[EDITORIAL]

Significant Knowledge Gaps Between Clinical Practice and Research on Femoroacetabular Impingement: Are We on the Same Path?

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Femoroacetabular impingement (FAI) is the abnormal osseous contact between the femur (cam impingement) and/or acetabular rim (pincer impingement) during end-range hip motions. The morphology typically seen in FAI has been found in both asymptomatic and symptomatic individuals.[14] An international consensus statement has provided some clarity around the diagnosis of FAI syndrome.[7] In particular, the statement highlighted that FAI syndrome was not a diagnosis based on radiology findings alone, but also on symptoms and clinical findings. However, the consensus statement did not explicitly describe the impairments seen in FAI syndrome,[6] or the specific diagnostic utility of clinical and imaging tests used in the assessment of FAI syndrome, and did not provide detailed evidence of an appropriate treatment for FAI syndrome.

People with FAI syndrome have levels of hip-related pain, physical impairments, and poor quality of life similar to those seen in hip osteoarthritis (OA).[4,6,11] They also have great difficulty with sports and physical activity participation when compared to age-matched controls.[4] The population with FAI syndrome is heterogeneous, from adolescent athletes to middle-aged, more inactive individuals. Younger age at surgery, limited hip range of motion, and hip morphology have been shown to accelerate the path toward development of hip OA.[1,22]

It is important to note that many people who have cam-type morphology do not have FAI syndrome, do not develop hip OA, and remain asymptomatic throughout life. Regrettably, this misunderstanding has created some confusion in clinical practice and in research. In some cases, the same terminology has been used interchangeably for cam-type deformities and FAI syndrome, such that asymptomatic people with cam-type deformity may have undergone treatment for FAI syndrome. At the other extreme, some argue that FAI syndrome does not exist and that treatment is unnecessary.

There are significant knowledge gaps regarding treatment of FAI syndrome. In recent years, the rate of diagnosis and treatment of FAI has rapidly increased, with the rate of hip arthroscopy treatment of FAI having increased by almost 400%.[3,15] High-quality randomized controlled trials on the efficacy of surgical interventions as well as exercise therapy interventions are lacking, though there are several ongoing randomized controlled trials. A recently published randomized controlled trial comparing hip arthroscopy to physical therapy for FAI found no difference between groups. However, the large number of patients crossing from the physical therapy group to the surgical group creates uncertainty.[13] Given this, it is vital for sports, musculoskeletal, and orthopaedic physical therapists to have a thorough understanding of the condition and the ability to conduct accurate assessment, and to provide effective nonsurgical treatment options. By collating the articles in this special issue, our intention is to better equip physical therapists around the globe to manage this common yet poorly understood musculoskeletal condition.

This special issue on FAI aims at closing some of the gaps between clinical practice and research findings, important for all health professions treating patients with hip pain. This special issue will explore several aspects of FAI syndrome. Specifically, it will provide clinicians with a greater understanding of the etiology and prevalence of hip morphology seen in FAI syndrome, and its relationship with hip range of motion, muscle strength, and hip OA.[16,21] This special issue also explores the clinical presentation of patients with FAI syndrome, assessment of movement quality as well as biomechanics during walking and step-down tasks, muscle function, and functional task performance.[2,5,12,18,20] An expert clinical commentary discusses best practice physical therapy assessment and how to distinguish FAI syndrome from other causes of groin pain.[19] Finally, physical therapy treatment and surgical options for FAI syndrome are described. These include studies of movement-pattern retraining; a pilot clinical trial of targeted, impairment-based physical therapy; and protocols describing a randomized clinical trial of hip arthroscopy for FAI syndrome and best-practice physical therapy following hip arthroscopy.[8-10,17]

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Kinematic Differences During Single-Leg Step-Down Between Individuals With Femoroacetabular Impingement Syndrome and Individuals Without Hip Pain

Femoroacetabular impingement syndrome (FAIS) classifies individuals presenting with hip pain that, in combination with structural hip morphology, is thought to contribute to premature contact between the proximal femur and acetabulum.[22] The abnormal morphology can either be of the femur (cam) or the acetabulum (pincer). When cam and pincer morphology coexist, the term *mixed* morphology is used. Impingement may occur during hip flexion alone or when combined with adduction and internal rotation, potentially leading to acetabular labral and chondral damage.[20,30] Cam morphology has been linked to an increased risk for the development of hip osteoarthritis.[2,54] The risk with pincer morphology, however, is still debated, with recent studies reporting no elevated risk of osteoarthritis.[3,54]

STUDY DESIGN: Controlled laboratory study, case-control design.

BACKGROUND: Despite recognition that femoroacetabular impingement syndrome (FAIS) is a movement-related disorder, few studies have examined dynamic unilateral tasks in individuals with FAIS.

OBJECTIVES: To determine whether movements of the pelvis and lower extremities in individuals with FAIS differ from those in individuals without hip pain during a single-leg step-down, and to analyze kinematic differences between male and female participants within groups.

METHODS: Individuals with FAIS and individuals without hip pain performed a single-leg step-down while kinematic data were collected. Kinematics were evaluated at 60° of knee flexion. A linear regression analysis assessed the main effects of group, sex, and side, and the interaction of sex by group.

RESULTS: Twenty individuals with FAIS and 40 individuals without hip pain participated. Individuals with FAIS performed the step-down with greater hip flexion (4.9°; 95% confidence interval [CI]: 0.5°, 9.2°) and anterior pelvic tilt (4.1°; 95% CI: 0.9°, 7.3°) than individuals without hip pain. Across groups, female participants performed the task with more hip flexion (6.1°; 95% CI: 1.7°, 10.4°), hip adduction (4.8°; 95% CI: 2.2°, 7.4°), anterior pelvic tilt (5.8°; 95% CI: 2.6°, 9.0°), pelvic drop (1.4°; 95% CI: 0.3°, 2.5°), and thigh adduction (2.7°; 95% CI: 1.3°, 4.2°) than male participants.

CONCLUSION: The results of this study suggest that individuals with FAIS have alterations in pelvic motion during a dynamic unilateral task. The noted altered movement patterns in the FAIS group may contribute to the development of hip pain and may be due to impairments that are modifiable through rehabilitation. *J Orthop Sports Phys Ther 2018;48(4):270-279. Epub 6 Mar 2018. doi:10.2519/jospt.2018.7794*

KEY WORDS: *FAIS, hip pain, impingement, step-down*

Despite agreement that FAIS is a "motion-related" disorder,[22] research on FAIS has primarily focused on the differences in bony morphology, with less attention given to altered movement in the presence of cam or pincer morphology and no attention given to the interaction between the type of morphology and the altered movement. The few published gait studies in individuals with FAIS have reported inconsistent results at the hip and pelvis. These results vary from no difference in kinematics[37] to decreased hip excursion in the sagittal plane[15,35,53] and frontal plane[35,53] in individuals with FAIS compared to individuals without hip pain. The decreased sagittal plane excursion may be from decreased hip extension[29] or decreased hip flexion.[53] The decreased frontal plane excursion likely is from decreased hip abduction,[27,35,53] although 1 study reported decreased hip adduction.[29] It is unclear why these alterations during gait occur, as they would not affect theorized positions of impingement. Deep bilateral squat is a more demanding task than walking, yet with this movement, the

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only findings have been increased hip adduction,[37] decreased sagittal plane pelvic excursion,[39] and decreased posterior pelvic tilt.[6] The limited differences between individuals with FAIS and individuals without hip pain suggest that these tasks may not be sufficiently challenging for detecting altered movement at the hip.

Dynamic unilateral activities that challenge the neuromuscular control of the hip in multiple planes of motion may be more appropriate for detecting deficits than bilateral tasks.[44] Stair climbing has been reported in 2 studies, with mixed results. Hammond et al[24] noted that individuals with FAIS ascended stairs more slowly and displayed more trunk flexion (measured relative to the pelvis) than individuals without FAIS. In contrast to the findings of no differences in hip motion by Hammond et al,[24] Rylander et al[53] reported reduced sagittal plane hip motion, primarily due to reduced extension, and reduced peak hip internal rotation in individuals with FAIS compared to healthy individuals. Additionally, they found increased transverse plane pelvic motion and increased peak anterior pelvic tilt in individuals with FAIS, and these alterations remained following arthroscopic osteochondroplasty to address hip morphology,[53] indicating that correcting the hip morphology was insufficient to normalize the movement pattern. These findings also highlight the importance of evaluating more challenging unilateral tasks than level walking.

A confounding factor to consider when evaluating movement is the substantial evidence of sex-specific movement-pattern differences during unilateral tasks such as single-leg landing,[31,57] single-leg squat,[21,46,61,63] and single-leg step-down.[17] For example, during the single-leg step-down task, Earl et al[17] noted that females performed the task with more hip adduction and knee abduction than males. Given these noted movement-pattern differences in healthy individuals, it is important to assess sex-specific movement patterns when evaluating unilateral tasks in a patient population, such as those with FAIS, to determine a potential interaction between the condition and sex.

The purpose of this study was to determine whether pelvic and lower extremity movement patterns in individuals with FAIS are different from those in individuals without hip pain during a single-leg step-down task. The secondary purpose was to analyze differences in the kinematics between male and female participants in both the FAIS and comparison groups during this task. We hypothesized that individuals with FAIS would have different pelvic and hip movement patterns from those in individuals without hip pain, and that these differences would be sex specific.

METHODS

Participants

Individuals with FAIS were recruited through area orthopaedic and rehabilitation clinics between January 2011 and December 2016. To be included in the FAIS group, individuals needed to have been diagnosed with unilateral or bilateral cam, pincer, or mixed morphology by a physician based on clinical presentation, physical examination, and imaging. Additionally, individuals had to report having pain for longer than 2 weeks and had to have their hip pain reproduced with at least 1 of 3 provocative tests: (1) flexion, adduction, internal rotation (FADIR) test; (2) flexion, abduction, external rotation (FABER) test; and (3) resisted straight leg raise (SLR). For the FADIR test, which is also called the anterior impingement test, the hip was passively flexed to 90° and then adducted and internally rotated.[20] For the FABER test, the hip was passively positioned in flexion, abduction, and external rotation, with the foot of the tested leg on top of the contralateral knee.[60] For the resisted SLR, the leg was passively positioned in 30° of hip flexion, with the knee extended.[43] The participant was then asked to keep the leg in that position without assistance and to continue to hold the position as resistance was applied at the distal leg. Each test was considered positive when the test reproduced the individual's pain. These 3 tests are sensitive for intra-articular hip pathology.[43,50]

Individuals in the comparison group were recruited through flyers, postings, and word of mouth. Exclusion criteria included current or recent (within the last 2 months) lower extremity injury, history of substantial lower extremity injury/surgery, and history of hip pain. Additionally, potential participants in the comparison group were excluded if they reported any hip or groin pain during any of the provocative tests (FADIR, FABER, and resisted SLR) or during any of the movement tasks. Although we did not assess morphology in these individuals, the absence of pain during the provocative tests or movement tasks eliminates the diagnosis of FAIS, even in the presence of cam or pincer morphology.

General inclusion criteria for both groups included being between 14 and 50 years of age and being able to walk safely for 10 minutes without assistance. Exclusion criteria for both groups included history of neurological disorder, history of lower extremity or back surgery, or current back, knee, or ankle pain.

The study was approved by the Institutional Review Boards of Boston University and Boston Children's Hospital, and all individuals provided written informed consent prior to participation.

Instrumentation

Three-dimensional kinematic data of the trunk, pelvis, and lower extremities were collected using a 10-camera motion-capture system (Vicon; Oxford Metrics plc, Oxford, UK) sampling at 100 Hz. Forty-two spherical, retroreflective markers (14-mm diameter) were placed over bony landmarks on the trunk and pelvis and bilaterally on the lower extremities as previously described.[41] Plastic shells that contained 4 noncollinear markers each were positioned laterally over the thighs and shanks and attached via neoprene wraps and hook-and-loop fasteners.[10]

Questionnaires

Participants completed self-report questionnaires consisting of the University of California at Los Angeles (UCLA) activity score,[4] the modified Harris Hip Score (mHHS),[9] and the Hip disability and Osteoarthritis Outcome Score (HOOS).[36] The mHHS scores can be interpreted as 90 to 100, excellent; 80 to 89, good; 70 to 79, fair; and below 70, poor.[36] The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was scored from the HOOS, which contains all the WOMAC questions.[47] While the mHHS and the HOOS activities of daily living (ADL) subscale do have ceiling effects when used in this patient population,[34] they are both reliable and have acceptable construct validity.[34] Additionally, these self-report measures have been used extensively in the FAIS literature.[24,25,29,35,38,39,55,56]

Experimental Protocol

Participants wore a tight-fitting shirt, spandex shorts, and their own comfortable exercise shoes. After placing the reflective markers on the participant, participants performed a static standing trial in a neutral posture. For this trial, the participant stood upright facing straight forward, with feet shoulder-width apart and shoulders in approximately 90° of abduction. A model that included joint centers for the hips and knees was created using this trial. The medial ankle and knee markers were removed after the static trial so that they did not affect the movement.

Movement Analysis

Participants were instructed to stand with both feet on a 16-cm box, with their arms by their sides. They were asked to shift their weight onto 1 limb and hold their nonstance limb out in front of the box, then to lower themselves in a controlled manner until the heel of the nonstance limb contacted the floor, then to return to the starting position. A metronome at 60 beats per minute was used to help standardize movement speed. Participants were instructed to move "down on a beat and up on a beat." While participants were given feedback if moving too slowly or too quickly, strict adherence to the metronome was not enforced. The step-down task was demonstrated and participants had an opportunity to practice prior to data collection. Five trials were collected of individual repetitions on each side. If the participant experienced a loss of balance during a trial, as indicated by substantial arm, trunk, or leg movement, contacting the ground with the nonstance leg in an uncontrolled manner, or performing the task with a jerky, noncontinuous motion, then the trial was not included in the analysis. Following each individual repetition of the task, all participants rated any pain they had in the hip or groin region on an 11-point numeric rating scale, with 0 being no pain and 10 being the worst imaginable pain.[16]

Data Processing

Marker trajectories were low-pass filtered using a 6-Hz, fourth-order Butterworth filter.[51] Commercially available software (Visual3D; C-Motion, Inc, Germantown, MD) calculated the joint kinematics from the marker trajectories using an 8-segment hybrid model. Instead of using the Visual3D pelvis, the CODA pelvis[12] model was used to define the pelvis,[8] as palpation of the anterior superior iliac spine and posterior superior iliac spine was possible in this non-obese population. Pelvic, thigh, and shank segment angles were determined with respect to the global coordinate system. Knee and hip joint angles were defined as the angle between the distal segment and the proximal segment using a Cardan x-y-z (mediolateral, anteroposterior, vertical) rotation sequence.[13]

Hip and knee joint angles and pelvic, thigh, and shank segment angles in the sagittal and frontal planes were extracted at 60° of knee flexion during the descent phase for each trial and averaged for each participant to produce the dependent variables. As 60° of knee flexion has been proposed as the depth criterion for a "good" single-leg squat,[14] we selected this same angle for our point of analysis. We have previously demonstrated that adjusting step height based on the individual's leg length or height is not required when analyzing data at the same knee angle for all individuals.[41]

Statistical Analysis

A sample-size calculation was performed for group differences in hip flexion angle based on preliminary data from our laboratory, which suggested a group difference of 9° and standard deviation of 9° during a step-down task. The calculation indicated that for statistical power of 0.80 and an alpha of .05 for the primary aim a minimum of 16 participants per group were needed.

