


# Relationship Between Hip Morphology and Hip-Related Patient-Reported Outcomes in Young and Middle-Aged Individuals: A Population-Based Study

Jacek A. Kopec,<sup>1</sup> Hong Qian,<sup>2</sup> Jolanda Cibere,<sup>1</sup> Hubert Wong,<sup>3</sup> Linda C. Li,<sup>1</sup>  Morgan Barber,<sup>4</sup> Helen M. Prlic,<sup>4</sup> Charlie Zhang,<sup>5</sup> Charles Ratzlaff,<sup>6</sup> Bruce B. Forster,<sup>3</sup> and John M. Esdaile,<sup>1</sup> on behalf of the IMPAKT-HIP Study Team

**Objective.** Radiographic measurements of the alpha angle and the lateral center edge (LCE) angle in the hip joint are important for the diagnosis of femoroacetabular syndrome, a potential risk factor for hip osteoarthritis. Our objective was to determine whether these measurements are associated with hip-related patient-reported outcomes in young and middle-aged individuals.

**Methods.** A stratified random sample of white men and women ages 20–49 years, with and without hip pain, was selected using random digit dialing from the population of metro Vancouver, Canada. The alpha and LCE angles were measured bilaterally on radiographs using Dunn and anteroposterior views, respectively. Patient-reported outcomes were measured by the Copenhagen Hip And Groin Outcome Score (HAGOS), which has scales for symptoms, pain, daily activities, sports, physical activity, and quality of life (QoL). We performed descriptive analyses and a regression analysis with restricted cubic splines, adjusted for age and sex and weighted for the sampling design.

**Results.** Data were obtained for 500 subjects. The alpha angle distribution was strongly skewed, with a mean of 54°. The LCE angle distribution was symmetric, with a mean of 34°. In the restricted cubic splines analysis, the relationship between the alpha angle and HAGOS scores was nonlinear, with higher alpha angles generally associated with worse HAGOS scores for alpha >60°. The associations were statistically significant for symptoms, sports, and QoL. No association was found between the LCE angle and HAGOS scales.

**Conclusion.** In a general population sample ages 20–49 years, we have found an association between the alpha angle and hip-related patient-reported outcomes.

## INTRODUCTION

Femoroacetabular impingement has been proposed as an important risk factor for hip pain and hip osteoarthritis (OA) (1,2). A recent consensus statement defined femoroacetabular impingement syndrome (FAIS) as a combination of symptoms in the hip joint associated with activity, physical signs (mainly range of motion limitations due to pain), and radiographic evidence of cam or pincer morphology (CPM) (3). Cam morphology is a bony prominence at the femoral head-neck junction, whereas pincer morphology is an excessive coverage of the femoral head by the acetabulum (1–3). Common radiographic measurements used

to determine CPM are the alpha angle for cam and the lateral center edge (LCE) angle and crossover sign for pincer (4).

Over the past decade, epidemiologic studies have shown a correlation between advanced hip OA and cam morphology (5–9). Nonsurgical treatment and surgical correction of CPM are increasingly offered to patients with FAIS (10). However, the concept of FAIS is relatively new, and important questions surrounding the epidemiology of this condition remain to be elucidated (3). A recent systematic review of 30 studies showed that the current data are insufficient to estimate the population prevalence of cam morphology or to determine its relationship with pain (11).

Supported by the Canadian Institutes of Health Research (grant PAF-107513).

<sup>1</sup>Jacek A. Kopec, PhD, Jolanda Cibere, MD, PhD, Linda C. Li, PhD, John M. Esdaile, MD, MPH: University of British Columbia, Vancouver, and Arthritis Research Canada, Richmond, British Columbia, Canada; <sup>2</sup>Hong Qian, MSc: St. Paul's Hospital, Vancouver, British Columbia, Canada; <sup>3</sup>Hubert Wong, PhD, Bruce B. Forster, MD: University of British Columbia, Vancouver, British Columbia, Canada; <sup>4</sup>Morgan Barber, MHA, Helen M. Prlic, MA: Arthritis Research Canada, Richmond, British Columbia, Canada; <sup>5</sup>Charlie Zhang,

MD: University of Calgary, Calgary, Alberta, Canada; <sup>6</sup>Charles Ratzlaff, PhD: University of Arizona, Tucson.

