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The relationship between cam morphology and hip and groin symptoms and signs in young male football players

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Background: Conflicting and limited high-quality prospective data are available on the associations between cam morphology and hip and groin symptoms and range of motion (ROM).

Objectives: This cross-sectional cohort study investigated associations between cam morphology presence, size and duration and symptoms and ROM.

Methods: Academy male football players (n = 49, 17-24 years) were included. Standardized antero-posterior pelvic and frog-leg lateral radiographs were obtained at baseline, 2.5- and 5-year follow-up. The femoral head-neck junction was quantified by:

1. Visual score. Cam morphology (flattening or prominence), large cam (prominence).
2. Alpha angle. Cam morphology ($\geq 60°$), large cam ($\geq 78°$).

Cam morphology duration was defined as long (first present at baseline) or short (only from 2.5- to 5-year follow-up). Current symptoms at 5-year follow-up were assessed using a hip and groin pain question and by the "Hip and Groin Outcome Score" (HAGOS). HAGOS scores were categorized into: most symptoms (≥ 2 domains in lowest interquartile range [IQR]), least symptoms (≥ 2 domains in highest IQR). Hip ROM was measured by goniometry at 5-year follow-up.

Results: Large cam morphology based on visual score was associated with hip and groin pain (23.8% vs. 7.1%, OR: 3.17, CI: [1.15-8.70], $P = .026$), but not with HAGOS scores. Cam morphology presence, size, and duration were associated with limited flexion of around 6° and/or 3° to 6° for internal rotation.

Conclusion: Cam morphology presence, size, and duration were associated with limited hip flexion and/or internal rotation, but differences might not exceed the minimal clinical important difference. Whether cam morphology results in symptoms is uncertain.

KEYWORDS
FAI syndrome, femoroacetabular impingement, pain, range of motion

1 | INTRODUCTION

Hip and groin symptoms are frequently observed in professional sports and football in particular. The prevalence of hip and groin symptoms in (elite) football is reported as 49% per season,[1] while the incidence varies between 4% and 19%.[2,3] One of the causes of hip and groin symptoms in athletes is femoroacetabular impingement (FAI) syndrome.[4] FAI syndrome is defined by a triad of symptoms, clinical signs, and imaging findings.[4]

Imaging findings consistent with FAI syndrome include cam and/or pincer morphology. Cam morphology is an extra bone formation on the anterolateral side of the head-neck junction of the femur which arises during growth.[5-9] It can potentially damage intra-articular structures such as the cartilage and acetabular labrum and might cause symptoms.[10,11]

Cam morphology prevalence in football players is high.[5-7,9,12] Although there is an association between cam morphology and hip osteoarthritis (OA),[12-17] the association between cam morphology and symptoms in athletes remains contradictory. Several cross-sectional studies showed conflicting results.[18-22] One available longitudinal case-control study[23] showed an association between cam morphology and development of hip pain in the general population with a relative risk of 4.3 (95% confidence interval [CI]: 2.3-7.8). Another prospective cohort study[24] found no association between cam morphology and groin injuries in professional football players. A large cam morphology is associated with a higher risk for developing hip OA[13] and cartilage damage.[25-27] It might therefore hypothetically result in more symptoms and more limited range of motion (ROM). The influence of cam morphology duration on both symptoms and ROM has never been investigated and can only be assessed when information on when cam morphology arises is available.

Therefore, the study aims of this cohort with young academy male football players were to assess the association between the cam morphology presence, size and duration and hip and groin symptoms and ROM within 5-year follow-up.

2 | METHODS

2.1 | Study participants

At baseline, all academy male football players of the Feyenoord Academy aged between 12 and 19 years (n = 141) received an invitational letter of whom 89 finally participated. All 89 baseline participants were invited again to participate at 2.5-year follow-up (n = 63 participants) and the 5-year follow-up (n = 49 participants) (Figure 1). Inclusion and exclusion criteria were described previously.[5,6] The inclusion for the 5-year follow-up took place between June 2015 and October 2015. Ethical approval was obtained from the Medical Ethical Committee of the Erasmus Medical Center (Rotterdam, the Netherlands). Each participant gave written

consent. For participants under 18 years, written consent was gathered from at least one parent. Participant characteristics, such as age, weight, height (and BMI), football experience, training intensity, and self-reported hip and/or groin symptoms, were collected (Table 1).