Group composition was assessed using chi-square tests for categorical variables, independent-samples t tests for continuous variables, and Mann-Whitney U tests for ordinal variables to ensure that groups did not differ in terms of sex, age, body mass index, or activity level. We used linear regression analysis with 2 between-subject factors (group, sex) and 1 within-subject factor (side). For FAIS participants, the more painful side was defined as the side that the participant stated had worse symptoms. The contralateral side was then considered the less painful side, whether symptoms were bilateral or unilateral. For participants without hip pain, the more painful side was randomly assigned. As each side was included in the analysis, a generalized estimating equation (GEE) correction was applied to the model. The GEE approach is similar to the more commonly used repeated-measures analysis of variance, but has higher power and is more robust.[42] We analyzed the main effects of group (FAIS versus comparison), sex, and side, a 2-way interaction of sex by group, and a 3-way interaction of sex by group by side. A separate GEE was performed for each variable of interest. Least-significant-difference pairwise comparisons were performed if a significant effect was found. All analyses were run in IBM SPSS Statistics Version 20 (IBM Corporation, Armonk, NY), and an alpha level of .05 was used for all comparisons.

RESULTS

Twenty individuals with FAIS and 40 individuals without hip pain participated in the study (**TABLE 1**). The groups were not different in terms of sex, age, height, mass, body mass index, or UCLA activity score. The majority of the individuals with FAIS had cam morphology (80%; 10 of 11 males and 6 of 9 females), with 10% having pincer morphology (2 females) and 10% having mixed morphology (1 male and 1 female). Nine individuals had been diagnosed with FAIS bilaterally. Three individuals had FAIS on the right only, and 8 on the left only. Ninety-five percent of individuals with FAIS had a positive FADIR test (**TABLE 2**).

Individuals with FAIS scored lower on the mHHS, all subscales of the HOOS, and the WOMAC (**TABLE 3**) than individuals without hip pain. While the average mHHS score for the FAIS group for the more painful side was in the fair category,[9] there was a wide range (34.1-95.7) of scores. Of the 19 participants with FAIS with an mHHS score, 3 had excellent, 7 good, 1 fair, and 8 poor (a score of below 70) function and pain ratings. During the step-down task, the average ± SD pain rating for the FAIS group was 1.7 ± 1.9 (range, 0-6.3) on the more painful side and 0.5 ± 1.0 (range, 0-4) on the less painful side.

Individuals in our study participated in a variety of sporting activities. Seventeen of the 20 individuals with FAIS reported participating in competitive sports in the past 12 months. The level of participation ranged from recreational to elite. Running and soccer were the 2 most frequently reported activities. Other activities included baseball, basketball, CrossFit, cycling, ice hockey, lacrosse, military service, rowing, rock climbing, rugby, skiing, softball, tennis, ultimate, volleyball, and yoga. Of the 40 individuals without hip pain, information about participation in competitive sports was available for 25 individuals. Ten of these 25 individuals in the comparison group reported participating in competitive sports at the recreational to college levels in the past 12 months. Running was the most commonly reported activity. Individuals also participated in the following sports: basketball, broomball, cycling, gymnastics, skiing, soccer, softball, tennis, track, triathlon, and weightlifting. Despite the differences in the proportions of individuals participating in competitive sports, the UCLA activity score, which was available for 19 of 20 individuals in the FAIS group and all 40 individuals in the comparison group, was not different between groups (U = 376, P = .95), and 58% of individuals in each group participated in impact sports either sometimes or regularly.

Group Comparison

The 3-way interaction of sex by group by side was significant for knee abduction angle (Wald χ^2 = 8.65, P = .034) (**TABLE 4**). However, none of the follow-up comparisons between males and females within the FAIS group ($P \geq .098$), between groups within males ($P \geq .111$), or between groups within females ($P \geq .052$) were significant. No other significant 3-way interactions were found. No significant effects of side were detected for any variable, and therefore the following data represent the average of the 2 sides.

No significant interactions of sex by group were detected for any of the analyzed variables. Individuals with FAIS

TABLE 1 Demographic Data*

Characteristic	FAIS	Comparison	P Value
Sex, n			.715†
Male	11	20	
Female	9	20	
Age, y	25.3 ± 8.9	24.1 ± 5.1	.583‡
Height, m	1.74 ± 0.10	1.71 ± 0.11	.385‡
Mass, kg	72.7 ± 13.2	68.6 ± 13.7	.276‡
Body mass index, kg/m²	23.9 ± 2.4	23.2 ± 3.0	.403‡
Median (range) UCLA activity score	10 (4-10)	9 (4-10)	.945§

Abbreviations: FAIS, femoroacetabular impingement syndrome; UCLA, University of California at Los Angeles.
**Values are mean ± SD unless otherwise indicated.*
†Chi-square test performed.
‡Independent-samples t test performed.
§Mann-Whitney U test performed.

TABLE 2 Number of Individuals With FAIS Who Had Pain With Provocative Tests*

Provocative Test	More Painful Side	Less Painful Side
FADIR	19 (95)	11 (55)
FABER	8 (40)	1 (5)
SLR	11 (55)	4 (20)

Abbreviations: FABER, flexion, abduction, external rotation test; FADIR, flexion, adduction, internal rotation test; FAIS, femoroacetabular impingement syndrome; SLR, straight leg raise resisted at 30°.
**Values are n (%). Individuals in the comparison group did not have any positive (painful) tests.*

performed the step-down task with greater hip flexion (**FIGURE 1**) (Wald χ^2 = 4.85, P = .028) and anterior pelvic tilt (**FIGURE 2**) (Wald χ^2 = 6.35, P = .012) than individuals without hip pain (**TABLE 4**). At 60° of knee flexion, pairwise comparisons indicated that individuals with FAIS were in 4.9° (95% confidence interval [CI]: 0.5°, 9.2°) more hip flexion (P = .028) and 4.1° (95% CI: 0.9°, 7.3°) more anterior pelvic tilt (P = .012) than individuals without hip pain.

Sex Comparison

Females performed the step-down task with different hip flexion (Wald χ^2 = 7.52, P = .006) and adduction (Wald χ^2 = 13.06, P<.001), pelvic anterior tilt (Wald χ^2 = 12.60, P<.001) and drop (Wald χ^2 = 6.32, P = .012), and thigh adduction (Wald χ^2 = 13.25, P<.001) from those of males (**FIGURES 1** and **2**). At 60° of knee flexion, pairwise comparisons indicated that females were in 6.1° (95% CI: 1.7°, 10.4°) more hip flexion (P = .006) and 4.8° (95% CI: 2.2°, 7.4°) more hip adduction (P<.001) than males. Females were also in 5.8° (95% CI: 2.6°, 9.0°) more anterior pelvic tilt (P<.001), 1.4° (95% CI: 0.3°, 2.5°) more pelvic drop (P = .012) to the nonstance side, and 2.7° (95% CI: 1.3°, 4.2°) more thigh adduction (P<.001) than males.

TABLE 3 DATA FROM SELF-REPORT QUESTIONNAIRES*

	FAIS			Comparison	
Questionnaire	n	More Painful Side	Less Painful Side	n	All
mHHS	19	73.5 ± 17.3	90.8 ± 14.2	40	100.0 ± 0.2
HOOS subscales					
Pain	19	68.0 ± 16.9	93.4 ± 11.4	40	100.0 ± 0.0
Symptoms	19	66.6 ± 14.9	89.2 ± 12.0	40	98.0 ± 3.7
Functional activities	18	83.0 ± 11.9	97.2 ± 6.5	40	100.0 ± 0.2
Recreation/sport activities	17	61.4 ± 20.8	89.1 ± 14.7	40	99.8 ± 1.0
Quality of life	19	45.1 ± 22.1	84.8 ± 17.8	40	99.8 ± 1.0
WOMAC	18	80.6 ± 12.1	96.6 ± 7.2	40	100.0 ± 0.2

Abbreviations: FAIS, femoroacetabular impingement syndrome; HOOS, Hip disability and Osteoarthritis Outcome Score; mHHS, modified Harris Hip Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
**Values are mean ± SD. Data were missing for 1 individual with FAIS, and 2 other individuals with FAIS had incomplete data.*

DISCUSSION

The results of this study indicate that individuals with FAIS have different pelvic and lower extremity movement patterns during a single-leg step-down task than individuals without hip pain. While it is commonly believed that individuals with cam or pincer morphology would avoid motions contributing to impingement (ie, hip flexion), individuals with FAIS in this study demonstrated increased hip flexion. This increased hip flexion was primarily due to increased anterior pelvic tilt, as there was no difference in segmental

TABLE 4 KINEMATIC DATA OF BOTH SIDES, AVERAGED AT 60° OF KNEE FLEXION, DURING THE STEP-DOWN TASK

	FAIS*		Comparison*		P Value†				
Variable	Female	Male	Female	Male	Group	Sex	Side	Sex by Group	Sex by Group by Side
Joint angles									
Hip flexion	40.2 ± 8.9	30.9 ± 5.9	32.1 ± 9.4	29.2 ± 9.9	.03	.01	.81	.15	.64
Hip adduction	12.0 ± 6.0	7.2 ± 5.1	10.8 ± 5.7	6.0 ± 6.0	.37	<.01	.39	.98	.45
Knee abduction	6.1 ± 8.7	4.6 ± 7.3	4.4 ± 6.9	4.1 ± 6.2	.56	.63	.84	.76	.03
Segment angles									
Pelvic anterior tilt	13.9 ± 6.1	6.1 ± 4.4	7.8 ± 7.4	4.1 ± 7.5	.01	<.01	.98	.22	.73
Pelvic drop	1.1 ± 2.4	−0.5 ± 3.1	1.1 ± 3.0	−0.2 ± 2.7	.81	.01	.70	.72	.84
Thigh flexion	26.9 ± 4.8	25.1 ± 3.4	25.0 ± 3.3	26.0 ± 4.4	.61	.74	.81	.18	.34
Thigh adduction	8.0 ± 3.2	5.4 ± 2.7	7.3 ± 3.4	4.5 ± 4.2	.28	<.01	.90	.90	.84
Shank flexion	34.4 ± 4.7	35.8 ± 3.6	36.2 ± 3.3	34.6 ± 4.1	.80	.95	.89	.15	.46
Shank abduction	6.6 ± 1.9	7.5 ± 2.1	7.0 ± 2.4	6.8 ± 3.3	.82	.55	1.00	.29	.87

Abbreviation: FAIS, femoroacetabular impingement syndrome.
**Values are mean ± SD degrees.*
†Main effects of group, sex, and side, and interactions of sex by group and sex by group by side.

thigh angle. The movement-pattern difference may be due to altered neuromuscular control and/or decreased hip strength, although there is no strong evidence of hip extensor weakness in this population.[19] Altered neuromuscular control and strength are both impairments that are modifiable through rehabilitation.[48,62]

Our finding of increased anterior pelvic tilt in individuals with FAIS is consistent with results of other studies. Rylander et al[53] noted increased peak anterior pelvic tilt during stair climbing in individuals with FAIS. During the bilateral deep squat, Lamontagne et al[39] reported decreased pelvic tilt excursion in individuals with FAIS compared to individuals without hip pain, and Bagwell et al[6] noted decreased posterior pelvic tilt motion, resulting in 10.9° more anterior pelvic tilt at peak hip flexion. Similarly, Azevedo et al[5] found decreased posterior pelvic tilt during active unilateral hip flexion in standing in individuals with FAIS compared to individuals without hip pain and individuals with other symptomatic hip conditions. However, in contrast to our results, none of these studies found differences in hip flexion angle. This could be due to differences in task or analysis point. In our study, a single-limb controlled-descent task may challenge the hip more than a bilateral task.[17,44] Additionally, in our study, as the step-down was performed from a single height (16 cm), the task had a predetermined end point and the analysis was conducted for a standard 60° knee flexion angle. This is in contrast to the bilateral squat used in other studies, where individuals without pain achieved a lower squat depth than individuals with FAIS.[6,39]

Increased anterior pelvic tilt may contribute to the development of pain in the presence of cam or pincer morphology. A modeling study by Ross et al[52] demonstrated that increased anterior pelvic tilt leads to simulated bony contact earlier in the flexion motion than when in a neutral pelvis position. Similarly, increased posterior pelvic tilt led to later simulated bony contact. The simulation study suggests that addressing increased anterior pelvic tilt could reduce impingement in individuals with the bony morphology of FAIS.

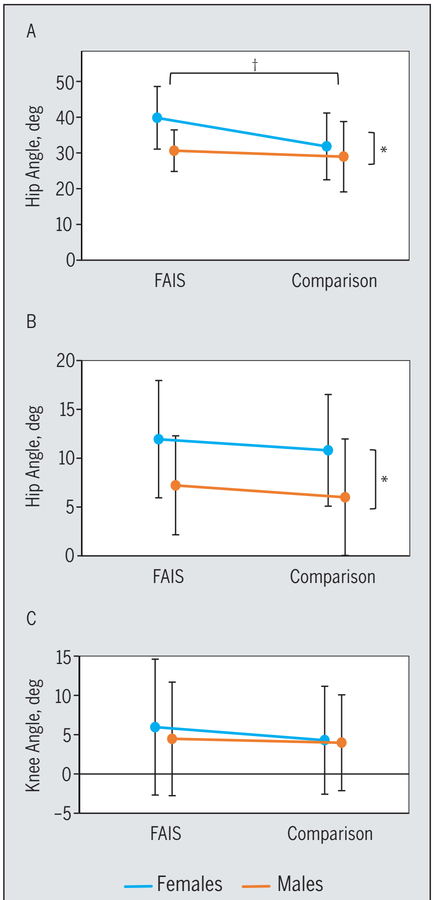

FIGURE 1. Joint angles of both sides averaged at 60° of knee flexion during the step-down task. (A) Hip flexion, (B) hip adduction, and (C) knee abduction. *Significant (P<.05) main effects of sex. †Significant (P<.05) main effects of group. Abbreviation: FAIS, femoroacetabular impingement syndrome.