No potential conflicts of interest relevant to this article were reported.

Address correspondence to Jacek A. Kopec, PhD, School of Population and Public Health, University of British Columbia, Senior Scientist, Arthritis Research Canada, 5591 No. 3 Road, Richmond, British Columbia, V6X 2C7 Canada. E-mail: jkopec@arthritisresearch.ca.

Submitted for publication April 17, 2018; accepted in revised form October 2, 2018.

### SIGNIFICANCE & INNOVATIONS

- Hip morphology is considered a risk factor for the development of hip pain and osteoarthritis, but reports on the association between hip morphology and hip-related patient-reported outcomes have been inconsistent.
- This is the first study to our knowledge to demonstrate a significant effect of cam morphology (and no effect of pincer morphology) on patient-reported outcomes, such as hip symptoms, limitations in sports activities, and quality of life, in young and middle-aged individuals in the general population.
- The study also shows that this relationship is non-linear and limited to an alpha angle above 60°, which supports previous recommendations to use this cutoff for the diagnosis of femoroacetabular impingement syndrome.

Studies of the association between CPM and pain have produced inconsistent results. While several authors reported no significant differences in hip morphology between those individuals with and without hip pain (12–16), some studies showed cam morphology to be predictive of pain and other symptoms in athletes and other selected groups (17–19). In a recent population-based study, CPM (defined as alpha >55°, LCE >40°, or crossover sign) was found in 49% of individuals with hip symptoms and 44% of asymptomatic controls, but the difference was nonsignificant in a multivariate analysis (20).

The lack of a significant association between CPM and symptoms in several published studies may be due to a number of reasons. First, hip pain in individuals with CPM may depend on the level of physical activity (20). Second, the relationship between CPM and pain may be nonlinear (5), so that showing an association would be more difficult. Third, the association may be limited to certain forms of CPM (e.g., cam morphology) or severity levels (e.g., a high alpha angle) (18). Finally, in some of the previous studies, the sample size may have been too small and/or the measurements of CPM (e.g., use of anteroposterior view) and pain (e.g., yes/no) too imprecise and insufficiently sensitive to detect an association. The purpose of the current study was to determine whether radiographic measurements of alpha angle and LCE angle, treated as continuous variables, are associated with hip-related patient-reported outcomes in young and middle-aged individuals in the general population.

### SUBJECTS AND METHODS

**Study design and subjects.** A random sample of white men and women ages 20–49 years was selected using random digit dialing from the population of metro Vancouver, Canada. The sample was stratified according to hip pain, as assessed

in a telephone interview. Pregnant women and individuals with bilateral hip replacement were excluded. Subjects who agreed to participate obtained radiographs of both hips and filled out a self-administered questionnaire. All subjects provided informed consent and the study was approved by the University of British Columbia Clinical Research Ethics Board.

**Radiographic measurements.** Standardized radiographs of the pelvis (anteroposterior) and Dunn views of both hips were obtained, as described in detail in a previous study (21). For the anteroposterior pelvis view, the subject was in a weight-bearing position, with legs internally rotated 15°. For the bilateral Dunn view, the subject was supine and the hip was positioned in 45° flexion and 20° abduction while maintaining neutral rotation. The alpha angle was defined in the Dunn view as the angle formed by the axis of the femoral neck and a line connecting the center of the femoral head to the point where the contour begins to stray from a spherical radius (4). The LCE angle was defined in the anteroposterior view as the angle between a line through the center of the femoral head, perpendicular to the transverse axis, and a line through the center of the femoral head, passing through the most superolateral point of the sclerotic weight-bearing zone of the acetabulum (4). All radiographic measurements were performed by a single, trained reader. In a reliability study in 49 subjects with the same reader, the intrarater intraclass correlation coefficient (ICC) was 0.97 for the alpha angle and 0.87 for the LCE angle (21).