2.2 | Radiographs

Three radiographs were obtained during this study by the same standardized radiographic protocol as described previously[5,6]; one supine antero-posterior pelvic radiograph and a frog-leg lateral radiograph of each hip.

2.3 | Visual scores

The femoral head-neck junction of all hips was scored qualitatively as normal, flattening, or prominence.[5,6] This additional

TABLE 1 Participant characteristics at 5-year follow-up

Number of participants (hips), n	49 (98)
Age, mean ± standard deviation (SD), (range), y	20.53 ± 2.17 (17-24)
Weight, mean ± SD (range), kg	73.77 ± 7.87 (57-91)
Height, mean ± SD (range), cm	180.33 ± 6.63 (165-190)
Body mass index, mean ± SD (range), kg/m^2	22.65 ± 1.59 (18.5-27.0)
Football experience, mean ± SD (range), y	14.29 ± 2.58 (9-19)
Training intensity, mean ± SD (range), h/w	9.30 ± 2.92 (5-20)
Self-reported hip and/or groin symptoms per hip, n (%)	14/98 (14.3%)
- Left	7 (50%)
- Right	7 (50%)
HAGOS domain scores, median (IQR, 25th-75th centile)	
- Pain	97.50 (92.50-100.00)
- Symptoms	82.14 (73.21-92.86)
- Activities of daily living	100.00 (95.00-100.00)
- Sports and recreational activity	100.00 (87.50-100.00)
- Physical activity	100.00 (87.50-100.00)
- Quality of life	95.00 (80.00-100.00)
Cam morphology based on alpha angle (≥60°) per hip (n = 98), n (%)	80 (81.6)
Cam morphology based on visual score (flattening or prominence) per hip (n = 98), n (%)	78 (79.6)

Abbreviations: HAGOS, Hip and Groin Outcome Score; IQR, interquartile range; SD, standard deviation.

method was used because of alpha angle limitations, especially in hips with an open growth plate.[5,7] An experienced musculo-skeletal radiologist and orthopedic surgeon determined all visual scores simultaneously, and any discrepancies were directly resolved based on consensus. Visual scores were obtained by scoring each hip of all three time points in one session. Visual scores showed a kappa of 0.68 for intra-observer reliability in the baseline study.[5]

2.4 | Alpha angle

The alpha angle was automatically calculated on all radiographs, as described by Nötzli et al[28] and was used previously.[5,6] In short, the shape of the proximal femur was outlined by a manually positioned anatomical set of points by one observer, by using Statistical Shape Modelling (ASM tool kit, Manchester University, Manchester, UK). The alpha angle was automatically calculated from this point set by using MATLAB v7.1.0 (MathWorks Inc). Intraclass correlation coefficient (ICC) for interobserver reliability was 0.73 (95% confidence interval [CI] 0.56-0.86). Intra-observer reliability ICC scores ranged from 0.85 (95% CI 0.49-0.96) to 0.99 (95% CI 0.93-1.00).[13] The standard error of measurement (SEM) was 3.45.

2.5 | Definition of cam morphology and large cam morphology

The independent variables cam morphology presence and size were analyzed on both the AP view and frog-leg lateral view at 5-year follow-up. The highest score of one of both views was used for analysis. Cam morphology was defined twice, based on the visual score and alpha angle. Cam morphology based on the visual score was defined when either a flattening or prominence was present. Cam morphology based on the alpha angle was defined as alpha angle ≥60°. Large cam morphology based on the visual score was defined as having a prominence. Large cam morphology based on the alpha angle was defined as alpha angle ≥78°.[29]

2.6 | Cam morphology duration

The third independent variable cam morphology duration was scored dichotomously as "long" or "short" for all radiographs from baseline, 2.5-year follow-up, and at 5-year follow-up. Long duration was defined as the first presence of cam morphology at baseline and short duration as having cam morphology for the first time at 2.5- and/or 5-year follow-up.

2.7 | Hip and groin pain/symptoms

2.7.1 | Questionnaire on hip pain and participant characteristics

Every participant filled out a questionnaire on several participant characteristics at 5-year follow-up (Figure 1). This questionnaire contained a question about hip pain: "Do you sometimes have pain in your hips?" A dichotomous answer was possible, "yes" or "no". When answered positive, the painful side was specified (left, right, and bilateral). They also filled in, if pain occurred during or after sporting activities, or in rest. As this question might include groin pain, we choose "hip and groin pain" as the overall term to define this outcome measure.

