Similar HAGOS profile in patients with long-standing hip and groin pain and alpha angle under or over 60 degrees

Maria Biesert, ST-läkare, Ortopedkliniken Ljungby,
maria.biesert@kronoberg.se

Supervisor: Ioannis Kostogiannis, MD, PhD
Specialistläkare ortopedi

Abstract

Background: Alpha angle is the most commonly used radiological measurement to evaluate and define cam-morphology. The cut-off value for a pathological alpha angle differ in the literature between 50 to 80 degrees. The purpose of this explorative study is to investigate if patients with long standing hip and groin pain and a high alpha angle (≥60 degrees) report worse patient-reported outcome scores compared to patients with a low alpha angle.

Methods: Fifty-seven patients (females= 28, males =29) with a mean age of 35.7 years (range 19-53) referred to the Department of Orthopedics at Skåne University Hospital for longstanding hip and groin pain (LHGP) were radiological examined and evaluated according to different radiological measurements, Alpha angle, LCE-angle, head neck offset ratio, coxa profunda and crossover sign. Plan X-ray films were used with Lauenstein and anteroposterior pelvic projections. All patients completed the PRO:s The Copenhagen Hip and Groin Outcome Score (HAGOS) as well as The Hip Sports Activity Scale (HSAS). Patients with LHGP and alpha angle <60 degrees were compared with patients with LHGP and an alpha angle ≥ 60 degrees.

Results: Twenty-eight patients (49.1%) had an increased alpha angle (≥60 degrees), among them 7 females, p = 0.676. The mean alpha angle in the symptomatic hip was 51.8 (95% CI: 47.3-56.2) among females and 65.5 (95% CI 60.6-70.4) among males p=0.000. All patients included had some kind of radiological abnormality. HAGOS scores among patients with LHGP an alpha angle <60 degrees presented no significant difference compared with patients with LHGP with an alpha angle >60 degrees. A significant change in HSAS level could be seen over time in both patient groups.

Conclusion: In this exploratory study patients with longstanding hip and groin pain and alpha angles over 60 degrees report similar outcomes to patients with alpha angles under 60 degrees.

Key words: Alpha angle, femoroacetubular impingement, FAI, FAI syndrome, patient reported outcomes, HAGOS

Table of contents

Introduction 3

Aim of study 3

Methods 4

Study design 4

Radiographic evaluation 5

Patient-reported outcome measures (PRO:s) 6

Statistics 7

Etics 7

Time plane 7

Fundings 7

Results 8

Patient characteristics and radiographic evaluation 8

Patient-reported outcomes (PRO:s) 9

Patients with bilateral symptomatic LHGP 10

Discussion 12

Limitations 15

Conclusion 15

References 16

Introduction

Femoroacetabular impingement (FAI) syndrome is a common cause of hip and groin pain in the young active population and is a diagnosis and patient group that is growing fast. Ganz et. al. (1) presented in 2003 a new surgical approach for FAI syndrome. Since then hip arthroscopic surgery has emerged and new options with joint preservation treatment can be offered more frequently. (2). The definition and management of FAI syndrome differ around the world and a lack of clarity of diagnosis criteria creates ambiguity. To guide the medical field the Warwick Agreement was established at an international congress In 2016. Consensus was made and femoroacetabular impingement (FAI) syndrome was described as a triad of symptoms, clinical signs as well as imaging findings (2).

The prevalence of radiographic signs that can predispose for FAI syndrome are reported in the literature between 1% up to 95% with an increased prevalence in the athletic population. FAI syndrome can relate to three different types of morphology: pincer, cam and mixed and can be identified and graded with different types of measuring techniques and x-ray views (3). In a review by Dickenson et al. (4) current studies show estimates of cam-morphology ranging from 5% to 75%, but are not truly population based and therefore the true prevalence and its relationship to hip pain cannot be determined. Alpha angle is the most commonly used radiological measurement to evaluate and define cam-morphology (5). In a study of collegiate athletes Larsen et. al (3) showed increasing alpha angle was predictor for hip and groin pain (3). However a threshold value for a pathological alpha angle has a range from 50 degrees to 80 degrees (5). Today no studies have evaluated the threshold for a pathological alpha angle in a patient population with hip and groin pain in respect to patient-reported outcomes.

Aim of study

The aim of this study was to investigate if patients with long-standing hip and groin pain and high alpha value (≥60 degrees) report worse PRO:s compared to patients with LHGP and low alpha angles.