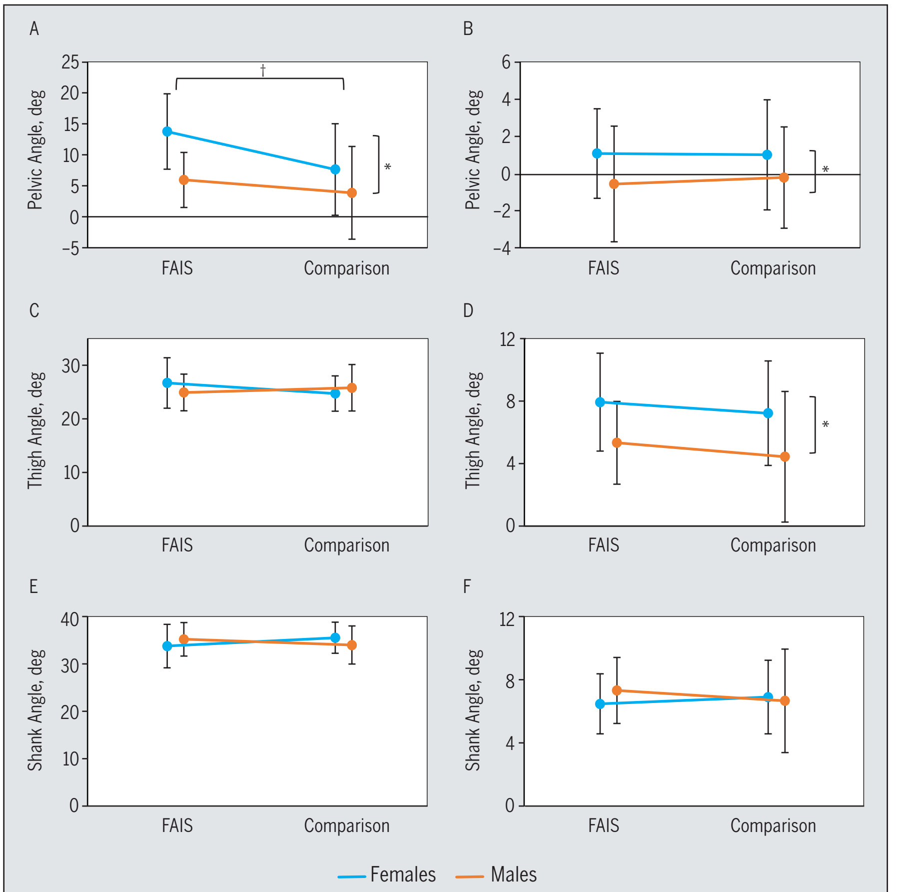

FIGURE 2. Segment angles of both sides averaged at 60° of knee flexion during the step-down task. Pelvic drop is positive and pelvic hike is negative. (A) Pelvic anterior tilt, (B) pelvic drop, (C) thigh flexion, (D) thigh adduction, (E) shank flexion, (F) shank abduction. *Significant (P<.05) main effects of sex. †Significant (P<.05) main effects of group. Abbreviation: FAIS, femoroacetabular impingement syndrome.

Sex Differences

Our data indicate that both females with FAIS and females without hip pain performed the step-down task with more hip flexion and hip adduction than males. The increased hip flexion was primarily due to increased anterior pelvic tilt, while the increased hip adduction was due to both increased pelvic drop and increased thigh adduction. Similar sex-specific differences in movement patterns during a single-leg step-down task were reported in a study by Earl et al,[17] which found that females performed the task with greater hip adduction and knee abduction than males.

The sagittal plane sex differences, while present in both groups, were more pronounced in the FAIS group than in the comparison group, despite the interaction not being statistically significant. The difference between males and females in hip flexion was 9.3° in the FAIS group and only 2.9° in the comparison group. At the pelvis, the sex difference in the FAIS group was 7.8°, while the difference in the comparison group was 3.8°. This is in addition to the sex difference in the thigh segment of 1.8° in the FAIS group and –1.1° in the comparison group. This finding indicates that females with FAIS may have slightly different movement patterns than males with FAIS. This may also indicate that the females with FAIS were the primary contributors to the group differences detected.

The relationship between sex, type of FAIS morphology, and movement pattern is unknown. It was once thought that pincer morphology was more common in females and that cam morphology was more common in males.[49] The majority of our FAIS participants, however, had cam morphology, with only 2 females having isolated pincer morphology. This is more consistent with a recent multicenter study, which indicated that cam was the predominant morphology in both sexes.[11] Given our participant distribution, we were unable to test the interactions between sex, type of morphology, and movement pattern. We did, however, perform an analysis including only individuals with cam FAIS compared to individuals without hip pain. Although not powered to adequately investigate the question, this analysis indicated that at 60° of knee flexion during the step-down, females with cam FAIS were in more hip flexion and anterior pelvic tilt compared to males with cam FAIS and compared to males or females without hip pain. This preliminary finding highlights potential sex-specific movement-pattern differences within a single type of FAIS.

While sex-specific differences have not been assessed in movement studies of individuals with FAIS, they have been noted in other aspects of the syndrome.[23] Females have poorer presurgical self-reported function than males.[32] Females with FAIS have smaller or less severe cam lesions than males with FAIS.[7,26] This finding led Hetsroni et al[26] to comment, "In women, cam lesions may be more subtle." In contrast, our findings suggest that the increased hip flexion in females with cam FAIS, combined with the increased hip adduction common to all females, may cause a smaller cam to be more symptomatic than in males with cam FAIS. These findings highlight the importance of conducting sex-specific analyses when investigating movement patterns in individuals with FAIS.

For the main effects of both group and sex, the differences at the hip, combined with the lack of differences at the knee, suggest that motion of the pelvis is the primary contributor to the noted differences. This assertion is further supported in that the pelvic segment angles are more disparate than the thigh segment angles. These findings highlight the need to closely examine pelvic motion in both research and rehabilitation.

The question of compensation versus causation is always of interest when a difference in movement pattern is noted; however, cross-sectional studies, such as the present one, cannot definitively answer that question. We can only theorize given our current understanding of the clinical diagnosis of FAIS. It seems unlikely that increased hip flexion and anterior pelvic tilt are beneficial in the presence of altered bony morphology that impinges with hip flexion. Instead, it is more plausible that the altered movement pattern is a modifiable contributor to the symptoms. Based on the pain theory by Hodges and Tucker,[28] it is plausible that the altered movement was once beneficial, but now has negative consequences. Regardless of its origin, this movement pattern may be a modifiable clinical target. Thus, improved control of the pelvis and hip during single-leg dynamic activities should be a focus of intervention for individuals with FAIS.

The present study does have limitations. Specific measurements of the alpha angle and the center-edge angle used to determine bony morphology of the participants with FAIS were not available to us. Instead, we were given the morphological classification (cam, pincer, or mixed) by the orthopaedic surgery group or, in 1 case, by the participant. We also did not conduct imaging studies on our comparison group to determine hip morphology. Some of these individuals without hip pain may have had cam or pincer morphology, as this morphology is often present in asymptomatic individuals, especially athletes.[18] However, to be classified as having FAIS, the individual must also have symptoms and clinical signs,[22] which were absent in our participants in the comparison group. An additional limitation of our group selection was the use of the UCLA activity score, a questionnaire originally intended for patients following total hip arthroplasty. The Hip Sports Activity Scale may be a more appropriate measure for individuals with FAIS.[45] In addition, as type of sporting activity appears to influence hip morphology,[1,33,40,58,59] matching groups on type of sporting activity, not just activity level, may provide a more appropriate comparison group. As discussed earlier, it is unknown whether the increased hip flexion and anterior pelvic tilt detected in the FAIS group may be contributing to the pathology or may represent an attempt at compensation, but mechanically it is reasonable to suggest that they should be considered modifiable altered movement patterns.

CONCLUSION

The results of this study suggest that individuals with FAIS have alterations in pelvic motion during a dynamic unilateral task. The increased anterior pelvic tilt may contribute to symptom development in the presence of cam or pincer morphology. In the FAIS group, the sex-specific differences in motion of the hip, pelvis, and thigh may indicate that movement impairments are more pronounced in females than in males.

KEY POINTS

FINDINGS: Individuals with femoroacetabular impingement syndrome (FAIS) performed a single-leg step-down task with greater hip flexion and anterior pelvic tilt than individuals without hip pain. Across both groups, females exhibited more hip flexion and hip and thigh adduction, as well as more anterior pelvic tilt and pelvic drop, than males during the step-down task; however, these sex differences were more pronounced in the FAIS group than in the comparison group.

IMPLICATIONS: The noted altered movement patterns in the FAIS group may contribute to the development of hip pain and may be due to impairments that are modifiable through rehabilitation.

CAUTION: This cross-sectional study design cannot definitively answer the question of cause versus compensation. Future studies are warranted to determine the effect that modifying these movement patterns has on symptoms.

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Translation, Cross-cultural Adaptation, and Validation of the Dutch International Hip Outcome Tool-33 (iHOT-33 NL) in Young, Physically Active Individuals With Symptomatic Hip Joint Pathology

Hip joint pathology is a common cause of hip pain and dysfunction.[8] Historically, hip joint pathology has often implied osteoarthritis of the hip in an older population.[1,2] But, over the past decade, the number of studies of symptomatic hip joint pathology in young, physically active individuals has increased rapidly.[5,21] A typical diagnosis in this population is femoroacetabular impingement.[8,10] Femoroacetabular impingement is described as a syndrome or motion-related clinical disorder of the hip in which 2 types of anatomical deformity are identified: cam deformity (in which impingement is caused by an osseous deformity of the femoral head-neck contour) and pincer deformity (a focal overcoverage of the femoral head by the acetabulum).[8,10] Femoroacetabular impingement syndrome is often associated with other symptomatic hip disorders, such as instability, labral tears, chondral lesions, and ligamentum teres tears.[8,10] Femoroacetabular impingement and these conditions are also linked to the development of hip osteoarthritis.[8,10]

STUDY DESIGN: Prospective cohort.

BACKGROUND: The international Hip Outcome Tool-33 (iHOT-33), developed in English, has been shown to be a valid and reliable questionnaire for young, physically active individuals with symptomatic hip joint pathology.

OBJECTIVES: To translate and validate the iHOT-33 in Dutch (iHOT-33 NL) in the target population.

METHODS: Translation and cross-cultural adaptation of the iHOT-33 were performed following existing guidelines. Young to middle-aged (18-50 years), active (Tegner activity score of 3 or greater) individuals presenting with symptomatic hip joint–related pain (numeric pain-rating score of 1 or greater) in a primary health care/hospital setting were included. The iHOT-33 NL, Hip disability and Osteoarthritis Outcome Score (HOOS), European Quality of Life-5 Dimensions questionnaire (EQ-5D), numeric pain-rating score, and Global Perceived Effect score were completed by 214 patients.

RESULTS: The intraclass correlation coefficient for test-retest reliability was 0.92 (95% confidence interval: 0.88, 0.94). Smallest detectable changes at individual and group levels were, respectively, 16.7 and 1.1 points. The Cronbach alpha was .9. Principal-component analysis revealed 4 domains of the iHOT-33 NL. Of the hypotheses used for construct validity, 87% were confirmed. No floor and ceiling effects were detected for the iHOT-33 NL total score. The minimal important change was 10.7 points.

CONCLUSION: The iHOT-33 NL is a reliable and valid patient-reported outcome questionnaire for young, physically active individuals with symptomatic hip joint pathology. It can be used in research and clinical settings. *J Orthop Sports Phys Ther 2018;48(4):289-298. doi:10.2519/jospt.2018.7610*

KEY WORDS: *groin pain, patient-reported outcome, quality of outcome measures*

Although there has been an increased amount of research on these intra-articular hip pathologies in young, active individuals, there is a lack of

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high-quality intervention studies for young, active patients with symptomatic hip joint pathology, and only a few intervention studies have used specific patient-reported outcome (PRO) questionnaires.[28,41]

Patient-reported outcomes are currently considered the gold standard in the assessment of musculoskeletal conditions in which the patient's perspective and health-related quality of life (QoL) are of primary interest.[26] Until recently, there has been a lack of PROs to be used for young, physically active individuals with hip and groin pain.[37,38] A systematic review of the clinimetric properties of PROs for this population identified only 4 questionnaires that could be recommended: the Hip and Groin Outcome Score (HAGOS), the Hip Outcome Score (HOS), the international Hip Outcome Tool-12 (iHOT-12), and the international Hip Outcome Tool-33 (iHOT-33).[37]

Of these 4 questionnaires, the iHOT-33 is the only questionnaire recommended for use in both research and clinical settings, having been specifically developed for young, active individuals with different types of symptomatic hip joint pathology.[18] It is a disease-specific questionnaire that consists of 33 questions grouped in 4 domains: symptoms and functional limitations, sports and recreational physical activities, job-related concerns, and QoL (social, emotional, and lifestyle concerns).[18] Earlier studies have shown that the original English version of the iHOT-33 is valid and reliable for use in a population of young, physically active individuals with symptomatic hip joint pathology.[11,14,18,27,37] In order to use the iHOT-33 in research and/or clinical settings in the Netherlands, the aim of this study was to translate and cross-culturally adapt the iHOT-33 into the Dutch language (iHOT-33 NL), according to existing guidelines,[4] and to validate this version in young and active individuals with symptomatic hip joint pathology.

METHODS

THE PRESENT STUDY CONSISTED OF 2 phases: translation and cross-cultural adaptation of the English iHOT-33 into Dutch (iHOT-33 NL) and validation of this version in young and active individuals with symptomatic hip joint pathology.

Translation and Cross-cultural Adaptation

The translation of the English iHOT-33 was performed according to existing guidelines.[4] Forward translation of the English version of the iHOT-33 into Dutch was performed by 2 native bilingual Dutch translators who worked independently from each other (1 medical health care professional and 1 nonmedical translator). Both versions were compared and synthesized into 1 preliminary iHOT-33 NL version in a consensus meeting. When differences between translators occurred, the original English version[18] was referred to during the consensus process. This preliminary iHOT-33 NL was tested by experienced health care professionals in the target population of 10 physically active patients with hip and/or groin pain. These patients were encouraged to make comments with their answers. Comments and responses from the patients and health care professionals were evaluated and consensus was reached on rephrasing and cultural adaptations. The preliminary iHOT-33 NL was then translated back into English by an independent native English–speaking nonmedical translator who was bilingual and had no knowledge of the study objectives or design. This translation was subsequently compared with the original questionnaire by an expert committee consisting of medical health care professionals (M.T. and I.T.). Minor discrepancies between these 2 versions of the iHOT-33, the original version and backward translation, were found concerning wording, understanding, and phrasing. These discrepancies were found to be small and were discussed, solved, and adjusted within the expert committee, aiming for better patient understanding. After this process, face validity, the extent to which the questionnaire looks as though it reflects the measured construct, was considered acceptable by the expert committee (M.T. and I.T.). Permission for the translation and cross-cultural adaptation was obtained from the originator of the iHOT-33 (personal communication with Nicholas Mohtadi). **APPENDIX A** (available at www.jospt.org) provides the final version of the iHOT-33 NL.