2.7.2 | Hip and groin outcome score

The "Copenhagen Hip and Groin Outcome Score" (HAGOS) is a valid patient-reported outcome measure to quantify hip and groin symptomatology.[30] The validated Dutch HAGOS translation was filled out by all participants only at the 5-year follow-up (Figure 1).[30-32] This questionnaire obtained information from six domains, specified per person. Each domain is scaled between 0 and 100, with 100 as indicator for no problems, and a lower score for hip and groin symptoms.[32] The football players completed the questionnaires before or on the day at which the radiographs were obtained. All participants were divided into 3 groups based on the level of symptomatology, as described before by Tak et al.[33] The first group is the most symptomatic group in this cohort, defined by at least 2 domains in the lowest interquartile range (IQR) of the HAGOS scores. The group with the least symptomatic participants was defined as having at least 2 domains in the highest IQR of the HAGOS scores. The middle group was the remaining group.

2.8 | Hip range of motion

The researcher performing the physical examination was blinded to the outcome of the HAGOS scores and for the radiographs. The same physical examination protocol was used at all time points.[5,6] In short, while maintained in neutral rotation, the first resistance/end feel during passive flexion, abduction, adduction, internal rotation and external rotation were measured in supine position and extension in prone position on a flat examination table with a goniometer. Internal and external rotation were measured with 90° of flexion in the hip joint. Stabilization was provided by the free hand of the examiner to the adjacent joints and regions.

Participant characteristics	Baseline (n = 49) 5-year follow-up participants	Baseline (n = 40) 5-year follow-up dropouts	P
Age, y	15.20 ± 2.13	15.25 ± 1.77	.88
Weight, kg	58.54 ± 14.71	60.43 ± 12.60[b]	.37
Height, cm	169.35 ± 13.16	171.47 ± 10.67[b]	.25
Body mass index, kg/m^2	20.01 ± 2.32	20.29 ± 2.17[b]	.42
Football experience, y	8.84 ± 2.65	9.13 ± 2.40[b]	.45
Training intensity, h/w	7.87 ± 1.57	8.08 ± 2.00[b]	.45
Prevalence of cam, symptoms, and ROM			
Cam morphology prevalence (VS/AA), %			
- Visual score	48.0	62.5	.05
- Alpha angle	48.0	50.0	.80
Hip and groin pain, % per hip	20.4	13.2	.20
Range of motion			
- Flexion			
a. Left	123.88 ± 6.54	123.87 ± 6.64	.99
a. Right	125.92 ± 8.05	123.45 ± 8.84	.05
- Abduction			
a. Left	41.92 ± 10.26	39.83 ± 9.40	.16
a. Right	41.22 ± 7.78	38.60 ± 8.25	**.031**
- Adduction			
a. Left	30.80 ± 3.95	28.80 ± 5.21	**.005**
a. Right	30.06 ± 5.27	28.55 ± 5.64	.07
- Internal rotation			
a. Left	27.57 ± 8.15	26.33 ± 8.36	.32
a. Right	23.71 ± 7.39	22.75 ± 9.40	.46
- External rotation			
a. Left	40.35 ± 8.82	35.50 ± 9.06	**<.001**
a. Right	37.22 ± 9.45	34.23 ± 8.74	**.031**
- Extension			
a. Left	14.89 ± 2.39	14.31 ± 3.22	.19
a. Right	15.03 ± 2.53	14.56 ± 2.89	.26

Abbreviations: AA, alpha angle; ROM, range of motion; VS, visual score.

[a]Values are expressed as mean ± standard deviation.

[b]Data of n = 38 are presented, due to missing data.

Bolded P-values indicate a statistically significant difference.

2.9 | Statistical analysis

The association between cam morphology presence, size and duration at 5-year follow-up and hip and groin pain (per hip) and most vs least hip and groin symptoms (based on HAGOS per person) were calculated by means of logistic regression and adjusted for age and body mass index (BMI). The association between cam morphology presence, size and duration at 5-year follow-up and ROM was calculated by a linear regression model, adjusted for age and BMI. All per hip regression analyses were performed in a Generalised Estimated Equations (GEE) model. These were all cross-sectional associations at 5-year follow-up. The only longitudinal outcome of this study was the duration of cam morphology which was measured at baseline, 2.5-year, and 5-year follow-up. Absolute rounded ROM averages are presented in Table 5 and 6, with differences observed in the statistical tests presented as estimated mean differences. Differences in baseline characteristics

TABLE 3 Association between cam morphology based on both visual score (VS) and alpha angle (AA) and symptoms at 5-year follow-up