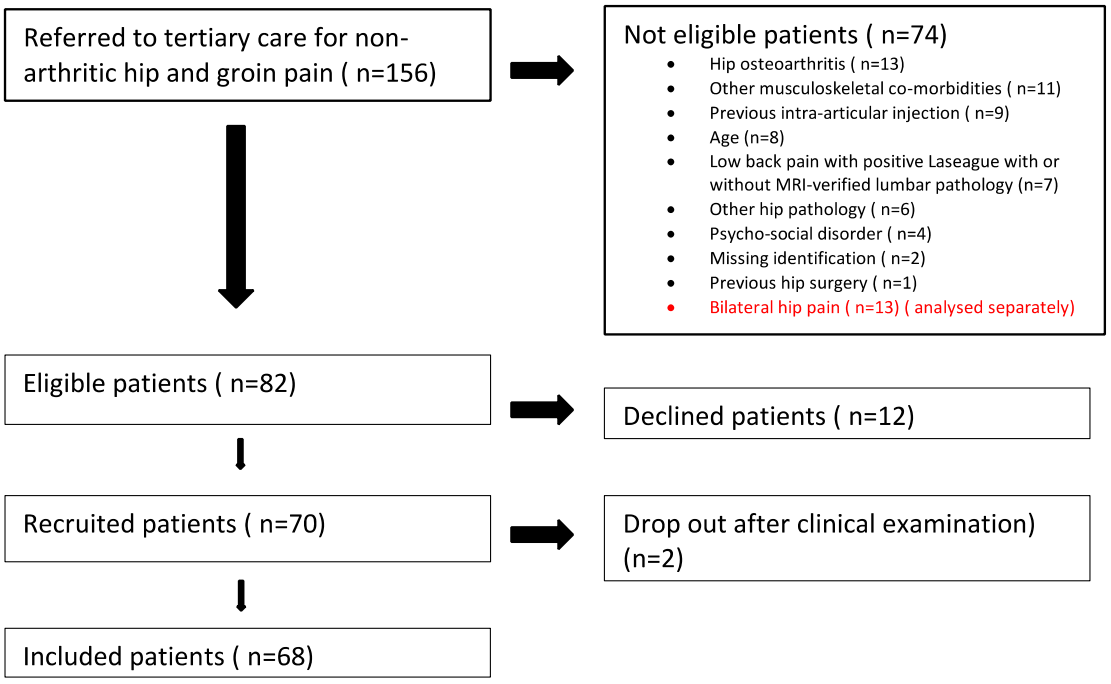
Methods

Study design

An explorative cross-sectional study was conducted between October 2014 to January 2017. All patients with longstanding hip/groin pain (LHGP) that were referred to the Department of Orthopedics, Skåne University Hospital in Malmö, Sweden were recruited and screened for eligibility according to the following inclusion criteria: Hip/groin pain for more than three months, age 18-55 years, no previous hip surgery. Exclusion criteria were patients with hip pathology (i.e Perthes's disease), verified moderate or severe osteoarthritis (Tönnis >1), patients that had received intra-articular or peri-articular injection with corticosteroids during the last 2 months, palpable hernia or low-back pain with positive Lasegue test, MR – verified pathology in the lower back/spine (i.e spinal stenosis and disc herniation), other musculoskeletal co-morbidities and patients with co-morbidities excluding physical activity and training, psychosocial disorders, drug abuse or not understanding the language of interest.

The patient selection is demonstrated in Figure 1. A total of 68 patients were initially included in this study. Lauenstein projections were missing for 5 participants, leaving 63 patients included for the radiographic evaluation. After excluding 6 participants for missing PRO:s 57 patients were included and presented in this study.

Figure 1: Flow chart on the patient selection



Patients experiencing bilateral pain were analyzed separately since the results were not possible to interpret correctly compare to the unilateral hip/groin pain. The alpha angle of the hip that presented most symptoms was analyzed. 13 patients experiences bilateral pain. Lauenstein projection was missing from 1 participant and PRO:s were missing from 3 leaving 9 patients with bilateral symptoms included in the study.

Radiographic evaluation

Patients underwent imaging tests (plain X-rays films) prior to examination. All radiographs were analyzed by the same radiologist who was not involved in the care of the patients. The alpha angle, head-neck offset ratio, lateral centre-edge angle, coxa profunda and crossover sign were identified and analyzed in accordance with a report by Clohisy et al. (6). The Lauenstein (frog-leg lateral) projection was used to obtain the alpha angle and the head-neck offset ratio and the anteroposterior pelvic view (AP) was used to obtain the remaining measurements. The preliminary analysis of the radiographic evaluations reported by Pålsson et al. (7) showed excellent reliability.

