion.

Group	Group name	Hip Dysplasia	Combination	Acetabular Retroversion	Figure	Impingement
A	Increased AV with increased FV	18%	**Aggravated**	1%	Fig. 3A	Posterior
B	Normal AV with increased FV	25%	**Moderate**	8%	Fig. 3B	Posterior
C	Decreased AV with increased FV	2%	**Compensated**	5%	Fig. 3C	
D	Increased AV with normal FV	16%	**Moderate**	0%	Fig. 3D	
E	Normal AV with normal FV	20%	**Normal**	34%	Fig. 3E	
F	Decreased AV with normal FV	1%	**Moderate**	21%	Fig. 3F	
G	Increased AV with decreased FV	3%	**Compensated**	0%	Fig. 3G	
H	Normal AV with decreased FV	12%	**Moderate**	19%	Fig. 3H	Anterior
I	Decreased AV with decreased FV	1%	**Aggravated**	12%	Fig. 3I	Anterior

FV = femoral version; AV = acetabular version. Normal values for AV and FV were 1–25°.

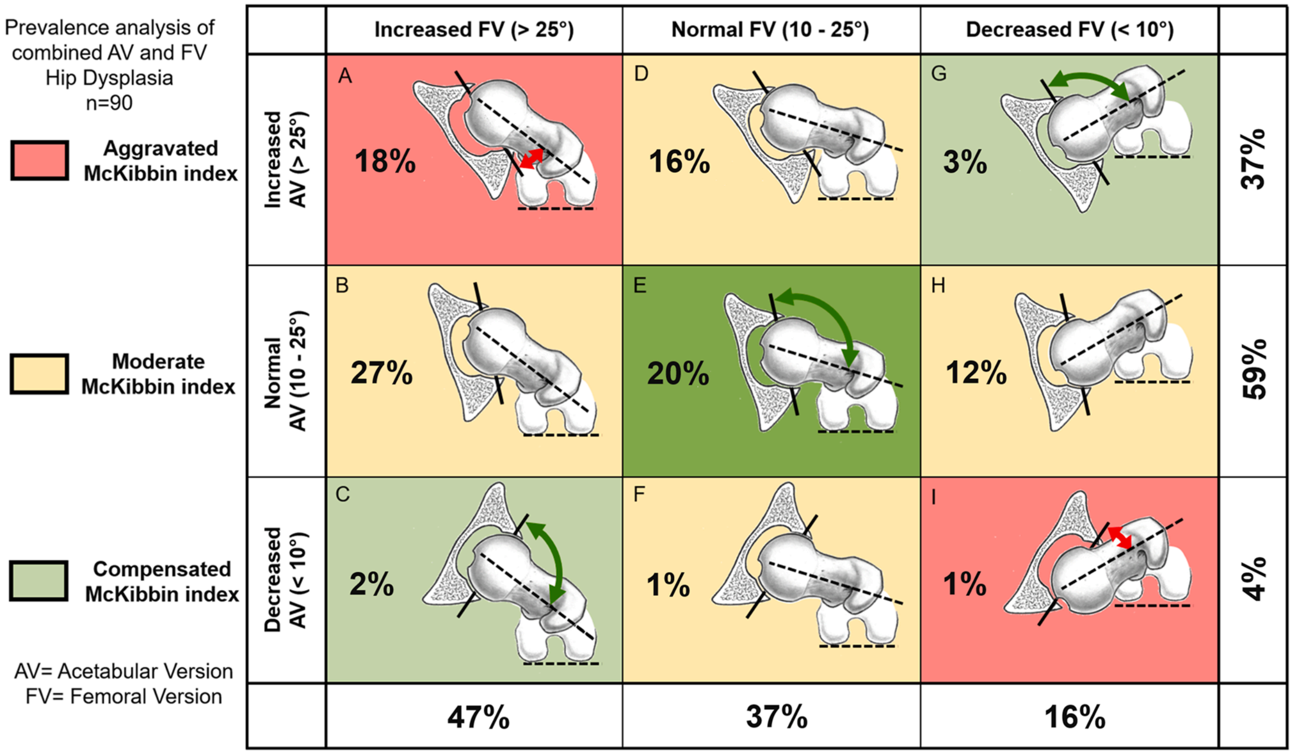

Fig. 3. Frequencies of nine combinations of femoral and acetabular version are shown for patients (90 hips) with hip dysplasia. Two combinations (top left, A and right below, I) had aggravated McKibbin index (red). Normal values for both AV and FV were between 10 and 25° according to Tönnis and Heinecke [16]. The two combinations on below left (C) and on top right (G) had compensated McKibbin index. Combined version was also called McKibbin index or COTAV index. Figure adapted with permission from Lerch et al[60].