HAGOS questionnaire (per person)	Normal	Flattening	Prominence	AA < 60°	AA 60°-78°	AA ≥ 78°	Cam, P^a (VS/AA)	Large cam, P^b (VS/AA)
Most symptoms	2/4 (50.0%)	3/16 (18.8%)	7/25 (28.0%)	3/5 (60.0%)	5/22 (22.7%)	4/18 (22.2%)	.21/.14	.88/.95
Least symptoms	2/4 (50.0%)	13/16 (81.3%)	18/25 (72.0%)	2/5 (40.0%)	17/22 (77.3%)	14/18 (77.8%)		
Hip and groin pain (per hip)								
- Yes	3/18 (16.7%)	1/38 (2.6%)	10/42 (23.8%)	5/20 (25.0%)	5/53 (9.4%)	4/25 (16.0%)	.27/.14	**.026**/.60

[a]Cam morphology vs having no cam morphology. For associations between cam morphology presence and size and HAGOS, "most vs least symptoms" is used.

[b]Large cam morphology vs having no large cam morphology.

Bolded P-values indicate a statistically significant difference.

between included participants and dropouts were tested using an independent samples *t* test. A sensitivity analysis was performed to see if analyzing the HAGOS outcome defined as most symptoms vs middle and least symptoms, gave different results than defining the HAGOS outcome as most vs least symptoms (Table S1). SPSS25.0 (Windows) was used.

3 | RESULTS

3.1 | Participant characteristics

Demographic data of the participants are summarized in Table 1. The mean follow-up time was 5.3 ± 0.1 years (range 5.0-5.6 years). Of the 89 baseline participants (12-19 years old), 49 (55%) participated at 5-year follow-up. No differences in baseline demographic data between these 49 participants and 40 dropouts were observed, Table 2.[9] Participants dropped out for various reasons: 24 rejected the invitation, 11 were unreachable, 4 lived abroad, and 1 person accepted the invitation but did not appear during the allocated time-slot. All 49 included participants still played football at the time of the 5-year follow-up study. Of those, 28 (57%) were still active in a first or second team of a professional football club. All other 21 football players (43%) played football at an amateur level. Cam morphology prevalence was 82% (80 of 98 hips) based on visual score and 80% (78 of 98 hips) based on the alpha angle.

3.2 | Cam morphology and hip and groin pain

Nine players (18.4%) reported hip and groin pain (5 bilateral and 4 unilateral). Of these 14 hips, 10 hips were painful at one occasion and 4 at two occasions; 1 hip both during sports and at rest and 3 hips directly after sports and at rest. In total, 4 hips were painful during sports, 6 hips directly after sports, and 8 hips at rest.

Of 80 hips with cam morphology based on visual score, 11 hips (13.8%) had hip and groin pain compared to 3 of 18 hips (16.7%) without cam (OR: 0.51, CI: [0.15-1.69]). Of 78 hips with cam morphology based on alpha angle, 9 hips (11.5%) had hip and groin pain, compared to 5 of 20 hips (25.0%) without cam (OR: 0.42, CI: [0.13-1.32]). Of the 42 hips with large cam morphology based on visual score, 10 hips (23.8%) had hip and groin pain compared to 4 of 56 hips (7.1%) without large cam (OR: 3.17, CI: [1.15-8.70], P = .026). Of 25 hips with large cam morphology based on alpha angle, 4 hips (16.0%) had hip and groin pain compared to 10 of 73 hips (13.7%) without large cam (OR: 1.21, CI: [0.60-2.43]) (Table 3).

Of 47 hips with long cam morphology duration based on visual score, 7 hips (14.9%) had hip and groin pain compared

TABLE 4 Spreading of all 6 HAGOS domain medians for the 3 different HAGOS groups at 5-year follow-up[a]

HAGOS group[b]	Persons	Pain	Symptoms	Function in DL	S&R	PA	QoL
Most symptoms	12	87.50 (80.63-94.38)	66.07 (58.04-76.79)	90.00 (85.00-95.00)	82.81 (67.97-84.38)	81.25 (75.00-100.00)	70.00 (61.25-80.00)
Middle	4	96.25 (93.13-99.38)	80.36 (67.86-82.14)	100.00 (96.25-100.00)	92.19 (81.25-96.09)	87.50 (78.13-87.50)	85.00 (68.75-97.50)
Least symptoms	33	100.00 (95.00-100.00)	89.29 (82.14-96.43)	100.00 (100.00-100.00)	100.00 (100.00-100.00)	100.00 (100.00-100.00)	100.00 (90.00-100.00)

Abbreviations: DL, daily living; PA, physical activities; QoL, quality of life; S&R, sports & recreation.