Alpha angle

The alpha angle was calculated by drawing the best fitting circle around the femoral head, thus identifying the centre of the head. Then, a line was drawn from the centre of the femoral head to the center of the femoral neck. A second line was drawn form the center of the femoral head to the point where the head loses its spherical appearance anterolaterally. The angle was then calculated between these lines and values $\geq$ 60 degrees were used as a cut- off defining a cam deformity (8).

Head-neck offset ratio

Firstly, a line "A" was drawn from the centre of the femoral head through the centre of the femoral neck. Secondly, a parallel line "B" was drawn touching the most anterior part of the femoral neck. Thirdly, a line "C" parallel to the other lines was drawn through the most anterior aspect of the femoral head. The head-neck offset ratio was obtained by measuring the distance between lines "B" and "C" and the dividing it by the diameter of the femoral head. Cam morphology was defined by an offset ratio <0.17 (6).

Lateral centre-edge angle (Wiberg's angle, LCE-angle)

A first line "A" was drawn connecting the inferior part of the acetabular teardrops. Then a line "B", perpendicular to "A" was drawn through the centre of the femoral head. Finally a line "C" was drawn from the centre of femoral head through the sclerotic part of the superolateral sourcil of the acetabulum. The angle between line "B" and "C" was calculated and an LCE >40 indicated a presence of a pincer deformity (6).

Crossover sign

The crossover sign was recognized if the anterior aspect of the acetabular rim was crossing the posterior line of the acetabular rim (6).

Coxa profunda

The ilioischial line and the floor of the acetabular fossa was identified. If the border of the acetabular fossa was medial to the ilioischial line it was classified as coxa profunda (6).

Patient-reported outcome measures (PRO:s)

All patients were asked to fill in a short history form about the duration and onset of symptoms, the Copenhagen Hip and Groin Outcome Score (HAGOS) (9) and Hip Sports Activity Scale (HSAS) (10) for patients reported outcome measures.

The Copenhagen Hip and Groin Outcome Score (HAGOS)

The HAGOS was developed for young active individuals with hip/groin pain in 2011 (11). The validated and adapted Swedish version was used in this study (9). It consists of 6 separately scored subscales: pain, symptoms, activity of daily living, function in sport/recreation, participation in physical activities, and hip-related quality of life. All questions contains standardized answers from a scale from 0-4 in each subscale. A maximum score of 100 indicates no symptoms or disability (9). For comparison the results from the Wörner et al. (12) study with 33 healthy controls are demonstrated.

The Hip Sports Activity Scale (HSAS)

A Swedish version of the validated sports activity scale designed for patients with hip/groin pain and femoroacetabular impingement was used to assess patients' sports activity level during early

adolescence (10-15 years), pre-injury as well as current activity level. The scale include nine levels range from 0 (no recreational or competitive sports) to 8 (competitive sports at elite level) (10).

Statistics

The statistical analysis was performed using the software program IBM SPSS 22:0 for MAC. Descriptive data were used for patient demographics. All variables were tested for skewness. The mean or median and appropriate distribution measurements will be presented depending on the nature of the data. Group-comparisons consisting of normally distributed data was analyzed using the Independent sample t-test and non-normally distributed data was analyzed with the Mann-Whitney's test. The HAGOS and HSAS levels were calculated with the Mann-Whitney's test. Friedman's test was used to determine change in HSAS levels over time. $P<0.05$ were considered statistically significant.

Etics

Ethical approval has been obtained prior to the study by The Regional Ethical Review Board in Lund (Dnr 2014/12). All participants were informed both in writing and orally about the study and completed informed consent forms before enrollment. All patients had the option to withdraw from the study at any time. All patients data was unidentified prior to analysis. The key code and data is stored at the Health Sciences Centre in Lund, and only a few members of the research team has access to the data. All data was handled as stated by "The General Data Protection Regulation".

Time plane

Study planning started in the begin of 2020. Data was collected in 2019. The data was analyzed in the beginning of 2021. The manuscript writing started 2021 and will be presented in the spring of 2022.

Fundings

No fundings were received.

Results

Patient characteristics and radiographic evaluation

Fifty-seven patients (females= 28, males =29) with a mean age of 35.7 years (range 19-53) were included in the study. Patient characteristics are presented in table 1. The prevalence of abnormal radiological sign in the symptomatic hip is presented in table 2. All patients included had some kind of radiological abnormality. Twenty-eight patients (49.1%) had an increased alpha angle (≥60 degrees), among them 7 females, p = 0.676. The mean alpha angle in the symptomatic hip was 51.8 (95% CI: 47.3-56.2) among females and 65.5 (95% CI 60.6-70.4) among males p=0.000.