Study Procedure

A multicenter prospective cohort study was performed to test the validity and reliability of the iHOT-33 NL following the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations on terminology and definitions of measurement properties.[36] The COSMIN checklist was formulated based on a recent international consensus process where consensus on the taxonomy, terminology, and definitions of measurement properties for health-related PROs was reached.[19,36] It is primarily a reporting checklist for measurement studies.[36]

All patients were clinically evaluated using Dutch versions of the iHOT-33, the Hip disability and Osteoarthritis Outcome Score (HOOS),[6] the European Quality of Life-5 Dimensions questionnaire (EQ-5D),[42] and 3 numeric pain-rating scales (NPRSs)[12] for average pain experienced, pain during sports, and pain after sports participation. These questionnaires (completed in this order) were used to establish construct validity of the iHOT-33 NL. Tegner activity scores were used to assess the participants' current and preinjury activity levels.[34] This information was used for inclusion purposes and between-group comparison of activity level in the test-retest reliability analysis.[34]

The iHOT-33 NL was repeated within 7 days after the initial assessment to establish test-retest reliability. All patients performed both assessments electronically at home. Patients were asked to perform these assessments under similar conditions, including time of day and physical activities performed during the day of assessment. The order in which patients answered the questionnaires was the same for both assessments. To optimize the response rate, patients were contacted by phone, text message, or mail to remind them to complete the questionnaires for the second time, 5 to 7 days following the first completion. This study was performed in accordance with the requirements of the Declaration of Helsinki.[45] The local medical ethics committee (Slotervaart Ziekenhuis/Reade Amsterdam) approved this study (number P1432). All patients signed an informed-consent form prior to participation.

Study Population

The target population of the iHOT-33 is young, active individuals with hip joint pathology.[18] Therefore, we included all patients who (1) presented with hip and/or groin pain at 1 of the clinical settings (hospitals and centers for sports medicine and sports physical therapy throughout the Netherlands; these centers were approached for participation in this study by authors M.T. and I.T.), (2) were between 18 and 50 years of age, (3) were physically active (preinjury Tegner activity score of 3 or greater),[34] (4) were scheduled for nonsurgical or surgical treatment of intra-articular hip pathology, based on physical examination and imaging (**APPENDIX B**, available at www.jospt.org),[39,40,43] and/or (5) were evaluated after hip arthroscopy and still reported pain (NPRS of 1 or greater) of the hip and/or groin during or after sport activities.

The physical examination was based on the Doha agreement meeting on terminology and definitions for groin pain in athletes, combined with information from earlier studies.[39,40,43] Patients with a postoperative status were not physically examined. Patients who (1) were not fluent in Dutch or (2) did not have access to a computer with the internet were excluded from the study.[6,12]

Questionnaires

The iHOT-33 NL is a disease-specific questionnaire that consists of 33 questions grouped in 4 domains: symptoms and functional limitations, sports and recreational physical activities, job-related concerns, and social, emotional, and QoL.[18] The iHOT-33 NL does not score the 4 domains separately. An overall score is calculated by taking the mean of the individual responses, based on a visual analog scale ranging from 0 to 100, in which 100 is the best possible score.[18] Higher scores thus reflect better physical functioning and health-related QoL.[18]

The Dutch version of the HOOS was initially developed for a population with hip osteoarthritis and contains 36 questions, grouped in 5 subscales (pain, symptoms, activities of daily living [ADL], sports/recreational activities, and QoL).[6] Each question is scored on a 5-point Likert scale, with higher scores representing fewer symptoms. A final score per domain is calculated, with 0 being the worst and 100 (no symptoms) being the best possible score.[6]

The EQ-5D assesses general experienced health status in 5 levels (mobility, self-care, daily activities, pain/discomfort, and anxiety/depression) on a 3-point scale.[42] Additionally, overall health is rated on a 0-to-100 visual analog scale, and a total score may be calculated.[9]

The NPRS assesses pain on an 11-point scale (0-10), in which 0 represents no pain and 10 represents the worst pain imaginable.[12] The patient is asked to choose a level of pain concurrent with the pain felt during the last week, during sports activities, or after sports activities.[12]

All included questionnaires were made available to patients by means of a web-based system with a self-checking function to identify missing data and to ensure full completion and submission of the questionnaires. This required patients to answer all questions per assessment, and there were no missing data on any questionnaire. For the validity analysis, all completed questionnaires from the first assessment were used. Patients who failed to complete the first assessment were excluded from the validity analyses. Patients who failed to fully complete the second assessment were excluded from the test-retest reliability analysis (**FIGURE**). As this study was also part of the translation and validation of the Dutch Hip and Groin Outcome Score (HAGOS NL), the assessments consisted of 102 questions.[33]

Statistical Analysis

All statistical analyses were performed with IBM SPSS Statistics Version 22.0 (IBM Corporation, Armonk, NY). Descriptive statistics were used to calculate the demographic variables and outcomes of questionnaires. The significance level was set at .05.

Reliability The reliability of a PRO indicates the extent to which the questionnaire is free from measurement error and is analyzed by test-retest reliability, internal consistency, and measurement error.[20]

Test-retest reliability is the extent to which the same results are obtained on repeated administrations of the same PRO when no change in clinical status has occurred.[20] Patients in this study were asked to complete the iHOT-33 NL twice. These assessments were performed independent of each other, so that patients were not able to access answers from the first assessment. Global Perceived Effect (GPE), assessed on a 7-point Likert scale, was used to check for changes in perceived health status between the 2 test occasions.[13,30] Patients with a GPE score of 3, 4, or 5 (indicating a "slightly worse," "unchanged," or "slightly better" health status) at the second assessment were included for the test-retest reliability analysis, as this was established a priori as a change between assessments that was not clinically relevant.[17] All patients with a GPE score of 1, 2, 6, or 7 were excluded from test-retest analysis.[17] Using a 2-way random-effects model with absolute agreement to assess test-retest reliability, outcomes were intraclass correlation coefficients (ICCs) with 95% confidence intervals.[35] An ICC of 0.7 or greater was considered acceptable.[35] Unpaired *t* tests and Mann-Whitney *U* tests were used to check for differences in age, physical activity levels (Tegner activity scores and hours of sports participation per week), and pain (NPRS) scores between the total group and the subgroup used for the reliability analyses.

The iHOT-33 NL is considered a reflective model.[36] Therefore, internal consistency, the extent of interrelatedness among the items of a PRO, was assessed using the Cronbach alpha.[31] The Cronbach alpha was based on the initial assessment and was deemed good at .8 or greater and excellent at .9 or greater.[35]

A principal-component analysis to identify common components among sets of items and to explain the extent of variance was performed for the 4 subscales to ensure that the translation did not affect the internal consistency of the original iHOT-33.[35] This analysis was based on data from the initial assessment and was performed with varimax rotation and the eigenvalue set at greater than 1.[35]

Furthermore, the measurement error, that is, the systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured, was analyzed by the standard error of the measurement (SEM), calculated by the formula SD $\times \sqrt{1 - \text{ICC}}$,[20] where SD is the standard deviation from scores from all patients at the initial assessment. The smallest detectable change (SDC) was then calculated as SEM $\times$ 1.96 $\times \sqrt{2}$ at an individual level and SEM $\times$ 1.96 $\times \sqrt{2}/\sqrt{n}$ at the group level.[44]

Validity The validity of a PRO determines the extent to which the questionnaire measures the construct(s) it purports to measure.[20] The construct validity refers to the extent to which scores on a particular measure relate to other measures, consistent with theoretically derived hypotheses concerning the constructs that are being measured.[20] Fifteen hypotheses between the iHOT-33 NL, the Dutch versions of the HOOS and EQ-5D, and the NPRS were formulated a priori to test construct validity, which was considered good when greater than 75% (n>11) were confirmed (**TABLE 1**).[35] Spearman correlation coefficients for nonparametric data were used to check the a priori hypotheses in the construct validity analysis. Strong correlations were defined as $r \geq 0.7$ (or $r \geq -0.7$ when a maximum achievable score of one scale correlates with a minimum achievable score on the comparative scale), moderate correlations as $0.5 \leq r < 0.7$ or $-0.5 \leq r < -0.7$, and weak correlations as $r < 0.5$ or $r < -0.5$.[7]

Interpretability Interpretability is the extent to which one can assign qualitative meaning—that is, clinical or commonly understood connotations—to an instrument's quantitative scores or change in scores.[20] This includes the distribution of scores, floor and ceiling effects, and an estimation of the minimal important change (MIC).[16,35]

Floor and ceiling effects were determined as the percentage of patients with, respectively, the lowest (0) and highest (100) possible scores on the iHOT-33 NL.[16] Floor and ceiling effects were identified when more than 15% of the patients scored the lowest (0) or highest (100) possible score, respectively, based on the initial assessment of the iHOT-33 NL.[16] The MIC was calculated as 0.5 $\times$ SD,[25] where SD is the standard deviation from scores from all patients at the initial assessment.

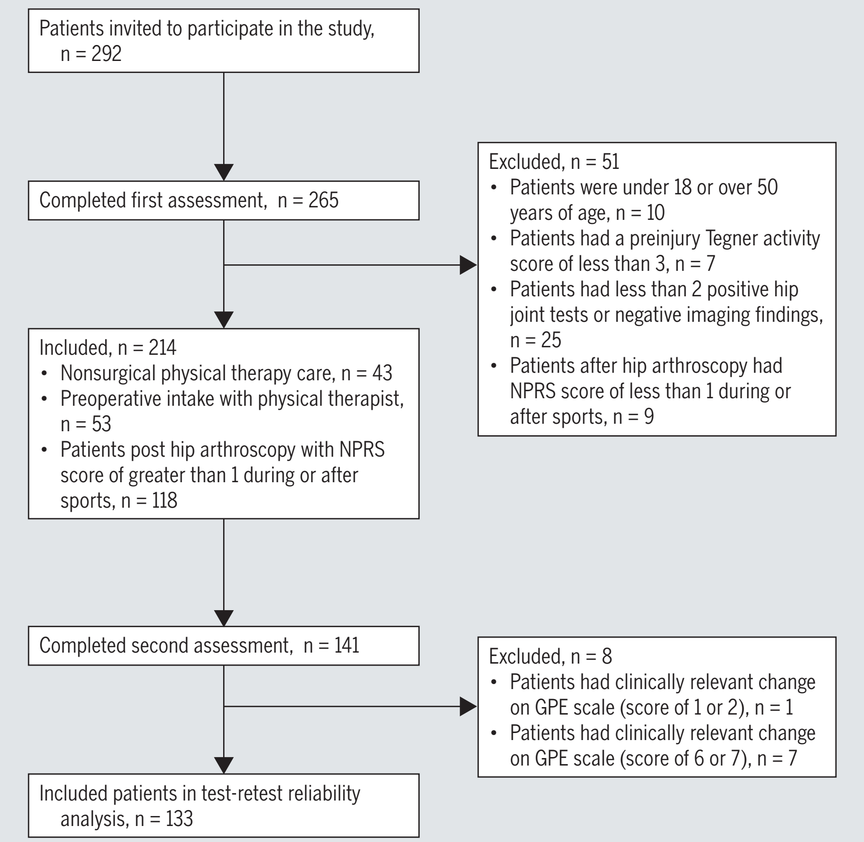

FIGURE. Flow chart of patient inclusion and exclusion. Abbreviations: GPE, Global Perceived Effect; NPRS, numeric pain-rating scale.

RESULTS

The **FIGURE** represents a flow chart of the patient inclusion process, which took place from March 2015 to August 2016. There were 214 patients who fully completed the first assessment and could be included in the validation analysis. Three major groups could be distinguished: (1) patients who came for nonsurgical treatment (n = 43), (2) patients who were assessed preoperatively (n = 53), and (3) patients who were assessed post surgery (n = 118).

A total of 141 patients returned the second assessment. Of these 141 patients, 133 reported no clinically relevant change (a GPE score of 3, 4, or 5). One patient scored a 2 on the GPE, and 7 patients scored a 6 on the GPE, and they were excluded from test-retest reliability assessment. The characteristics of all included patients at baseline are presented in **TABLE 2**. There were no significant differences for age, pain levels, and activity levels between the total group (n = 214) and those who were in the reliability assessments (n = 133) (all, $P>.75$). The average ± SD time between assessments was 8.5 ± 8.7 days (range, 1-23 days).

Reliability

The iHOT-33 NL initial test scores, retest scores, and the reliability analysis results are presented in **TABLE 3**. A Wilcoxon paired test revealed no statistically significant difference between the test and retest scores ($P\geq.06$), except for questions 16 ($P<.01$) and 18 ($P = .01$). The principal-component analysis revealed that the 4 iHOT-33 NL subscales each had 1 strong factor with an eigenvalue greater than 1, as in the original iHOT-33, explaining the degree of variance (**TABLE 4**).

Validity

Spearman correlation coefficients between the iHOT-33 NL, the Dutch versions of the HOOS and EQ-5D, and the NPRS are presented in **TABLE 1**. All 15 of the a priori hypotheses were tested, and 13 (87%) were confirmed.

Interpretability

The distribution of the scores of all questions of the iHOT-33 NL at baseline and the MIC are presented in **TABLE 5**. No floor and ceiling effects were present in this study population for the total score on the iHOT-33 NL. One question showed a floor effect (16%), and 2 showed ceiling effects (from greater than 15% to 21%). The MIC of the total iHOT-33 NL score was 10.7 points.