[a]Values are expressed as median (IQR, 25th-75th centile).

[b]Most symptoms are defined by at least 2 domains in the lowest interquartile range (IQR), least symptoms by at least 2 domains in the highest IQR and the middle group is the remaining group.

to 4 of the 33 hips (12.1%) with short cam duration (OR: 1.99, CI: [0.19-21.19]). Long cam morphology duration defined by the alpha angle, resulted in 6 of 47 hips (12.8%) with hip and groin pain, compared to 3 of 31 hips (9.7%) with short cam duration (OR: 1.63, CI: [0.24-10.93]).

3.3 | Cam morphology and hip and groin symptoms

Hip and Groin Outcome scores were not normally distributed. The median and IQRs of all 6 HAGOS domains of this cohort are presented in Table 1. An overview of the distribution of the HAGOS domains per HAGOS group (most, middle, and least symptoms) in this cohort is presented in Table 4. The group with most symptoms consisted of 12 of 49 football players (25%), the group with the least symptoms consisted of 33 football players (67%) and the middle group consisted of 4 football players (8%).

In the group with cam morphology based on visual score, 10 of 41 persons (24.4%) were classified into the group with most symptoms. In the group without cam, most symptoms were observed in 2 of 4 persons (50.0%) (OR: 0.24, CI: [0.03-2.20]). In the group with cam morphology based on alpha angle, 9 of 40 persons (22.5%) were classified into the group with most symptoms. In the group without cam, most symptoms were observed in 3 of 5 persons (60.0%) (OR: 0.22, CI: [0.03-1.67]). Large cam morphology based on visual score was observed in 25 persons (51.0%), and 7 of them (28.0%) were classified in the group with most symptoms. In the group without large cam, most symptoms were observed in 5 of 20 persons (25.0%) (OR: 1.12, CI: [0.28-4.46]). Large cam morphology based on alpha angle was observed in 18 persons (36.7%), and 4 of them (22.2%) were classified into the group with most symptoms. In the group without large cam, most symptoms were observed in 8 of 27 persons (29.6%) (OR: 0.95, CI: [0.21-4.30]) (Table 3).

Long cam morphology duration defined by the visual score, resulted in 9 of 27 persons (33.3%) in the group with most symptoms. Short cam duration was observed in 1 of 14 persons (7.1%) in the group with most symptoms (OR: 12.92, CI: [0.88-188.93], $P = .062$). Long cam morphology duration defined by the alpha angle resulted in 8 of 29 persons (27.6%) in the group with most symptoms. Short cam duration was observed in 1 of 11 persons (9.1%) in the group with most symptoms (OR: 4.27, CI: [0.40-45.52]).

3.4 | Cam morphology and range of motion

The average flexion was lower in hips with cam morphology than in hips without cam based on visual score (116° ± 6° vs 121° ± 8°, $P = .001$) and alpha angle (116° ± 6° vs

TABLE 5 Association between cam morphology based on visual score and range of motion at 5-year follow-up (n = hips)

Range of motion	Normal (n = 18)	Flattening (n = 38)	Prominence (n = 42)	Cam, P (degrees)[a]	Large cam, P (degrees)[b]
Flexion	121° ± 8	116° ± 6	116° ± 7	**.001** (6°)	.30 (2°)
Abduction	43° ± 6	41° ± 4	42° ± 5	.40 (1°)	.71 (0°)
Adduction	26° ± 6	27° ± 6	27° ± 6	.80 (0°)	.90 (0°)
Internal rotation	28° ± 10	26° ± 6	24° ± 8	.12 (3°)	**.033** (3°)
External rotation	36° ± 6	34° ± 5	34° ± 7	.17 (2°)	.84 (0°)
Extension	22° ± 4	23° ± 5	22° ± 5	.06 (1°)	.58 (1°)

Note: Values are expressed as mean ± standard deviation.

[a]Cam morphology vs having no cam morphology. Difference between groups is also presented in degrees range of motion.

[b]Large cam morphology vs having no large cam morphology. Difference between groups is also presented as the estimated mean difference in degrees range of motion. Bolded P-values indicate a statistically significant difference.