Table 1. Patients characteristics for all patients with unilateral pain, patients with an alpha angle < 60 degrees and patients with an alpha angle ≥60 degrees. Data is expressed as mean and standard deviation (SD) unless otherwise stated

Descriptive data	All patients (n=57) Mean (SD)	Patients with an alpha angle <60 (n=29) Mean (SD)	Patients with an alpha angle ≥60 (n=28) Mean (SD)
Age (year) (range)	35.7 (19-53)	37.2 (29-52)	34.2 (19-53)
Gender women (n)(%)	28 (49.1%)	21 (72.4%)	7 (25%)
BMI (kg/m2)	25 (4)	23.9 (4)	26 (3.7)
Unilateral symptoms left/right (n)	26/31	12/17	14/14
Duration of pain (n)(%)			
3-6 months	1 (1.8%)	1 (3.4%)	n/A
6-12 months	11 (19.3%)	5 (17.2%9	6 (21.4%)
more than 12 months	13 (22.8%)	7 (24.1%)	6 (21.4%)
several years	30 (52.6%)	14 (48.3%)	16 (57.1%)
unknown	2 (3.5%)	2 (6.9%)	n/A

Table 2. The prevalence of abnormal radiological signs in all patients with unilateral symptoms

Radiographic data	Patients n	Present n (%)	Absent n (%)
Alfa angle >60 (CAM morphology)	57	28 (49.1)	29 (50.9)
LCE angle >40 (Pincer morphology)	56[a]	13 (22.8)	43 (75.4)
Head-neck offset ratio <0.17	57	50 (87.7)	7 (12.3)
Coxa profunda	57	24 (42.1)	33 (57.9)
Cross over sign	57	0 (0)	57 (100)
Any Radiological signs	57	57 (100)	0 (0)

a=missing data (n=1) due to missing radiographs

Patient-reported outcomes (PRO:s)

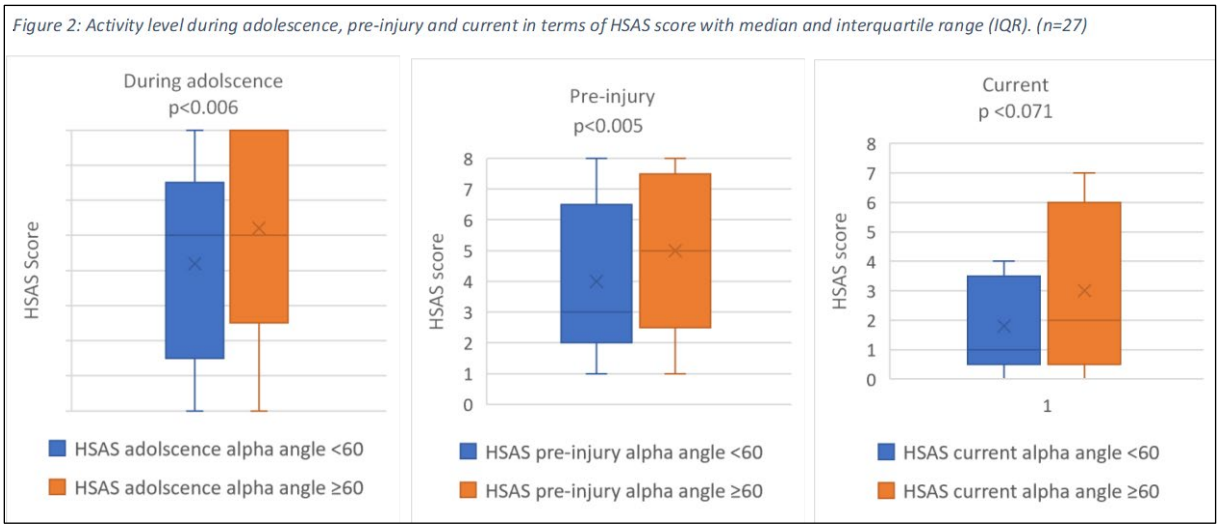
All included patients (females =28, males= 29) completed a short history form and the HAGOS. 64.9% experienced an insidious onset of hip/groin pain. 52.6% reported symptom duration for several years before being referred to tertiary care.

HAGOS scores among patients with LHGP an alpha angle < 60 degrees as well as patients with LHGP with an alpha angle >60 degrees are presented in table 3. The worst scores on the HAGOS were reported for subscale Physical activity and Quality of Life and the best score could be seen for the subscale Activity of daily living, Table 3. Both groups scored similar in all HAGOS subscales and thus no statistically significant differences could be seen between the groups. Both groups had significant worse score in all subscales compared to the normal controls (12) (p=0.000).