TABLE 1 A Priori Set Hypotheses and Actual Spearman Correlation Coefficients for the iHOT-33 NL Compared to the HOOS NL, EQ-5D NL, and NPRS (n = 214)

Scale/Subscale	A Priori Hypothesis	Actual Correlation
iHOT-33 NL with HOOS NL		
HOOS pain	≥0.7	0.76*
HOOS symptoms	≥0.7	0.69*
HOOS ADL	0.5≤r≤0.7	0.75*
HOOS sports/recreation	≥0.7	0.75*
HOOS quality of life	0.5≤r≤0.7	0.53*
iHOT-33 NL with EQ-5D NL		
EQ-5D mobility	–0.5≤r≤–0.7	–0.65*
EQ-5D self-care	≤–0.5	–0.04*
EQ-5D usual activities	–0.5≤r≤–0.7	–0.60*
EQ-5D pain/discomfort	–0.5≤r≤–0.7	–0.63*
EQ-5D anxiety/depression	≤–0.5	–0.40*
EQ-5D health score	–0.5≤r≤–0.7	–0.58*
EQ-5D overall score	–0.5≤r≤–0.7	–0.52*
iHOT-33 NL with NPRS		
NPRS average	–0.5≤r≤–0.7	–0.68*
NPRS during sport	–0.5≤r≤–0.7	–0.56*
NPRS after sport	–0.5≤r≤–0.7	–0.64*

Abbreviations: ADL, activities of daily living; EQ-5D NL, Dutch version of the European Quality of Lifel-5 Dimensions questionnaire; HOOS NL, Dutch version of the Hip disability and Osteoarthritis Outcome Score; iHOT-33 NL, Dutch version of the international Hip Outcome Tool; NPRS, numeric pain-rating scale.
**Correlations were statistically significant ($P\leq.05$).*

DISCUSSION

The results of this study show that the iHOT-33 NL is a reliable, internally consistent, and valid measurement tool to assess physical functioning in a Dutch population of young, physically active individuals with symptomatic hip joint pathology.

Reliability

The test-retest reliability of the iHOT-33 NL was good (ICC = 0.92; 95% confidence interval: 0.88, 0.94). This is higher than the test-retest reliability of the original iHOT-33 (ICC = 0.78) and comparable to values found in earlier studies, which ranged from ICCs of 0.87 to 0.96.[3,11,14,15,18,27,29] No significant differences were found between test results from the first and second assessments of the iHOT-33 NL, except for questions 16 and 18. Questions 16 and 18 ask about pain experienced in general and after (sports) activities. The mean difference between the test-retest measurements for these questions was 8.2 and 4.6 points, respectively. Based on the MIC values found in the current study (question 16, 13.6 points; question 18, 16.7 points), the mean differences in test-retest scores are significantly different, but can be interpreted as clinically nonrelevant.[25] Also, to establish whether no relevant change in clinical status occurred, the GPE score was used, and all patients who reported a GPE score of 1,

TABLE 2 Baseline Characteristics of Included Patients (n = 214)*

Characteristic	Value
Sample, n (%)	
All patients	214 (100)
Male	108 (50.5)
Female	106 (49.5)
Age, y	
All patients	32.7 ± 8.9
Male	32.2 ± 8.9
Female	33.3 ± 9.0
Affected hip, n (%)	
Left	114 (53.3)
Right	100 (46.7)
Pain (NPRS, 0-10)	
Average	
All patients	4.7 ± 2.5
Male	4.5 ± 2.3
Female	5.0 ± 2.7
During sport	
All patients	6.3 ± 2.7
Male	6.3 ± 2.5
Female	6.3 ± 2.7
After sport	
All patients	6.7 ± 2.5
Male	6.6 ± 2.5
Female	6.7 ± 2.7
Tegner activity score†	
Preinjury	
All patients	6 (4-8)
Male	7 (5-9)
Female	4 (3-7)
Current	
All patients	3 (2-6)
Male	4 (2-7)
Female	2.5 (1-4)
Sport activity, h/wk	
Preinjury	
All patients	3.3 ± 2.1
Male	3.4 ± 1.9
Female	3.2 ± 2.2
Current	
All patients	2.1 ± 1.9
Male	2.4 ± 1.5
Female	1.9 ± 2.1

Abbreviation: NPRS, numeric pain-rating scale.
**Values are mean ± SD unless otherwise indicated.*
†Values are median (25%-75% interquartile range).

2, 6, or 7 were already excluded from reliability analysis.[17]

The SEM of the iHOT-33 NL was 6.0, and the SDC was 16.7 points at an individual level and 1.1 points at the group level. This is consistent with the original iHOT-33 as well as iHOT-33 translations in German and Spanish.[3,11,14,29] The SDC values show that the iHOT-33 NL is more sensitive to detect changes at the group level than at the individual level, similar to the original iHOT-33.[11,14]

The average time between the 2 measurements, 8.5 days, was relatively short. This was a consequence of the choice of convenience to assess patients in primary health care, usually having a second appointment for treatment within the first 2 weeks after presenting with hip and/or groin pain. However, as this study was part of the translation and validation of the HAGOS NL as well, each assessment consisted of 102 questions, which decreases the chance of recall bias.

Internal consistency was good to excellent, with a Cronbach alpha of .9 for the iHOT-33 NL total score and .85 to .95 for the 4 subscales.[31] The original iHOT-33 reported a slightly higher Cronbach alpha of .99.[18] The 3 known translations of the iHOT-33 (in German, Spanish, and Chinese) reported values ranging from .96 to .98.[3,15,29] Every subscale had 1 strong factor explaining the degree of variance to a large extent, similar to the original iHOT-33.

Validity

The construct validity was deemed to be good (87% of hypotheses confirmed).[35] Only 2 hypotheses proved incorrect, as the correlation between the iHOT-33 NL and the symptoms subscale of the HOOS was slightly lower than expected ($r = 0.69$ versus expected $r \geq 0.7$), whereas the correlation with the ADL subscale of the HOOS was higher than expected ($r = 0.75$ versus expected $0.5 \leq r < 0.7$).

The iHOT-33 NL was compared to the HOOS to establish convergent construct validity. In general, strong to moderate correlations were found, as hypothesized, because both questionnaires were specifically developed to assess functioning in patients with hip and/or groin pain. The correlations between the iHOT-33 NL and the ADL subscale and QoL subscale of the HOOS were expected to be moderate, because the HOOS was originally developed for an older, presumably less active population.[6,18] This proved correct for the QoL subscale, but the ADL subscale showed a strong correlation, indicating that young, active patients with hip pain might experience problems in daily life activity similar to those experienced by older patients. Correlation with the symptoms subscale was slightly less than expected, which may indicate that these young, active patients experience different symptoms than those experienced by the older patients, who are the target population of the HOOS. To our knowledge, correlations between the iHOT-33 and HOOS have not been previously investigated. Other translation and validation studies have used the HOS and Western Ontario and McMaster Universities Osteoarthritis Index to establish convergent construct validity.[3,15,29] The HOS, however, is not available in Dutch, whereas the Western Ontario and McMaster Universities Osteoarthritis Index was not specifically developed for patients with hip and/or groin pain only.[3,15,29]

Correlation between the iHOT-33 NL and the EQ-5D was investigated to assess divergent construct validity. The EQ-5D was used for this validation purpose instead of the often used Medical Outcomes Study 36-Item Short-Form Health Survey, because it includes fewer questions and therefore decreases patient burden.[9]

TABLE 3 RELIABILITY ANALYSIS OF THE iHOT-33 NL (N = 133)

Measures	Outcomes
Test*	46.8 ± 20.1
Retest*	46.3 ± 22.8
Test-retest difference*	0.5 ± 11.9
P value	.66
SEM	6.0
ICC†	0.92 (0.88, 0.94)
SDC at individual level	16.7
SDC at group level	1.1
Cronbach alpha	.9

Abbreviations: ICC, intraclass correlation coefficient; iHOT-33 NL, Dutch version of the international Hip Outcome Tool; SDC, smallest detectable change; SEM, standard error of the measurement.
**Values are mean ± SD.*
†Values in parentheses are 95% confidence interval.

TABLE 4 INTERNAL CONSISTENCY OF THE 4 SUBSCALES OF THE iHOT-33 NL BASED ON PRINCIPAL-COMPONENT ANALYSIS (N = 214)

Subscale	Cronbach Alpha	Eigenvalue	Variance Explained, %
Symptoms and functional limitations	.95	9.04	56
Sports and recreational physical activities	.91	3.68	61
Job-related concerns	.85	3.14	79
Social, emotional, and lifestyle concerns	.91	3.68	52

Abbreviation: iHOT-33 NL, Dutch version of the international Hip Outcome Tool.

A comparison between the iHOT-33 NL and the NPRSs was made to investigate whether the iHOT-33 NL answers were influenced by pain only. Therefore, moderate correlations between the 2 questionnaires were expected, and this was confirmed.

Interpretability

The mean iHOT-33 NL total score was 46.3 points, with a MIC of 10.7 points and no floor or ceiling effects. This is comparable to the original version (mean total score of 32 points, no floor or ceiling effects) and to the Spanish version (mean total score of 39.4 points, MIC of 12.5 points) and the Chinese version (mean total score of 32.7 points, no floor or ceiling effects) of the iHOT-33, which were also validated in the target population.[15,18,29]

Although no floor or ceiling effects for the total iHOT-33 NL score were found, 1 question showed a floor effect and 2 showed ceiling effects. No floor or ceiling effects should be observed when a patient's condition can no longer change in either direction (become better or worse).[20] However, the floor and ceiling effects found in this study only occurred in 3 individual questions, whereas the iHOT-33 is to be interpreted as a total (subscale) score. No other studies have reported floor or ceiling effects, but not all have examined individual questions for these effects.[11,27,37] Further studies are needed to establish possible floor or ceiling effects for these individual questions and clinical implications.

Limitations

The electronic questionnaire system used in the present study only accepted fully completed questionnaires. Therefore, there were no data from patients who did not fully complete the questionnaires, which might have resulted in bias. However, the extent of this effect and how it might have affected the data are unknown.

Another limitation is due to the selection of the study population. At present, the gold standard for diagnosing intra-articular hip pathology is hip surgery.[10] Although many of our patients diagnosed with hip joint pathology eventually underwent hip arthroscopy, this was not used as an inclusion criterion. However, we used reliable examination techniques advocated in a recent consensus statement[39,40,43] that are comparable to those used in clinical practice.[8,10,40]

The Tegner activity scores used in this study were originally developed to assess levels of physical activity in patients with knee injury.[34] At the time this study was developed, no specific hip activity scales were available. Recently, the Hip Sports Activity Scale was published for this purpose.[22]

Finally, the MIC calculation applied in this study was based on a rule of thumb as described by Norman et al.[25] At the time of the study, there was no consensus on the methods by which the MIC should be measured. Therefore, the authors decided that the description by Norman et al,[25] which has been used in similar clinical populations,[27,37] was the most appropriate for the study design. An investigation into the responsiveness of the iHOT-33 NL would have helped to resolve this issue, and this is certainly warranted for future research.

TABLE 5 Distribution of Scores of the iHOT-33 NL, With Floor and Ceiling Effects and Minimal Important Change (n = 214)

Item Number	Score*	Floor Effect, n (%)	Ceiling Effect, n (%)	MIC
1	34.6 ± 28.7	17 (7.9)	3 (1.4)	14.4
2	47.0 ± 29.4	8 (3.7)	14 (6.5)	14.7
3	41.9 ± 32.3	15 (7.0)	17 (7.9)	16.2
4	55.5 ± 30.6	3 (1.4)	32 (15.0)	15.3
5	43.8 ± 32.0	10 (4.7)	16 (7.5)	16.0
6	53.8 ± 30.8	2 (0.9)	26 (12.2)	15.4
7	51.7 ± 29.4	2 (0.9)	20 (9.4)	14.7
8	57.7 ± 33.5	9 (4.2)	32 (15.0)	16.8
9	53.5 ± 28.8	3 (1.4)	22 (10.3)	14.4
10	62.2 ± 30.0	3 (1.4)	32 (15.0)	15.0
11	59.3 ± 28.1	1 (0.5)	20 (9.4)	14.1
12	55.8 ± 29.7	3 (1.4)	25 (11.7)	14.8
13	55.5 ± 30.5	3 (1.4)	33 (15.4)	15.2
14	56.3 ± 33.1	8 (3.7)	31 (14.5)	16.6
15	60.8 ± 32.0	2 (0.9)	45 (21.0)	16.0
16	44.1 ± 27.3	4 (1.9)	4 (1.9)	13.6
17	37.1 ± 30.0	24 (11.2)	11 (5.1)	15.0
18	32.6 ± 27.4	15 (7.0)	6 (2.8)	16.7
19	29.8 ± 28.3	30 (14.0)	9 (4.2)	14.1
20	41.7 ± 29.2	8 (3.7)	13 (6.1)	14.6
21	29.5 ± 42.6	8 (3.7)	10 (4.7)	21.3
22	30.9 ± 27.1	24 (11.2)	5 (2.3)	16.6
23	65.2 ± 45.9	3 (1.4)	7 (3.3)	23.0
24	18.3 ± 33.1	3 (1.4)	14 (6.5)	16.6
25	19.6 ± 32.6	7 (3.3)	2 (0.9)	16.3
26	19.5 ± 32.7	2 (0.9)	3 (1.4)	16.3
27	36.8 ± 29.8	22 (10.3)	11 (5.1)	14.9
28	18.4 ± 32.5	3 (1.4)	24 (11.2)	16.3
29	47.3 ± 28.2	3 (1.4)	17 (7.9)	14.1
30	55.1 ± 31.1	6 (2.8)	25 (11.7)	15.6
31	51.6 ± 30.8	8 (3.7)	23 (10.8)	15.4
32	57.1 ± 46.8	1 (0.5)	15 (7.0)	23.4
33	29.3 ± 27.3	34 (15.9)	6 (2.8)	16.7
Total score	46.3 ± 21.3	0 (0)	0 (0)	10.7

Abbreviations: iHOT-33 NL, Dutch version of the international Hip Outcome Tool; MIC, minimal important change.
**Values are mean ± SD. The score range for each item is 0 to 100.*

CONCLUSION

This study followed existing guidelines for translation, cross-cultural adaptation, and validation and found the iHOT-33 NL to be a reliable, internally consistent, and valid measurement tool to assess physical functioning in a Dutch population of young, physically active individuals with symptomatic hip joint pathology. The iHOT-33 NL can be used both in research and clinical settings to assess patients seeking nonsurgical and preoperative/postoperative care. ◉

KEY POINTS

FINDINGS: The Dutch version of the international Hip Outcome Tool-33 (iHOT-33 NL) is a reliable, internally consistent, and valid questionnaire for use in a young, physically active Dutch population with symptomatic hip joint pathology.

IMPLICATIONS: The iHOT-33 NL can be used by clinicians in both research and clinical settings for patients seeking nonsurgical and preoperative/postoperative care. It is disease specific and can provide objective data.

CAUTION: Use of the iHOT-33 NL in different populations or as a diagnostic or evaluative instrument needs further investigation, as responsiveness was not investigated in this study.

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APPENDIX A

DUTCH VERSION OF THE INTERNATIONAL HIP OUTCOME TOOL-33 (IHOT-33 NL)

iHOT33

Internationale
heup uitkomst instrument

Naam

Geboortedatum

Datum van vandaag

Over welke heup gaat deze vragenlijst?
Als we u van te voren gevraagd hebben naar een heup in het bijzonder kruis die dan aan. Geef anders de heup aan die de meeste klachten veroorzaakt.