TABLE 6 Association between cam morphology based on alpha angle (AA) and range of motion at 5-year follow-up (n = hips)

Range of motion	AA < 60° (n = 20)	AA 60°-78° (n = 53)	AA ≥ 78° (n = 25)	Cam (P)[a]	Large cam (P)[b]
Flexion	122 ± 9	117 ± 6	113 ± 7	**.032** (5°)	**.049** (3°)
Abduction	44 ± 5	41 ± 5	42 ± 5	.18 (2°)	.42 (1°)
Adduction	26 ± 5	27 ± 5	26 ± 6	.99 (0°)	.48 (1°)
Internal rotation	30 ± 9	26 ± 7	21 ± 7	**.005** (4°)	.05 (3°)
External rotation	35 ± 6	34 ± 6	33 ± 7	.55 (1°)	.28 (2°)
Extension	23 ± 5	23 ± 5	20 ± 4	.25 (1°)	.11 (1°)

Note: Values are expressed as mean ± standard deviation.

[a]Cam morphology vs having no cam morphology. Difference between groups is also presentsed in degrees range of motion.

[b]Large cam morphology vs having no large cam morphology. Difference between groups is also presented as the estimated mean difference in degrees range of motion. Bolded P-values indicate a statistically significant difference.

122° ± 9°, P = .032) (Tables 5 and 6). Lower average internal rotation was observed in hips with cam morphology based on alpha angle, compared to hips without cam (24° ± 7° vs 30° ± 9°, P = .005) (Table 6). The average internal rotation in hips with large cam morphology based on visual score was lower than in hips without large cam (24 ± 8° vs 27° ± 7°, P = .033) (Table 5). Limited flexion was observed in hips with large cam morphology based on alpha angle, compared to hips without large cam (113° ± 7° vs 118° ± 7°, P = .049) (Table 6). Lower flexion was observed in hips with cam morphology based on alpha angle for at least 5 years (long duration), than hips with cam for 2.5 years or less (short duration) (115° ± 6° vs 116° ± 7°, P = .016).

4 | DISCUSSION

The relationship between cam morphology and hip and groin symptoms is inconsistent. A large cam morphology based on the visual score in young male academy football players showed an association with hip and groin pain, but not with more hip and groin symptoms as defined by the HAGOS score. A longer cam morphology duration was not significantly associated with more hip and groin symptoms. Cam morphology presence and size were associated with limited flexion and internal rotation, whereas a longer cam morphology duration was only associated with limited flexion.

4.1 | Cam morphology and hip and groin pain/symptoms

Large cam morphology was significantly associated with hip and groin pain, but not with the HAGOS scores. Other cross-sectional studies on this association showed conflicting results. Mayes et al[22] did not find an association between cam morphology and with HAGOS scores < 100 in ballet dancers. Anderson et al,[19] who investigated 547 individuals (1081 hips, mean age 67 years), did not find a significant association between cam morphology and the "modified Harris Hip Scores" or "Hip Outcome Scores." Also, no association between cam morphology and self-reported hip pain was found by Gosvig et al[20] who studied 3202 participants from the general population. A longitudinal study by Mosler et al[24] could not identify an association between cam morphology and groin injuries in professional athletes.