Table 3. HAGOS score for all patients with unilateral pain with an alpha angle <60 degrees and patients with an alpha angle ≥60 degrees. Data is expressed as median and interquartile range (IQR)

HAGOS	alpha angle <60 (n=29)	alpha angle ≥60 n=28)	P-value
Pain	57.5 (46.2-72.5)	57.5 (45-70)	p=0.743
Symptoms	60.7 (48.2-67.6)	57.1 (42.9-66.9)	p=0.456
ADL	65 (45-85)	65 (46.2-77.5)	p=0.625
Sports	56.2 (28.1-67.2)	51.6 (25-71.1)	p=0.690
Physical activities	25 (6.2-43.7)	25 (0-62.5)	p=0.981
QoL	30 (20-35)	27.5 (15-38.7)	p=0.694

The HSAS level, presented as median (interquartile range) can be seen in Figure 2.



Patients with bilateral symptomatic LHGP

Patients with bilateral symptomatic hip/groin pain were calculated separately. Descriptive data is presented in Table 4. Three (33.3 %) patients had an increased alpha angle (> 60 degrees), all male. The mean alpha angle in the symptomatic hip was 43.8 (95% CI 37.5-50.1) among females and 67 (95% CI 47.4-86.6) among males p=0.058.

Table 4. Patients characteristics for all patients with bilateral pain, patients with an alpha angle < 60 degrees and patients with an alpha angle ≥60 degrees. Data is expressed as mean and standard deviation (SD) unless otherwise stated

Descriptive data	**All patients (n=9) Mean (SD)**	**Patients with an alpha angle <60 (n=6) Mean (SD)**	**Patients with an alpha angle ≥60 (n=3) Mean (SD)**
Age (year) (range)	34.1 (18-44)	34 (18-44)	34.3 (18-43)
Gender women (n)(%)	5 (55.6%)	5 (83.3%)	0 (0%)
BMI (kg/m2)	23.5 (3.3)	23 (3.8)	24.7 (2)
Most symptomatic side left/right (n)	2/7	1/5	1/2
Duration of pain (n)(%)			
3-6 months	n/A	n/A	n/A
6-12 months	1 (11.1%)	1 (16.7%)	n/A
more than 12 months	2 (22.2%)	2 (33.3%)	n/A
several years	6 (66.7%)	3 (50%)	3 (100%)
unknown	n/A	n/A	n/A

HAGOS subscale results in patients with bilateral LHGP showed overall similar results as patients with unilateral pain. Median and interquartile range showed Pain 70 (45-78.7), symptoms 53.6 (44.6-

67.9), ADL 75 (35-87.5), sports 43.7 (23.4-57.8), Physical activities 12.5 (0-56.2), QoL 25 (20-35). Only three patients presented with an increased alpha angle. The HSAS level among patients with bilateral symptomatic LHGP was 6 (5-7) during adolescence, 5 (4.5-7) pre-injury, and present level was 3 (1-5.5). No significant change in HSAS can been seen since the patient group is too small.

Discussion

This exploratory study is to our knowledge, the first to investigate the alpha angle's association, in a symptomatic patient group, to validated PRO:s. The results suggest that an alpha angle >60 degrees is not associated with worse patient-reported outcomes in patients with long-standing hip and groin pain. Patients with LHGP showed overall lower results in all HAGOS subscales compared to a control group (12) but very similar HAGOS results were seen between patients with LHGP with an alpha angle <60 degrees as with an alpha angle >60 degrees. Kopec et al. (13) examined the association between radiographic measurements of hip morphology (cam and pincer) among a general population with and without hip pain. The alpha angle was defined in the 45 degree bilateral Dunn view and the LCE angle was defined in the AP view. Data from 500 subjects were obtained. Even if a higher alpha angle indicated worse HAGOS scores no significant difference could be seen in the HAGOS profile between those with an alpha angle <60 degrees versus >60 degrees. Measuring the alpha angle in plain radiographs is simpler, cheaper and less-time consuming than CT or MRI. Nepple et al. (14) describe that plain radiographs effectively identify femoral head-neck malformation. The Dunn view showed highest sensitivity of detecting abnormal alpha angles (71-80%) but the lauenstein (frog-leg lateral) showed the best specificity (91-100%). Pålsson et al. (7) have demonstrated that measuring the alpha angle in the Lauenstein position is simple and reproducible, even in unexperienced examiners. Even if we have the same alpha angle criteria as Kopec et al.(13) the inclusion criteria differed and our study only contained symptomatic subjects. By using the Dunn view Kopec et al.(13) might have categorized a larger patient group with a pathological alpha angle compared to our study that used the Lauenstein projection. Our study presented overall a lower score in all HAGOS subscales compared to Kopec et al.(13). However our patient population might have had worse radiographic findings and therefore more symptoms which is shown in the HAGOS profile. This can be an obvious reason why our patient group had overall a worse HAGOS profile. Sansone et al. (15) compared HAGOS scores pre-operative with PRO:s two(15) and five(16) years after hip arthroscopic surgery. All patients met inclusion criterias for surgery but no alpha angle was described. The pre-operative HAGOS results were very similar to ours.