O Links
O Rechts

Kwaliteit van Leven Vragenlijst voor jonge, actieve patiënten met heupproblemen.

Instructies

- Deze vragenlijst vraagt naar de problemen die u mogelijk ervaart in uw heup, hoe deze problemen uw leven beïnvloeden en naar de emoties die u mogelijk voelt vanwege deze problemen.
- Geef de ernst aan door de lijn onder elke vraag te markeren met een streepje.

›› Als u een streepje uiterst **links** plaatst betekent dit dat **u zich duidelijk beperkt voelt.** Bijvoorbeeld:

DUIDELIJK BEPERKT ———————— HELEMAAL GEEN PROBLEMEN

›› Als u een streepje uiterst **rechts** plaatst betekent dit dat u denkt dat **u helemaal geen problemen hebt** met uw heup. Bijvoorbeeld:

DUIDELIJK BEPERKT ———————— HELEMAAL GEEN PROBLEMEN

›› Als het streepje in het midden van de lijn gezet wordt geeft dat aan dat u gemiddeld beperkt bent, of in andere woorden, tussen de extremen “duidelijk beperkt” en “helemaal geen problemen”. Het is belangrijk om het streepje te zetten op het einde van de lijn als de extreme beschrijving uw situatie accuraat omschrijft.

- Beschrijf met uw antwoorden alstublieft de gemiddelde situatie van de afgelopen **maand.**

Tip: als u een activiteit niet doet, stel dan voor hoe uw heup zou voelen als u het zou moeten proberen.

SECTIE 1 | SYMPTOMEN EN FUNCTIONELE BEPERKINGEN

De volgende vragen gaan over symptomen die u kunt ervaren in uw heup en over de functie van uw heup met betrekking tot dagelijkse activiteiten.
Denkt u hierbij alstublieft aan hoe u zich meestal gevoeld heeft in de afgelopen maand en antwoord overeenkomstig.

V01 Hoe vaak doet uw heup/ lies pijn?

CONSTANT ———————— NOOIT

APPENDIX A

V02 Hoe stijf is uw heup na zitten of rusten gedurende de dag?

EXTREEM STIJF ———— HELEMAAL NIET STIJF

V03 Hoe moeilijk is het voor u om lange afstanden te lopen?

EXTREEM MOEILIJK ———— HELEMAAL NIET MOEILIJK

V04 Hoeveel pijn heeft u in uw heup tijdens het zitten?

EXTREME PIJN ———— HELEMAAL GEEN PIJN

V05 Hoeveel moeite heeft u met lang staan?

ERNSTIGE MOEITE ———— HELEMAAL GEEN MOEITE

V06 Hoe moeilijk is het voor u om op de vloer/grond te komen en weer op te staan?

EXTREEM MOEILIJK ———— HELEMAAL NIET MOEILIJK

V07 Hoe moeilijk is het voor u om op oneffen ondergrond te lopen?

EXTREEM MOEILIJK ———— HELEMAAL NIET MOEILIJK

V08 Hoe moeilijk is het voor u om op uw aangedane zijde te liggen?

EXTREEM MOEILIJK ———— HELEMAAL NIET MOEILIJK

V09 Hoeveel moeite heeft u met het stappen over obstakels?

ERNSTIGE MOEITE ———— HELEMAAL GEEN MOEITE

V10 Hoeveel moeite heeft u om de trap op/af te lopen?

ERNSTIGE MOEITE ———— HELEMAAL GEEN MOEITE

V11 Hoeveel moeite heeft u om vanuit een zittende positie op te staan?

ERNSTIGE MOEITE ———— HELEMAAL GEEN MOEITE

APPENDIX A

V12 Hoeveel ongemak heeft u bij het nemen van grote passen?

EXTREEM ONGEMAK ——— HELEMAAL GEEN ONGEMAK

V13 Hoe moeilijk is het voor u om in en/of uit een auto te stappen?

EXTREEM MOEILIJK ——— HELEMAAL NIET MOEILIJK

V14 Hoeveel last heeft u van kraken, gevoel van blokkeren of klikken in uw heup?

ERNSTIGE LAST ——— HELEMAAL GEEN LAST

V15 Hoeveel moeite is het voor u om sokken, kousen of schoenen aan/uit te trekken?

EXTREEM MOEILIJK ——— HELEMAAL NIET MOEILIJK

V16 Hoeveel pijn heeft u over het algemeen in uw heup/lies?

EXTREME PIJN ——— HELEMAAL GEEN PIJN

SECTIE 2 | SPORT EN RECREATIEVE ACTIVITEITEN

De volgende vragen gaan over uw **heup** wanneer u deelneemt aan sport en recreatieve activiteiten. Denkt u hierbij alstublieft aan hoe u zich meestal gevoeld heeft in de afgelopen **maand** en antwoord overeenkomstig.

V17 Hoe bezorgd bent u over uw mogelijkheid om uw gewenste fitheidsniveau te behouden?

EXTREEM BEZORGD ——— HELEMAAL NIET BEZORGD

V18 Hoeveel pijn ervaart u in uw heup na activiteiten?

EXTREME PIJN ——— HELEMAAL GEEN PIJN

V19 Hoe bezorgd bent u dat de pijn in uw heup toe zal nemen als u deelneemt aan sport of recreatieve activiteiten?

EXTREEM BEZORGD ——— HELEMAAL NIET BEZORGD

APPENDIX A

V20 Hoeveel is uw kwaliteit van leven achteruit gegaan omdat u niet kunt deelnemen aan sport / recreatieve activiteiten?

EXTREEM ACHTERUIT GEGAAN — HELEMAAL NIET ACHTERUIT GEGAAN

V21 Hoe bezorgd bent u over wenden/ keren tijdens uw sport of recreatieve activiteiten?
☐ Dit doe ik niet in mijn activiteiten

EXTREEM BEZORGD — HELEMAAL NIET BEZORGD

V22 Hoeveel is uw prestatieniveau afgenomen in uw sport of recreatieve activiteiten?

EXTREEM AFGENOMEN — HELEMAAL NIET AFGENOMEN

SECTIE 3 | WERK GERELATEERDE ZAKEN

De volgende vragen gaan over uw heup met betrekking tot uw huidige werk.
Denkt u hierbij alstublieft aan hoe u zich meestal gevoeld heeft in de afgelopen maand en antwoord overeenkomstig.

☐ Ik werk niet vanwege mijn heup (sla deze sectie over)
☐ Ik werk niet, door andere redenen dan mijn heup (sla deze sectie over).

V23 Hoeveel moeite heeft u met het duwen, trekken, tillen of dragen van zware objecten op uw werk?

☐ Ik doe deze activiteiten niet op mijn werk.

ERNSTIGE MOEITE — HELEMAAL GEEN MOEITE

V24 Hoeveel moeite heeft u met hurken of door de knieën gaan?

ERNSTIGE MOEITE — HELEMAAL GEEN MOEITE

V25 Hoe bezorgd bent u dat door uw werk uw heup slechter wordt?

EXTREEM BEZORGD — HELEMAAL NIET BEZORGD

V26 Hoeveel moeite heeft u op uw werk vanwege een beperkte beweeglijkheid van uw heup?

ERNSTIGE MOEITE — HELEMAAL GEEN MOEITE

APPENDIX A

SECTIE 4 | SOCIALE, EMOTIONELE EN LEVENSSTIJL ZORGEN

De volgende vragen gaan over sociale, emotionele en levensstijl gerelateerde zorgen die u mogelijk heeft met betrekking tot uw heupprobleem. Denkt u hierbij alstublieft aan hoe u zich meestal gevoeld heeft in de afgelopen maand en antwoord overeenkomstig.

V27 Hoe gefrustreerd bent u over uw heupprobleem?

EXTREEM GEFRUSTREERD ———————— HELEMAAL NIET GEFRUSTREERD

V28 Hoeveel moeite heeft u met seksuele activiteiten vanwege uw heup?
☐ Dit is voor mij niet relevant

ERNSTIGE MOEITE ———————— HELEMAAL GEEN MOEITE

V29 Hoeveel wordt u afgeleid door uw heupprobleem?

EXTREEM AFGELEID ———————— HELEMAAL NIET AFGELEID

V30 Hoe moeilijk is het voor u om spanning en stress kwijt te raken door uw heupprobleem?

EXTREEM MOEILIJK ———————— HELEMAAL NIET MOEILIJK

V31 Hoe moedeloos bent u door uw heupprobleem?

EXTREEM MOEDELOOS ———————— HELEMAAL NIET MOEDELOOS

V32 Hoe bezorgd bent u over het optillen of dragen van kinderen door uw heup?
☐ Dit doe ik niet in mijn activiteiten

EXTREEM BEZORGD ———————— HELEMAAL NIET BEZORGD

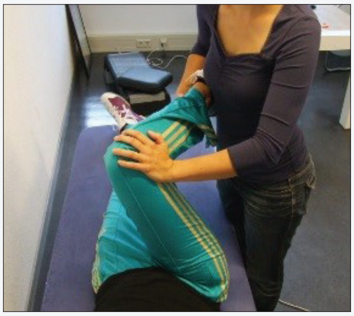
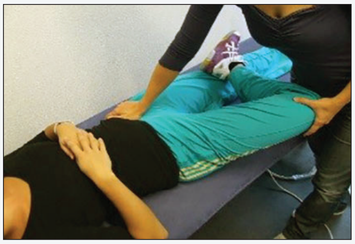
V33 Hoe vaak bent u zich bewust van de beperking in uw heup?

CONSTANT BEWUST ———————— HELEMAAL NIET BEWUST

APPENDIX B

PHYSICAL DIAGNOSTIC TESTS AND IMAGING USED FOR PATIENT INCLUSION

Patients were diagnosed with symptomatic intra-articular hip pathology based on the Doha agreement meeting on terminology and definitions for groin pain in athletes,[43] combined with data from earlier studies of our group.[39] Intra-articular hip pathology was suspected when hip joint–related physical examination tests were positive for pain and/or impaired range of motion, combined with at least 1 abnormal/aberrant imaging finding, in patients who reported themselves to have hip and/or groin pain.

Physical Diagnostic Test	Definition	Example
Anterior hip impingement test	Patient lies supine while the examiner moves the affected hip into combined 90° of flexion, adduction, and internal rotation until end range is achieved. Pain in any location is considered a positive test[39]	
Flexion, abduction, external rotation test	Patient lies supine. The affected hip is simultaneously flexed, abducted, and externally rotated so that the patient's lateral ankle rests on the contralateral thigh just proximal to the knee. While stabilizing the anterior superior iliac spine on the opposite side, the knee of the affected limb is lowered toward the table. A positive test result may be either a decrease in range of motion compared to the nonaffected hip or reproduction of pain[39]	

Parameter	Definition	Normal Value/Abnormal Value
RX		
Alpha angle	Angle between the axis of the neck of the femur and a line connecting the center of the head of the femur with the point of beginning asphericity of the head-neck contour[23,24]	<50°/>50°
Lateral center-edge angle	Angle formed by a vertical line through the center of the head of the femur and a line connecting the center of the head of the femur with the lateral edge of the acetabulum[23,24]	20°-39°/>39°
Crossover sign	Present if the anterior rim runs more laterally in the most proximal part of the acetabulum and crosses the posterior rim distally[23,24]	Anterior rim line projects medially to the posterior wall line
Protrusio acetabuli	Present if the femoral head touches or crosses the ilio-ischial line[23,24]	...
Joint space	The distance between the roof of the acetabulum and the femoral head[23,24]	>2.5 mm/<2.5 mm
MRI-A		
Labral pathology	Disruption of cartilage ring (labrum) in hip joint[23,24,32]	NA
Cam deformity	Angle between the axis of the neck of the femur and a line connecting the center of the head of the femur with the point of beginning asphericity of the head-neck contour[23,24]	<50°/>50°
Cysts	Subchondral cysts[23,24]	NA
Chondropathy	Contrast material-filled defect, area of cartilage signal-intensity alteration at acetabulum or femoral head[23,24]	NA
Ligamentum teres rupture	Disruption of ligamentum teres within hip joint[23,24]	NA

Abbreviations: MRI-A, magnetic resonance imaging arthrography; NA, not applicable; RX, radiographic imaging.

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The Prevalence of Cam and Pincer Morphology and Its Association With Development of Hip Osteoarthritis

Femoroacetabular impingement (FAI) syndrome has recently been defined by authors of an international consensus statement as "a motion-related clinical disorder of the hip with a triad of symptoms, clinical signs, and imaging findings."[26] They also described the most commonly seen symptoms and clinical signs. The primary symptom of FAI syndrome is motion-related or position-related pain in the hip or groin. Pain may also be felt in the back, buttock, or thigh. In addition to pain, patients may also describe clicking, catching, locking, stiffness, restricted range of motion, or giving way. Diagnosis of FAI syndrome does not depend on a single sign. The flexion, adduction, internal rotation test is most commonly used, and is sensitive but not specific. There is often limited hip motion, especially restricted internal rotation when in hip flexion.[26] Imaging findings, the focus of this clinical commentary, include the presence of cam and/or pincer hip morphology. Cam hip morphology is characterized by a nonspherical femoral head, while pincer morphology is defined as overcoverage of the acetabulum relative to the femoral head, which can be either global (bony overgrowth of the acetabulum or a deep socket) or focal (acetabular retroversion). This clinical commentary provides an overview of studies that report on the prevalence of cam and pincer morphology, as well as studies investigating the relationship between cam and pincer morphology and hip osteoarthritis (OA). Future research directions for FAI syndrome will be discussed.

SYNOPSIS: Our understanding of femoroacetabular impingement syndrome is slowly improving. The number of studies on all aspects (etiology, prevalence, pathophysiology, natural history, treatment, and preventive measures) of femoroacetabular impingement syndrome has grown exponentially over the past few years. This commentary provides the latest updates on the prevalence of cam and pincer hip morphology and its relationship with development of hip osteoarthritis (OA). Cam and pincer morphology is highly prevalent in the general population and in this paper is presented for different subgroups based on age, sex, ethnicity, and athletic activity. Methodological issues in determining prevalence of abnormal hip morphology are also discussed. Cam morphology has been associated with development of hip OA, but the association between pincer morphology and hip OA is much less clear. Results from reviewed studies, as well as remaining gaps in literature on this topic, are critically discussed and put into perspective for the clinician.

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KEY WORDS: *cam, etiology, FAI syndrome, hip, impingement, osteoarthritis, pincer*

Cam Morphology

Prevalence A recent systematic review[16] that included 30 studies showed that the prevalence of cam morphology has yet to be defined in an overall population–based cohort. The prevalence of cam morphology in that systematic review ranged from 5% to 75%. This wide variation in prevalence among studies was based on population characteristics (age, sex, ethnicity, athletic activity, presence/absence of symptoms), the measures and concurrent threshold values used to quantify hip morphology, and the imaging techniques.