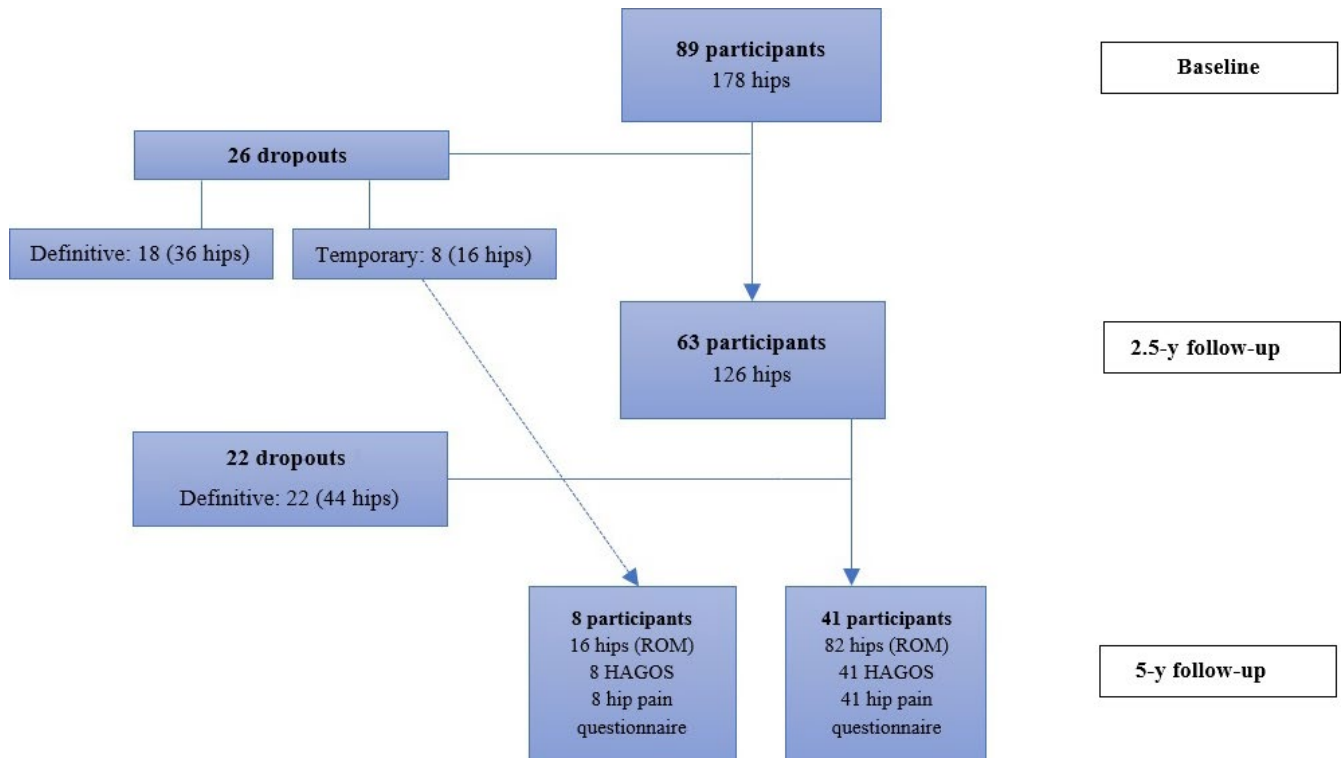However, other studies did show an association between cam morphology and hip and groin symptoms. A longitudinal

FIGURE 1 Flowchart of all analysed HAGOS questionnaires, hip pain questionnaires and ROM at all time-points

study by Khanna et al[23] focused on the development of hip pain at 4.4-year follow-up in 170 asymptomatic volunteers (mean age 29.5 years) at baseline. Seven of 14 (50.0%) painful hips had cam morphology compared with 37 of 318 (11.6%) painless hips at follow-up (RR: 4.3, $P = .0002$). Other cross-sectional studies also found an association. Larson et al[21] studied 125 National Football League prospects and observed a significantly higher cam morphology prevalence in the symptomatic group ($P = .009$). Allen et al[18] demonstrated a significant association between higher alpha angles in painful hips (mean 69.9°) than in asymptomatic hips (mean 63.1°). In a retrospective study of 334 patients, a significant association between hip symptoms and increased alpha angles ($P < .001$) was observed as well.[34]

An explanation for the absence of association between cam morphology (flattening or prominence and/or alpha angle ≥60°) and symptoms within 5-year follow-up could be that only larger cam morphology can cause rapid intra-articular damage. This is in line with the higher risk of developing hip OA when cam morphology is bigger.[12,29] No association between cam morphology and HAGOS scores was observed in this study. HAGOS scores in the group classified as most symptoms in this cohort were ranging between 66.07 and 90.00, indicating that symptoms were mild. Also, the HAGOS score is a score per person rather than per hip, which might dilute the association in the presence of unilateral cam morphology. Also, the HAGOS questionnaire captures hip

and groin symptoms and not only hip-related pain, as other entities of groin pain might be more prevalent in football players than pain arising from the hip joint. Another explanation could be that participants were young. Cam morphology arises from 12 to 14 years old[5-9,35] and continues to grow thereafter until growth plate closure. During 5-year follow-up, participants were aged 20.5 years (17-24 years) on average. Therefore, the cam morphology duration might have been too short to create hip damage and symptoms. This is supported by our findings that 33.3% of the group with long cam morphology duration based on visual score was classified in the most symptoms group, compared to 7.1% in the short duration group. Although not statistically significant ($P = .06$), future studies on the relationship between cam morphology and symptoms should also take into account the duration of cam morphology. It could also be that football players are not keen to report about their (hip and groin) complaints as they may be afraid of losing their place on the pitch. Finally, the pathway from having cam morphology into developing the clinical entity of FAI syndrome and thus pain is complex and also involves the amount of femoral and acetabular version, soft-tissue structures, activities which a person undertakes and many other person-specific factors. Obviously, it can also be that the presence of cam morphology itself is not associated with symptoms or reduced range of motion, as cam morphology is also highly prevalent in asymptomatic populations.[11]