The alpha angle is commonly used as a radiologic sign that defines a CAM-morphology and although the cut-off for pathological alpha angle differs in different studies, a common used

threshold is 60 degrees. It is therefore used as an indication for surgery (5). However, several studies have failed to demonstrate a correlation between alpha angle correction after surgery and patient-reported outcomes, as well as patient satisfaction. Stähelin et al. (17) included 22 patients undergoing hip arthroscopic offset correction. A normal alpha angle was defined as 50 degrees or less. Restoration was consider accurate if a normal angle or a reduction of 20 degrees or more was achieved. No more than 20% of the femoral neck diameter was removed to avoid risk of fracture. The mean alpha angle preoperative was 75.1 + 12.7 (range 58-100) degrees and postoperative 53.8 + 9.2 (40-72) degrees. Postoperative no significant difference could be seen clinically and in PRO:s between patients with an alpha angle reduced to <50 degrees compared to patients with a alpha angle that remained >50 degrees. Neither a difference depending on the precent of correction. However all patients experienced improved mobility and less pain postoperative (17). Briggs et al (Briggs) presented similar result with 230 patients included. The median preoperative alpha angle was 72 (50-105) degrees and the median postoperative alpha angle was 45 (30-100) degrees. Two groups were compared, patients that postoperative had an alpha angle <55 degrees and >55 degrees. PRO:s 5 years after surgery did not show that patients with a larger postoperative alpha angle had lower patient-reported outcomes (18). A recent systematic review compared relationship between alpha angle correction and outcomes. A reduction of alpha angle to 55 degree or less were recommended and should improve outcome scores. However the review also point out that a no reduction more than 20 degrees should be considered. Mixed evidence on the ability of the alpha angle to predict patient-reported outcomes were also highlighted (19).

Beck et al. (20) described that the main difference between a normal hip and a hip with FAI syndrome is abnormal joint morphology. Threshold values defining normal from pathological is therefore difficult. However since many patients without symptoms have an increased alpha angles it is important that the threshold value is considered as one of several classification criteria that supports the diagnosis of FAI syndrome and not a diagnostic criteria for surgery. (5, 21, 22). Threshold values differs between literature partly due to different measuring techniques. Most studies use CT or MRI but some use plain radiographs. Different radiographic views are also debatable in order to obtained optimal scans. The frog-lateral, Lauenstein or Dunn-view is the most recommended (14, 23). Pollard et. al (8) examined the reference interval for cam deformity in the cross-table lateral view and found a mean value of 46-49 degrees (sex dependent) and a 95% confidence interval of 32-62 degrees. Nötzli et al. (24) reported an average alpha angle using MRI scans of 74 degrees among patients and 42 degrees among controls but recommended a threshold value of 55 degrees. Sutter et al. (22) showed a great overlap in alpha angle measurement between

symptomatic and asymptomatic patients who underwent MRI. While 55 degrees alpha angles had a good sensitivity the specificity was low. By increasing the cutoff value to 60 degrees the false positive results were reduced but a good sensitivity still remained. Barrientos et. al. (25) reported using CT an average angle of 67 degrees among patients compared to 58 degrees among controls. They used a cutoff value of 57 degrees. Allen et al. (26) chose in 2009 a cutoff value of 55 degrees for defining a cam-deformity using CT-imaging. However this study also showed that painful hips were more likely to have an alpha angle over 60 degrees with an odds ratio of 2.59 compared to hips with alpha angles of 60 degrees or less.

One theory is that the range of alpha angles depends on gender and that males overall have higher alpha angle value compared to females (8, 22, 27). Discussions if different cut-off values depending on gender have been proposed (28) but overall a non-sex specific threshold value are described in the literature (5).

There is a risk with overanalyzing radiographic findings, since common radiographic signs of FAI syndrome are prevalent even in asymptomatic individuals (29). In our study 100% of the patients had one or more signs of impingement such as high alpha angle, low head-neck offset, pincer or coxa profunda. The risk of using only radiological findings as diagnostic criterions could risk over-diagnosing. Palsson et al. (7) present, from the same data as this report, that only about half of the patients referred to tertiary care were potential candidates for surgery.