Age Cam morphology is less prevalent in adolescents than in adults and has been shown to gradually increase during skeletal growth.[1,3,55,56,63-65] Cam morphology can first be identified and starts to develop from the age of 12 years,[1,55,63] with prevalence increasing with age until the completion of growth.[3] In addition, the extent of athletic activity during skeletal growth may increase the risk of cam morphology development.[3,55,64] Cam morphology is, therefore, an acquired phenomenon during the second growth spurt and highly influenced by exercise-related loads applied to the hip during this phase.

Sex Cam morphology is probably more common in males. The prevalence of cam morphology in asymptomatic males ranges from 13.0% to 72.0%, compared to 0.0% to 11.7% in asymptomatic women (**TABLE 1**).[30,32,39,57] Studies on symptomatic

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TABLE 1 Prevalence of Cam Morphology in Asymptomatic Individuals

Study (Follow-up)	Group	Definition of Cam Morphology	Individuals (Hips), n	Age, y*	Sex (Male, Female), %	Imaging Modality	Prevalence (Male, Female), %†
Agricola et al[1]	Athletes: soccer	AA >60° and/or VS: flattening or prominence	89 (178) cases, 92 (184) controls	Cases, 14.8 (12-19); controls, 13.8 (12-19)	100, 0	AP and FLL radiography	Cases: AA, 26; VS, 66 Controls: AA, 17; VS, 18 (per hip)
Agricola et al[3] (2 y)	Athletes: soccer	AA >60° and/or VS: flattening or prominence	63 (126)	16.63 ± 2.07	100, 0	AP and FLL radiography	AA, 38.9; VS, 69.0 (per hip)
Anderson et al[9]	Senior athletes	NA	547 (1081)	67 ± 8	55, 45	AP and FLL radiography	66.7 (per hip)
Hack et al[27]	Volunteers	AA >50.5°	200 (400)	29.4 (21.4-50.6)	44, 56	MRI	24.7, 5.4 (per person)
Jung et al[30]	Abdominal, pelvic, or other medial issue	AA >68° (men), AA >50° (women)	380 (755)	60.4 (25-92)	28, 72	Abdominal or pelvic AP scout CT	28.8, 11.7 (per hip)
Kang et al[31]	Abdominal trauma or nonspecific abdominal pain	AA >55°	50 (100)	NA (15-40)	46, 54	Abdominal CT	10.0 (per hip)
Kapron et al[32]	Athletes: collegiate football	AA >50° and/or HNO <8 mm	67 (134)	21 ± 1.9	100, 0	AP and FLL radiography	AA, 72; HNO, 64 (per hip)
Kapron et al[33]	Athletes: collegiate volleyball, soccer, track and field	AA >50° and/or HNO <8 mm	63 (126)	19.6 ± 1.4	0, 100	AP and FLL radiography	48 (per hip), 60 (per person)
Khanna et al[35] (4.4 y)	Volunteers	AA >50.5° and second analysis with AA >60°	Baseline, 200 (400); follow-up, 170 (340)	Follow-up, 29.5 (25.7-54.5)	45.3, 54.7	MRI	Follow-up, 25.9 (per hip)
Laborie et al[36]	Follow-up of initial newborns	Pistol-grip deformity, flattening, and prominence	2060 (4120)	18.6 (17.2-20.1)	42.1, 57.9	AP and FLL radiography	35.0, 10.2 (per person)
Larson et al[37]	Athletes: collegiate football	AA >55°	125 (239)	NA	100, 0	AP and FLL radiography	65.3 (per hip), 75.2 (per person)
Lerebours et al[38]	Athletes: ice hockey	AA ≥55°	130 (260)	24.4 ± 4.3	NA	AP and FLL radiography	69.4 (per hip)
Leunig et al[39]	Females from vocational/grammar school, males from Swiss Army	AA >50.5°	324 (324)	Male, 20.0 ± 0.9; female, 19.3 ± 1.3	75.3, 24.7	MRI	24.0, 0.0 (per person)
Li et al[40]	Children with disorder unrelated to hip	AA ≥55°	558 (1116)	14.4 (10-18.2)	49.5, 50.5	Pelvic CT	23.9, 9.9 (per person)
Mineta et al[44]	Disorder unrelated to hip (Japanese)	AA >55° and/or FHNO ratio <0.15	1178 (1178)	58.2 ± 14.8 (20-89)	59, 41	Abdominal and pelvic CT	54.4, 32.3 (per hip)
Mosler et al[47]	Athletes: soccer	AA >60°	445 (890)	25 ± 4.9	100, 0	AP pelvic and Dunn-view radiography	72 (per person)
Philippon et al[56]	Athletes: ice hockey	AA ≥55°	61 (NA) cases, 27 (NA) controls	Cases, 14.5 ± 2.7 (10-18); controls, 15.2 ± 2.7 (10-18)	100, 0	MRI	Cases, 75; controls, 42 (per person)
Pollard et al[57]	General population	AA >62° and AOR <0.14	83 (166)	Male, 47.5 (25-69); female, 44.4 (22-67)	47, 53	Cross-table lateral radiography	13.0, 7.0 (per person)
Reichenbach et al[59]	Swiss Army recruiters	2: cam, AHNO <10 mm 3: severe cam, AHNO >10 mm	244 (244)	19.9 (18-24)	100, 0	MRI	24.0 (per person)
Van Houcke et al[68]	Chinese and Belgian	AA >55°	Chinese, 102 (204); Belgian, 99 (198)	NA (18-40)	52.2, 47.8	CT	Chinese: 31, 17; Belgian: 41, 39 (per hip)

Abbreviations: AA, alpha angle; AHNO, anterior head-neck offset; AOR, anterior offset ratio; AP, anteroposterior; CT, computed tomography; FHNO, femoral head-neck offset; FLL, frog-leg lateral; HNO, head-neck offset; MRI, magnetic resonance imaging; NA, not available; VS, visual scoring.
**Values are mean ± SD (range) or mean (range).*
†If prevalence per sex is not specified, then the overall prevalence is presented.

individuals are more inconsistent because of the selection bias related to symptomatic status. A study by Clohisy et al[14] showed an average prevalence of cam morphology of 47.6% in a symptomatic group of 1076 patients (55% women and 45% men) who underwent surgery for FAI syndrome. Symptomatology and functional limitations are preoperatively significantly more severe in females compared with males.[29,51]

Ethnicity Mosler et al[47] identified a significantly lower prevalence of cam morphology among young East Asian (19%) professional soccer players when compared to other ethnicities, including Arabic, black, Persian, and white players, in whom the prevalence ranged between 58% and 72%. Similarly, cam morphology prevalence was shown to be lower in asymptomatic Chinese men and women compared to Caucasians in another article.[68] In contrast, another prevalence study of asymptomatic older-aged individuals reported that East Asian populations have a high prevalence of cam morphology (45.3% of 1178 hips).[44]

Athletic Activity In their systematic review and meta-analysis, Nepple et al[52] reported that professional athletes exhibit a higher prevalence of cam morphology relative to nonathletic individuals. The pooled prevalence of cam morphology in male athletes was 41%, compared with 17% in male controls. In another systematic review,[20] the authors reported prevalence of cam morphology in up to 55% of male athletes, compared with 23% in the general population. In their systematic review, Dickenson et al[16] reported prevalence of cam morphology in athletes ranging from 48% to 75%.

Symptomatology It is currently unknown whether the presence of cam morphology by itself is associated with symptoms. Only 1 prospective study is available, which investigated 200 asymptomatic volunteers over a period of 4.4 years and showed that the presence of cam morphology resulted in a relative risk of 4.3 (95% confidence interval [CI]: 2.3, 7.8) of developing hip pain.[35] Similarly, a cross-sectional study found an association between an increased alpha angle (indicative of cam morphology) and prior or current athletic-related groin pain in 125 collegiate National Football League prospects.[37] This is consistent with the results of another study that showed a relationship between cam morphology based on higher alpha angles and hip symptoms.[8] However, Gosvig et al,[24] studying a large population of 3202 individuals, showed no significant association between self-reported hip pain and cam morphology. Other studies also could not identify an association between symptoms and cam morphology.[9,33,48] When asymptomatic and symptomatic subgroups were compared, Mascarenhas et al[41] found a higher prevalence of cam morphology in symptomatic hips compared to asymptomatic hips. However, these studies consisted generally of less than 50 participants per subgroup.

Pincer Morphology

Prevalence Pincer morphology is even more heterogeneously defined than cam morphology. However, similar to cam morphology, the prevalence of pincer morphology appears to vary across different subpopulations.

Age Only a few studies have been published on how the prevalence of pincer morphology changes with age. A study on an asymptomatic pediatric and adolescent population with a mean age of 10.4 years identified the presence of pincer morphology starting at 12 years of age.[45] In adolescents with an average age of 14.4 years, Li et al[40] reported a prevalence of pincer morphology of 32.4%. Laborie et al,[36] in a study of 2081 young adults with an average age of 18.6 years, reported the prevalence of pincer morphology to be 34.3% in men and 16.6% in women (**TABLE 2**).

Sex Multiple studies have directly compared the incidence of pincer morphology between males and females, showing very little difference. Li et al[40] did not find a difference in prevalence of pincer morphology between asymptomatic males and females. Prevalences of 29.7% and 35.1% in males and females (P = .17) were presented. Other studies showed conflicting results. A higher prevalence of pincer morphology in males was observed in the study of 2081 individuals by Laborie et al,[36] who reported a prevalence of pincer morphology of 34% in males, compared to 17% in females (P<.001). In contrast, coxa profunda was found to be significantly associated with female sex in 3 studies.[15,17,28] Two additional studies provided data on the prevalence of pincer morphology only in women, which ranged between 1% and 10%.[33,39] In comparison, the reported prevalence in males has ranged between 3% and 66%.[32,47] There is also probably not a great difference in prevalence of pincer morphology between sexes in symptomatic individuals, based on a study by Nepple et al,[51] who showed a prevalence of isolated pincer morphology in 56% of males and 47% of females (P = .46) undergoing FAI surgery.

Ethnicity Less is known about the association between pincer morphology and ethnicity. The study of Mosler et al[47] compared the prevalence of pincer morphology (lateral center-edge angle [LCEA] greater than 40°) between young soccer players with different ethnic backgrounds. No pincer morphology was found in white and East Asian soccer players. Arabic (3.6%), black (2.3%), and Persian soccer players (1.7%) also showed a low prevalence. Tannenbaum et al[66] did not find a difference in acetabular retroversion of pelvic specimens between African Americans and Caucasians. Several studies only investigated Asian persons, specifically Japanese, and found a prevalence of pincer morphology ranging from 7.4% to 37.4%.[7,21,44,46]

Athletic Activity The prevalence of pincer morphology in athletes is highly variable. Harris et al[28] investigated a group of elite ballet dancers and found a prevalence of 74%. In studies that investigated soccer/football players, prevalence of pincer morphology ranged from 3% to 66%.[22,32,47] A study that combined different types of athletes (volleyball, soccer, and track and

TABLE 2 Prevalence of Pincer Morphology in Asymptomatic Individuals

Study	Group	Definition of Pincer Morphology	Individuals (Hips), n	Age, y*	Sex (Male, Female), %	Imaging Modality	Prevalence (Male, Female), %†
Ahn et al[7]	Korean volunteers	COS, PWS, or LCEA >40°	200 (400)	34.7 (21-49)	36.5, 63.5	AP, Sugioka, and 45° Dunn radiography	27, 21 (per person)
de Bruin et al[15]	Pelvic radiography patients	CEA >39°, AI <0°, CP, PA, AR	262 (522)	NA	38, 62	AP radiography	63.2 (per hip)
Diesel et al[17]	Volunteers	LCEA >40°, AI <0°, COS, CP	226 (452)	36.5 (28-50)	46.3, 53.7	AP radiography	10.9, 10.9 30.3, 31.2 10.9, 16.7 60.5, 92 (per hip)
Gerhardt et al[22]	Athletes: elite soccer	COS	95 (190)	25.4 ± 4.2	79, 21	AP pelvis and FLL radiography	26.7, 10 (per person)
Harris et al[28]	Athletes: elite ballet	PWS, COS, ISS, LCEA >40°, CP, PA	47 (94)	23.8 ± 5.4	45, 55	AP pelvis, false-profile, and Dunn 45° radiography	74 (per person)
Kang et al[31]	Abdominal trauma or nonspecific abdominal pain	AV <15°, COS, AO/CP (CEA >40°)	50 (100)	NA (15-40)	46, 54	Abdominal CT	13, 1 20 9, 7 (per hip)
Kapron et al[32]	Athletes: collegiate football	LCEA >40°, AI <0°, and/or COS	67 (134)	21 ± 1.9	100, 0	AP pelvis and FLL radiography	52 (1 sign), 10 (2 signs), 4 (3 signs) (per hip)
Kapron et al[33]	Athletes: collegiate volleyball, soccer, track and field	LCEA >40°, LCEA >40° and AI <0°	63 (126)	19.6 ± 1.4	0, 100	AP pelvis and FLL radiography	1 (per hip), 2 (per person) 1 (per hip), 2 (per person)
Laborie et al[36]	Follow-up of initial newborns	1 or more findings: COS, PWS, AO	2060 (4120)	18.6 (17.2-20.1)	42.1, 57.9	AP and FLL radiography	34.3, 16.6 51.4, 45.5 23.4, 11 14.6, 4.9 (per person)
Lerebours et al[38]	Athletes: ice hockey	COS	130 (260)	24.4 ± 4.3	NA	AP and FLL radiography	59.8 (per person)
Leunig et al[39]	Females from vocational/grammar school, males from Swiss Army	AD ≤3 mm	324 (324)	Male, 20.0 ± 0.9; female, 19.3 ± 1.3	75.3, 24.7	MRI	6, 10 (per person)
Li et al[40]	Children with disorder unrelated to hip	LCEA >40°	558 (1116)	14.4 (10-18.2)	49.5, 50.5	Pelvic CT	29.7, 35.1 (per person)
Mineta et al[44]	Japanese population, reason unrelated to hip	LCEA >40°, AI <0°, COS	1178 (1178)	58.2 (20-89)	59, 41	Pelvic CT	41.7, 31.3 (per hip)
Monazzam et al[45]	Abdominal problems	LCEA ≥40°, TA ≤0°, AR (AV ≤0° and LCEA ≥40°)	225 (450)	10.4 (2-19)	45.8, 54.2	Pelvic CT	5.8, 2.0 4.4, 5.3 6.8, 4.1 (per hip)
Mosler et al[47]	Athletes: elite soccer	LCEA >40°	445 (890)	25 ± 4.9	100, 0	AP and Dunn radiography	3.0 (per person)

Abbreviations: AD, acetabular depth; AI, acetabular index; AO, acetabular overcoverage; AP, anteroposterior; AR, acetabular retroversion; AV, acetabular version; CEA, center-edge angle; COS, crossover sign; CP, coxa profunda; CT, computed tomography; FLL, frog-leg lateral; ISS, ischial spine sign; LCEA, lateral center-edge angle; MRI, magnetic resonance imaging; NA, not available; PA, protrusio acetabuli; PWS, posterior wall sign; TA, Tönnis angle.
**Values are mean ± SD, mean ± SD (range), or mean (range).*
†If prevalence per sex is not specified, then the overall prevalence is presented.

field) found a pincer morphology prevalence of 1%.[33] In elite ice hockey players, Lerebours et al[38] found a prevalence of pincer morphology of 59.8%. Systematic reviews by Frank et al[20] and Mascarenhas et al[41] found a prevalence of pincer morphology in athletes of 49.5% and 51.2%, respectively.