4.2 | Cam morphology and range of motion

Significant associations between cam morphology presence and limited flexion and internal rotation were observed and influenced by cam morphology size. A longer cam morphology duration only negatively influenced the amount of flexion. Our findings partly correspond with current available literature. Audenaert et al[36] observed a significantly lower range of internal rotation in the cam morphology group (based on CT) vs a group without cam morphology. In collegiate football players, Kapron et al[37] found a significant association between alpha angle and limited internal rotation. Mosler et al[38] screened 426 male professional football players in Qatar for 2 consecutive seasons and observed that asymptomatic hips with cam morphology and large cam morphology were associated with lower internal rotation. Interestingly, a systematic review of Freke et al[39] did only find limited and conflicting evidence on the association of cam morphology and limited ROM in symptomatic patients. However, ROM in symptomatic hips might also be influenced by pain rather than cam morphology only.[33] In the current study, the average differences between hips with and without cam morphology were around 6° for flexion and 3°-6° for internal rotation. This raises questions on whether these differences are clinically relevant.

Not all growth plates were closed (93.9%) at 5-year follow-up. This means that hips with open growth plates might still have the potential to develop cam morphology or increase to a large cam morphology.[9] This can possibly cause more severe impingement, and therefore result in more symptoms and limited ROM in the future.

4.3 | Limitations

Some limitations in this study have to be acknowledged. During 5-year follow-up, 40 participants (44.9%) were lost to follow-up. Although there were no differences in baseline characteristics between participants and dropouts, it has bias, as it resulted in a relatively small sample size. Due to the small sample size and low proportion of hips without cam morphology, the resulting findings have wide confidence intervals. Of the included 49 participants, 42.9% played football at an amateur level, with lower intensity and training hours per week. This could have resulted in lower cam morphology prevalence[12,35] and might have influenced symptoms.[40] A possible limitation of the patient characteristics questionnaire is that it cannot be excluded that the question "Do you sometimes have pain in your hips?" also included patients with groin symptoms and made no distinction between long standing and acute hip and groin symptoms. However, large cam morphology based on the alpha angle was associated with hip and groin pain based on this question, which indicates that

type II errors are not likely. As the HAGOS-domain scores were not normally distributed and as the median scores in 3 out of 6 domains are having the maximum score of 100, a ceiling effect cannot be ruled out.

By using radiographs, the prevalence of cam morphology might have been underestimated as compared to cross-sectional imaging such as magnetic resonance imaging (MRI) or computed tomography (CT). However, by using two radiographic views (AP and frog-leg lateral), as recommended by the Warwick Agreement,[4] the risk of false-negative measurements was minimalized.

4.4 | Range of motion

The ROM was obtained before or after training, which could have resulted in different outcomes. Range of motion measurement by goniometry could result in measurement errors and can give an overestimation of the ROM.[41] Beside this limitation, range of motion is an acceptable and reliable measurement method for longitudinal studies in FAI syndrome patients. The reliability of range of motion testing of the hip is described in literature as good to excellent by Prather et al.[42]

5 | CONCLUSION

Data of this cohort study suggest that the presence, size, and duration of a bony cam morphology have a direct but small effect on the range of motion. Symptoms might develop in some football players with large cam morphology or several years after cam morphology development. A larger prospective cohort is needed to further elucidate these findings.

6 | PERSPECTIVES

Our study showed that large cam morphology is only associated with hip and groin symptoms but not with HAGOS scores. The presence, size, and duration of cam morphology are associated with limited flexion and/or internal rotation, although the clinical relevance of these differences is questionable. This suggests that a bony cam morphology has a direct but small effect on the range of motion and symptoms which might develop in some players several years after cam morphology has developed. More factors are involved in the complex pathway between cam morphology and developing the clinical entity of FAI syndrome with symptoms and limited function, such as femoral and acetabular orientation, soft-tissue condition (eg, labrum, cartilage, ligamentum teres), activity level, and many other person-specific factors. This needs further investigation in a larger cohort.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.