Both patient groups had a lower current activity level compared to pre-injury level as well as adolescence. The patients with an alpha angle >60 degrees showed a significant higher activity level during both adolescence, pre-injury and current compared to the patients with and alpha angle < 60 degrees. Indications of high impact training at a young age has been showed in previous studies to be a predispose factor to develop CAM morphology during skeletal maturation and thereby results in increased alpha angles (30-32).

The same patient group has a higher pre-injury and higher current HSAS score which could indicate that the group has greater physical demands since youth. However the scale has categorized different sports into different levels depending on the assumed load of the hip joint and range of motion and do not describe duration of activity and frequency of exercise making it more difficult to make larger clinical assumptions (10).

Limitations

This is an exploratory study. The number of patients included in the study is small and therefore there is a risk for type II statistical error.

All patients had been referred to the Orthopedic Department of a University hospital, serving as a regional hospital, to an orthopedic surgeon for assessment for surgery. Therefore the patient group had server hip related symptoms where prior treatments had failed. One can therefore argue that these patients had worse symptoms compared to the average FAI syndrome patient.

By including patients with long-standing hip and groin pain prior to diagnosis, one can argue that our patient population is heterogenic.

Since we only used plain radiographs, we may have underestimated the size of the CAM-lesion in some patients. Furthermore, our threshold values can be used in order to detect patients with more symptoms, although a number of patients with alpha angles lower than 60 degrees may also suffer from FAI syndrome.

HSAS was used to investigate patient-reported activity level. However the patient reported outcome measure do not report the load of the hip as duration of activity, frequency and intensity. Therefore comparison between patients can be difficult. The pre-injury activity level as well as adolescence activity level is reported retrospectively.

Conclusion

In this exploratory study patients with longstanding hip and groin pain and alpha angles over 60 degrees report similar outcomes to patients with alpha angles under 60 degrees.

References

1. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003(417):112-20.
2. Griffin DR, Dickenson EJ, O'Donnell J, Agricola R, Awan T, Beck M, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. **Br J Sports Med**. 2016;50(19):1169-76.
3. Larson CM, Sikka RS, Sardelli MC, Byrd JW, Kelly BT, Jain RK, et al. Increasing alpha angle is predictive of athletic-related "hip" and "groin" pain in collegiate National Football League prospects. **Arthroscopy.** 2013;29(3):405-10.
4. Dickenson E, Wall PD, Robinson B, Fernandez M, Parsons H, Buchbinder R, et al. Prevalence of cam hip shape morphology: a systematic review. **Osteoarthritis Cartilage**. 2016;24(6):949-61.
5. van Klij P, Reiman MP, Waarsing JH, Reijman M, Bramer WM, Verhaar JAN, et al. Classifying Cam Morphology by the Alpha Angle: A Systematic Review on Threshold Values. **Orthop J Sports Med.** 2020;8(8):2325967120938312.
6. Clohisy JC, Carlisle JC, Beaulé PE, Kim YJ, Trousdale RT, Sierra RJ, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. **J Bone Joint Surg Am**. 2008;90 Suppl 4(Suppl 4):47-66.
7. Pålsson A, Kostogiannis I, Lindvall H, Ageberg E. Hip-related groin pain, patient characteristics and patient-reported outcomes in patients referred to tertiary care due to longstanding hip and groin pain: a cross-sectional study. **BMC Musculoskelet Disord**. 2019;20(1):432.
8. Pollard TC, Villar RN, Norton MR, Fern ED, Williams MR, Simpson DJ, et al. Femoroacetabular impingement and classification of the cam deformity: the reference interval in normal hips**. Acta Orthop**. 2010;81(1):134-41.
9. Thomeé R, Jónasson P, Thorborg K, Sansone M, Ahldén M, Thomeé C, et al. Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement. **Knee Surg Sports Traumatol Arthrosc**. 2014;22(4):835-42.