Symptomatology Comparisons between symptomatic and asymptomatic subgroups were presented in a recent systematic review by Mascarenhas et al,[41] which included 60 studies. Pincer morphology prevalence in the asymptomatic subgroup, as reported in only 1 study, was 57%. In symptomatic individuals across studies, the average mean ± SD prevalence of pincer morphology was 28.5% ± 19.2%. The reported prevalence of pincer morphology in asymptomatic individuals in the systematic review by Frank et al[20] was 67% (range, 61%-76%). That systematic review, which included 26 studies, did not report on symptomatic individuals. These results differ from data of Gosvig et al,[25] who reported lower prevalence rates of pincer morphology in men (15.2%) and women (19.4%) in a population-based study. A study by Ahn et al[7] showed pincer prevalence rates in asymptomatic males and females of 27% and 21%, respectively.

Relationship Between Cam Morphology and Hip OA

In most studies, cam morphology has been associated with hip OA. The strength of association in several cross-sectional and retrospective studies has varied between odds ratios (ORs) of 2.2 (95% CI: 1.7, 2.8) and 20.6 (95% CI: 3.4, 34.8).[12,18,25] The number of well-designed epidemiological studies assessing the relationship between cam morphology and hip OA is limited. Three prospective cohort studies and 2 nested case-control studies that included people without hip OA at baseline demonstrated an association between cam morphology and development of hip OA later in life (**TABLE 3**).[2,49,53,62,67] The strength of association varies between ORs of 2.1 (95% CI: 1.6, 2.9) and 9.7 (95% CI: 4.7, 19.8), primarily depending on the alpha angle threshold used for diagnosis. The positive predictive value for developing end-stage OA within 5 years when having cam morphology was 10.9% for an alpha angle greater than 60° and 25.0% for an alpha angle greater than 83°.[2]

Relationship Between Pincer Morphology and OA

Pincer morphology does not appear to play a role in the development of hip OA. Three prospective cohort studies defined the presence of pincer morphology by a center-edge angle of greater than 33.7° or 40°.[4,62,67] In the CHECK cohort,[4] pincer morphology was measured both laterally (on anteroposterior [AP] pelvic radiographs) and anteriorly (on false-profile lateral radiographs). Neither anterior pincer morphology nor lateral pincer morphology was associated with development of hip OA within 5 years. Surprisingly, when pincer morphology was present both anteriorly and laterally, a significant protective effect for development of end-stage OA was found (OR = 0.34; 95% CI: 0.13, 0.87). This is consistent with the data from the Chingford cohort,[67] which did not identify an association between higher LCEAs (only measured on AP radiographs) and development of hip OA. In this cohort, the continuous measure of the LCEA was

TABLE 3 CHARACTERISTICS OF MULTIPLE LONGITUDINAL STUDIES ON RELATIONSHIP BETWEEN CAM/PINCER MORPHOLOGY AND OA, ALL BASED ON AP RADIOGRAPHS

Study/Follow-up	Individuals (Hips), n	Age, y*	Sex (Male, Female), %	Definition of Cam and Pincer Morphology	Cam Morphology Prevalence, %	Pincer Morphology Prevalence, %	Definition of OA	Odds Ratio for Hip OA†
Agricola et al[2] 5 y	723 (1411)	55.9 ± 5.2 (45-65)	20, 80	Cam: AA >60°, AA >83°, AA >83° and IR ≤20°	11.1	NA	End-stage OA: KL grade ≥3 or THR	3.67 (1.68, 8.01) 9.66 (4.72, 19.78) 25.21 (7.89, 80.58)
Agricola et al[4] 5 y	720 (1391)	55.9 ± 5.2 (45-65)	21, 79	Pincer: LCEA >40° or ACEA >40°	NA	54.6	End-stage OA: KL grade ≥3 or THR	0.34 (0.13, 0.87)
Nelson et al[49] 6 y, 12.7 y	120 (239: cases, 71; controls, 168)	Cases, 63 ± 8; controls, 62 ± 9	25, 75	Cam: AA >60° Pincer: LCEA >40°	Male: cases, 59; controls, 40 Female: cases, 47; controls, 18	Male: cases, 10; controls, 6 Female: cases, 24; controls, 17	OA: KL grade ≥3 or THR	Male, 3.57 (1.17, 10.90) Female, 4.61 (2.09, 10.16) NS in males and females
Nicholls et al[53] 19 y	135 (268: cases, 25; controls, 243)	55 (50-60)	0, 100	Cam: AA Pincer: LCEA	NA	NA	End-stage OA: THR	1.052 per 1° increase NS
Saberi Hosnijeh et al[62] 9.2 y	4438 (RS-I, 2960; RS-II, 1478)	RS-I, 65.1 ± 6.4; RS-II, 62.9 ± 6.4	RS-I: 43, 57; RS-II: 44, 56	Cam: AA >60° Pincer: CEA >40°	RS-I: left, 8.3; right, 6.4 RS-II: left, 7.2; right, 7	RS-I: left, 10.9; right, 8.9 RS-II: left, 13.5; right, 8.6	Incident OA: KL grade ≥2 or THR	2.11 (1.55, 2.87) NS
Thomas et al[67] 19 y	OA group, 340 (634); THR group, 734 (1466)	54.2 (44-67)	0, 100	Cam: AA >65° Pincer: LCEA >33.7°	NA	NA	OA: KL grade ≥2; end-stage OA: THR	OA, 1.05 (1.01, 1.09) THR, 1.04 (1.00, 1.08) NS for OA and THR

Abbreviations: AA, alpha angle; ACEA, anterior center-edge angle; AP, anteroposterior; CEA, center-edge angle; IR, internal rotation; KL, Kellgren-Lawrence; LCEA, lateral center-edge angle; NA, not applicable; NS, not significant; OA, osteoarthritis; RS, Rotterdam study; THR, total hip replacement.
**Values are mean ± SD, mean ± SD (range), or mean (range).*
†If odds ratios per sex are not specified, then the overall odds ratio is presented. Values in parentheses are 95% confidence interval.

divided into tertiles. Having an LCEA in the highest tertile (greater than 33.7°) was neither associated with development of radiographic hip OA (defined as a Kellgren and Lawrence[34] grade of 2 or greater [P = .64]) nor with the need for total hip replacement (P = .67) 19 years later. Finally, results from the Rotterdam study[62] also failed to show an increased risk of developing hip OA at a follow-up of 9.2 years, with an OR of 1.24 (95% CI: 0.93, 1.66) for pincer morphology.

DISCUSSION

Cam and pincer morphology is common in the general population, but the prevalence rates vary greatly among studied subpopulations. Cam morphology is associated with future development of hip OA, whereas a link between pincer morphology and OA has never been identified in epidemiological studies. It is important to recognize that all of the studies on the prevalence of cam morphology and its association with OA investigated morphology only and that cam morphology does not equate to FAI syndrome, which also includes the presence of symptoms and clinical findings.[26]

Differences and Limitations in Quantifying Cam Morphology

There is a large variation in the reported prevalence of cam and pincer morphology between subgroups, with some of that variation attributed to the variability in methodology used to determine the presence of cam and pincer morphology. In the literature, while the alpha angle is an accepted measure to define cam morphology,[54] the angular thresholds that are used vary from 50° to 83°.[5,23,54] Furthermore, alpha angles can be measured by different imaging techniques, including radiographs, computed tomography, and magnetic resonance imaging. Generally, using radial imaging (computed tomography and magnetic resonance imaging) with multiple measurement points around the femoral neck is more likely to detect the presence of cam morphology than 2-dimensional imaging (radiographs), and thus results in higher prevalence.[19] However, the use of multiple measurement points might increase the false-positive rate.

Differences in Cam Morphology Prevalence in Subgroups

The differences in the prevalence of cam morphology between subgroups might provide some clues on etiology. The greatest differences in prevalence are observed between athletes and nonathletes. The high prevalence of cam morphology observed in athletes might be due to repetitive axial loading, especially during skeletal maturation.[3,55,61,64] This might also partly explain the lower prevalence in females, as they mature earlier than males and probably have less exposure to repetitive axial loading during the second growth spurt, when cam morphology usually develops in males. Cam morphology is probably less frequent in the East Asian population, even in those with an athletic background. However, evidence is conflicting, and no direct relationship between genetics and cam morphology has been established yet. Finally, whether the isolated presence of cam morphology is associated with, or predictive for, symptoms and/or hip pain is unknown. Though subgroups with a higher prevalence of cam morphology have been identified, it should be emphasized that most of these studies suffer from a high risk of bias,[16] and caution should be exercised when interpreting their findings.

Differences and Limitations in Quantifying Pincer Morphology

The prevalence of pincer morphology is also highly dependent on how it is quantified and the imaging technique used.[4] Pincer morphology can be further defined as having focal or global (acetabular) overcoverage. Focal overcoverage has been defined by several indirect measures, such as the crossover sign, posterior wall sign, and ischial spine sign, which all have generally poor reliability and validity to define true retroversion/pincer morphology.[69] Global overcoverage can be defined by the presence of coxa profunda or protrusio acetabuli or the center-edge angle.[10,50] Coxa profunda and protrusio acetabuli do not seem to be associated with the presence of pincer morphology.[50] Therefore, due to this heterogeneity in definition, it is difficult to compare prevalence studies on pincer morphology.

Pincer Morphology and Hip OA

The prospective studies on the association between pincer morphology and hip OA all used the LCEA on AP radiographs and are therefore comparable.[4,49,53,62,67] However, none of these epidemiological studies could identify an association between pincer morphology and development of OA. It is also notable that 2 systematic reviews found a higher prevalence of pincer morphology in asymptomatic individuals than in symptomatic patients.[20,41] The reader should also bear in mind that although discussed separately, cam and pincer morphology types are frequently found together, also known as a mixed-type morphology.[42]

Cam Morphology and Hip OA

Despite the reported association between cam morphology and development of hip OA, one should keep in mind that the majority of people with cam morphology will not develop hip OA. Of the hips with cam morphology, between 6% and 25% will develop future OA within 5 to 19 years.[2,53] For cross-sectional and retrospective studies, an important confounder is that the radiographic appearance of OA might mimic cam morphology. For example, the presence of osteophytes on the femoral head and/or flattening of the femoral head may be related to the OA process. This is hard to distinguish when OA and cam morphology are assessed on the same radiographs. This is less of an issue in a few well-designed prospective studies summarized in **TABLE 3**, but these studies have other methodological limitations, such as the imaging modalities used and age of the participants.[2,4,49,53,62,67] All of these studies used AP pelvic radiographs, and although this is the gold standard to quantify hip OA, it is suboptimal to define the presence of cam morphology. Only the more laterally located cams are seen on AP radiographs, and the prevalence is therefore underestimated. The influence of this underestimation on the true association with hip OA is unknown. Further, the studies summarized only included middle-aged to older people. The youngest participants included in the CHECK[2] and Chingford[67] cohorts were approximately 45 years of age, with mean ages of 56 and 54 years, respectively. The oldest people were included in the Rotterdam study[62] (minimum age, 55 years; mean age, 64 years) and in the Johnston County OA cohort study[49] (mean age, 62 years). As cam morphology develops during skeletal growth, in most cases, it is already present during early adulthood. Therefore, the relationship between cam morphology and hip degeneration between early adulthood and the age of 45 years is unknown. Some indications suggest that this relationship might be stronger in younger people than in middle-aged to older people. First, the Rotterdam study showed a stronger relationship between cam morphology and OA in people 65 years of age or younger (OR = 3.1; 95% CI: 2.1, 4.6), while the association disappeared in people over 65 years of age (OR = 1.4; 95% CI: 0.9, 2.2).[62] Second, features known to be associated with hip OA have been identified in younger populations,[11,43,58] with the severity of cam morphology associated with the presence of labral tears and chondral defects.[58] A cross-sectional study of asymptomatic participants with a mean age of 20 years showed a decrease in cartilage thickness in those with cam morphology.[60] Finally, from intraoperative findings, it is known that severe cartilage damage can already exist in young people with cam morphology.[13,14] However, well-designed studies in young adults are lacking.

Future Studies

Based on the results of this overview, there is a need for standardizing criteria to determine the presence of cam and pincer morphology. The alpha angle is most often used and, despite its limitations, is probably the best measure to date of cam morphology. Future studies should therefore, at least, report the alpha angle. An alpha angle threshold of 60° has been proposed for AP radiographs,[6] but there is no validated threshold for other radiographic views. To aid future comparison between studies, it might be helpful to present results for different alpha angle threshold values. Many people with cam or pincer morphology will not develop any symptoms from this bony variant. Future studies should, therefore, also focus on characteristics that can differentiate persons with cam and pincer morphology who will become symptomatic and/or develop hip OA. Characteristics that may be worth considering include hip muscle strength, hip range of motion, gait-pattern characteristics, the size of cam morphology, and the type and amount of physical activities performed. This might lead to the identification of modifiable risk factors to prevent, stop, or slow down disease progression and also help avoid overtreatment. Future studies should also monitor whether treatment for FAI syndrome, nonsurgical or surgical, can stop or slow down the progression toward hip OA.

CONCLUSION

Cam and pincer morphology is highly prevalent in the general population. Cam morphology is linked to hip OA in the middle-aged population, but no data are available on its relationship among younger people. The association between pincer morphology and hip OA has not been demonstrated in the available prospective cohort studies. The presence of cam and/or pincer morphology does not always lead to FAI syndrome and subsequent hip OA, and future research should focus on identifying factors that may predict who becomes symptomatic (FAI syndrome) in the presence of cam and/or pincer morphology and who subsequently will progress to have hip OA later in life. ◉

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