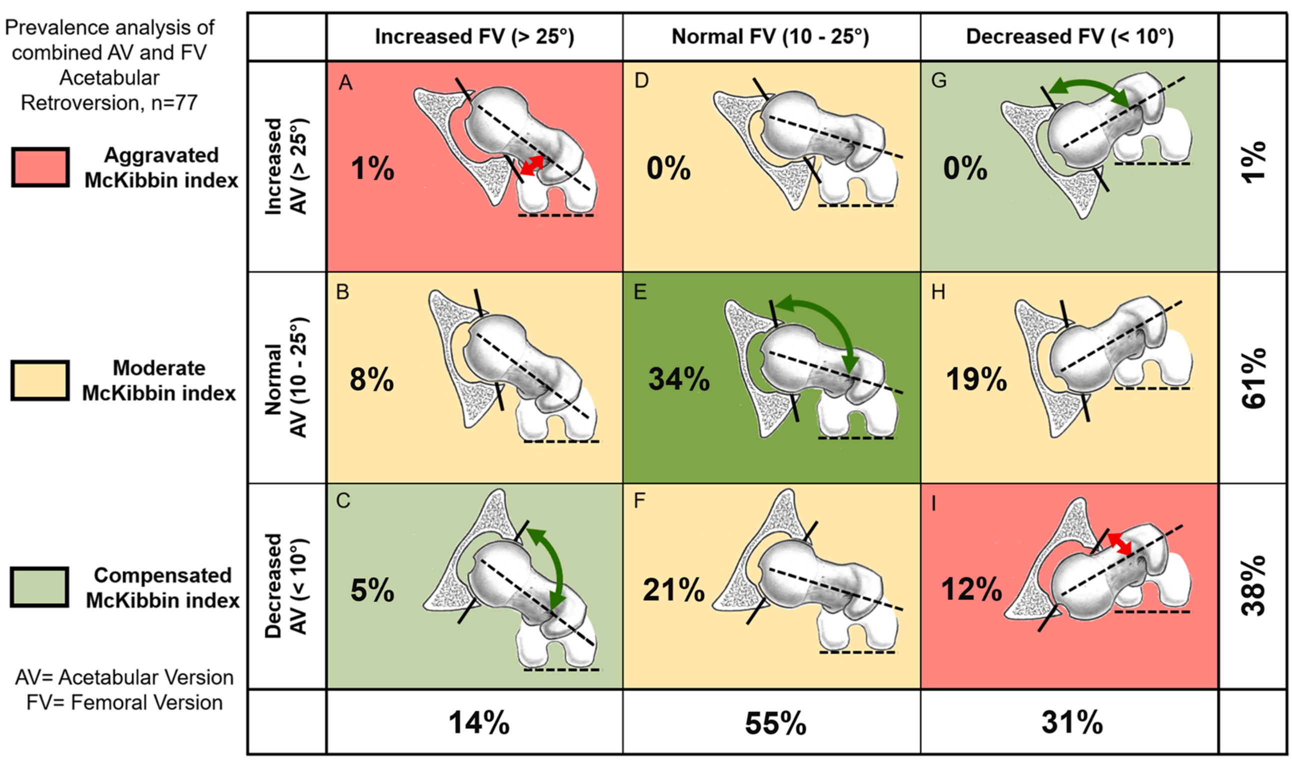

Fig. 4. Frequencies of nine combinations of femoral and acetabular version are shown for patients (77 hips) with acetabular retroversion. Two combinations (top left, A and right below, I) had aggravated McKibbin index (red). Normal values for both AV and FV were between 10 and 25° according to Tönnis and Heinecke [16]. The two combinations on below left (C) and on top right (G) had compensated McKibbin index. Combined version was also called McKibbin index or COTAV index. Figure adapted with permission from Lerch et al[60].

recognized as a cause for posterior extraarticular hip impingement between the ischium and the greater/lesser trochanter [39].

This study has limitations.

Although this is a consecutive patient series, it rather should be interpreted as a selective patient group from an European university hospital, that could include a higher percentage of abnormal values compared to the general population. There could be a potential selection bias of complex patients with limited generalizability. Second, all patients were symptomatic at time of imaging. Third, not all recommendations of the Lisbon agreement for hip imaging were applied for this study, because inclusion criteria were defined before publication of the agreement. Additionally, no normal values for FV and CV were studied. Another limitation is, that we have not evaluated spino-pelvic parameters [13] and have no 3D or 4D information [57] of these patients.

In addition, the age of the FAI patients ranged from 14 to 59 years (Table 2). This might be problematic because FV reportedly decreases in the first two decades of life before closure of the growth plates. [16,19,54] In accordance with previous reports [58,59], there are no substantial age-dependent changes of FV after skeletal maturity is reached. [54] Patients with skeletal immaturity were excluded and this should not affect the results of this study.

5. Conclusion

Patients with DDH have remarkable sex differences of FV (9°) and CV (14°). Frequency of severely increased FV > 35° (23%) is considerable for patients with DDH, but 17% exhibited decreased FV, that could influence IR. Patients with acetabular retroversion can be combined with femoral retroversion. The different combinations underline the importance of patient-specific evaluation of these patients before open hip preservation surgery and hip arthroscopy.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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