10. Naal FD, Miozzari HH, Kelly BT, Magennis EM, Leunig M, Noetzli HP. The Hip Sports Activity Scale (HSAS) for patients with femoroacetabular impingement. **Hip Int**. 2013;23(2):204-11.
11. Thorborg K, Hölmich P, Christensen R, Petersen J, Roos EM. The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. **Br J Sports Med**. 2011;45(6):478-91.
12. Wörner T, Nilsson J, Thorborg K, Granlund V, Stålman A, Eek F. Hip Function 6 to 10 Months After Arthroscopic Surgery: A Cross-sectional Comparison of Subjective and Objective Hip Function, Including Performance-Based Measures, in Patients Versus Controls. **Orthop J Sports Med**. 2019;7(6):2325967119844821.
13. Kopec JA, Qian H, Cibere J, Wong H, Li LC, Barber M, et al. Relationship Between Hip Morphology and Hip-Related Patient-Reported Outcomes in Young and Middle-Aged Individuals: A Population-Based Study. Arthritis Care Res (Hoboken). 2019;71(9):1202-8.
14. Nepple JJ, Martel JM, Kim YJ, Zaltz I, Clohisy JC. Do plain radiographs correlate with CT for imaging of cam-type femoroacetabular impingement? **Clin Orthop Relat Res.** 2012;470(12):3313-20.
15. Sansone M, Ahldén M, Jónasson P, Thomeé C, Swärd L, Öhlin A, et al. Outcome after hip arthroscopy for femoroacetabular impingement in 289 patients with minimum 2-year follow-up. **Scand J Med Sci Sports.** 2017;27(2):230-5.
16. Öhlin A, Ahldén M, Lindman I, Jónasson P, Desai N, Baranto A, et al. Good 5-year outcomes after arthroscopic treatment for femoroacetabular impingement syndrome. **Knee Surg Sports Traumatol Arthrosc.** 2020;28(4):1311-6.
17. Stähelin L, Stähelin T, Jolles BM, Herzog RF. Arthroscopic offset restoration in femoroacetabular cam impingement: accuracy and early clinical outcome. **Arthroscopy.** 2008;24(1):51-7.e1.
18. Briggs KK, Soares E, Bhatia S, Philippon MJ. Postoperative alpha angle not associated with patient-centered midterm outcomes following hip arthroscopy for FAI. **Knee Surg Sports Traumatol Arthrosc**. 2019;27(10):3105-9.
19. de Sa D, Urquhart N, Philippon M, Ye JE, Simunovic N, Ayeni OR. Alpha angle correction in femoroacetabular impingement. **Knee Surg Sports Traumatol Arthrosc.** 2014;22(4):812-21.
20. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip**. J Bone Joint Surg Br.** 2005;87(7):1012-8.

21. Mascarenhas VV, Ayeni OR, Egund N, Jurik AG, Caetano A, Castro M, et al. Imaging Methodology for Hip Preservation: Techniques, Parameters, and Thresholds. **Semin Musculoskelet Radiol.** 2019;23(3):197-226.
22. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CW. How useful is the alpha angle for discriminating between symptomatic patients with cam-type femoroacetabular impingement and asymptomatic volunteers? **Radiology.** 2012;264(2):514-21.
23. Saito M, Tsukada S, Yoshida K, Okada Y, Tasaki A. Correlation of alpha angle between various radiographic projections and radial magnetic resonance imaging for cam deformity in femoral head-neck junction. **Knee Surg Sports Traumatol Arthrosc**. 2017;25(1):77-83.
24. Nötzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement**. J Bone Joint Surg Br.** 2002;84(4):556-60.
25. Barrientos C, Barahona M, Diaz J, Brañes J, Chaparro F, Hinzpeter J. Is there a pathological alpha angle for hip impingement? A diagnostic test study**. J Hip Preserv Surg.** 2016;3(3):223-8.
26. Allen D, Beaulé PE, Ramadan O, Doucette S. Prevalence of associated deformities and hip pain in patients with cam-type femoroacetabular impingement. **J Bone Joint Surg Br.** 2009;91(5):589-94.
27. Kapron AL, Anderson AE, Aoki SK, Phillips LG, Petron DJ, Toth R, et al. Radiographic prevalence of femoroacetabular impingement in collegiate football players: AAOS Exhibit Selection**. J Bone Joint Surg Am**. 2011;93(19):e111(1-10).
28. Gosvig KK, Jacobsen S, Palm H, Sonne-Holm S, Magnusson E. A new radiological index for assessing asphericity of the femoral head in cam impingement. **J Bone Joint Surg Br**. 2007;89(10):1309-16.
29. Frank JM, Harris JD, Erickson BJ, Slikker W, 3rd, Bush-Joseph CA, Salata MJ, et al. Prevalence of Femoroacetabular Impingement Imaging Findings in Asymptomatic Volunteers: A Systematic Review. **Arthroscopy**. 2015;31(6):1199-204.
30. Agricola R, Bessems JH, Ginai AZ, Heijboer MP, van der Heijden RA, Verhaar JA, et al. The development of Cam-type deformity in adolescent and young male soccer players. **Am J Sports Med.** 2012;40(5):1099-106.
31. Siebenrock KA, Ferner F, Noble PC, Santore RF, Werlen S, Mamisch TC. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. **Clin Orthop Relat Res.** 2011;469(11):3229-40.

32. Philippon MJ, Ho CP, Briggs KK, Stull J, LaPrade RF. Prevalence of increased alpha angles as a measure of cam-type femoroacetabular impingement in youth ice hockey players**. Am J Sports Med.** 2013;41(6):1357-62.