**Assessment of patient-reported outcomes.** To measure patient-reported outcomes we used the Copenhagen Hip And Groin Outcome Score (HAGOS) (22). HAGOS is a validated, multidimensional 37-item instrument developed specifically for use in young to middle-aged patients with chronic hip and/or groin pain and recommended by Griffin et al (3) for assessing outcomes in FAIS. It consists of 6 subscales: symptoms (7 items), pain (10 items), physical function in daily living (activities of daily living [ADL], 5 items), physical function in sport and recreation (sports, 8 items), participation in physical activities (2 items), and hip and/or groin-related quality of life (QoL, 5 items). Each scale is scored on a scale of 0–100, with a higher score indicating better health. Internal consistency and reliability in the validation study were high, with Cronbach's alpha ranging from 0.79 (symptoms) to 0.91 (pain) and test–retest ICC from 0.82 (physical activities) to 0.91 (ADL) (22). Construct validity and responsiveness of the HAGOS scales were also assessed and found adequate (22,23).

**Statistical analysis.** We calculated weighted percentages for demographic variables and weighted means, medians, and frequency distributions for CPM measurements and HAGOS scores. To assess the relationship between radiographic measurements and HAGOS scores, we used weighted linear regression adjusted for age and sex. In the model, the potential nonlinear relations were identified using restricted cubic splines with 3 knots placed at

**Table 1.** Descriptive data for the study sample (n = 500)\*

| Variable                           | Values     | Weighted % (95% CI) |
|------------------------------------|------------|---------------------|
| Sex                                |            |                     |
| Male                               | 181 (36.2) | 48.9 (41.6–56.2)    |
| Female                             | 319 (63.8) | 51.1 (43.8–58.4)    |
| Age, years                         |            |                     |
| 20–29                              | 50 (10.0)  | 32.2 (23.8–40.6)    |
| 30–39                              | 109 (21.8) | 31.4 (25.1–37.7)    |
| 40–49                              | 341 (68.2) | 36.4 (30.5–42.3)    |
| Education                          |            |                     |
| High school or less (0–13 grade)   | 101 (20.2) | 27.3 (20.0–34.6)    |
| Vocational or some college         | 178 (35.6) | 27.8 (21.8–33.7)    |
| College or university              | 221 (44.2) | 44.9 (37.7–52.1)    |
| Body mass index, kg/m <sup>2</sup> |            |                     |
| <25                                | 241 (48.2) | 58.8 (51.9–65.6)    |
| 25–29.9                            | 155 (31.0) | 26.1 (20.3–31.9)    |
| ≥30                                | 104 (20.8) | 15.1 (10.6–19.6)    |
| Hip injury                         |            |                     |
| Yes                                | 26 (5.2)   | 2.0 (0.8–3.1)       |
| No                                 | 474 (94.8) | 98.0 (96.9–99.2)    |

\* Values are the number (%) unless indicated otherwise. 95% CI = 95% confidence interval.

the 5th, 50th, and 95th percentiles. Splines are smooth functions that can assume virtually any shape, and the most useful type of spline is generally a cubic spline function, which is restricted to be smooth at the junction of each cubic polynomial (24). *P* values were obtained for tests of overall association and nonlinearity. The analysis was done by selecting for each subject the worst hip, defined as the hip with a largest alpha or LCE angle. All descriptive statistics and analyses were conducted using Proc Survey procedures in SAS software, version 9.4, to account for the sampling design of the study. We performed a sensitivity analysis of the associations between alpha angle and HAGOS scales restricted to individuals reporting any hip pain.

## RESULTS

A sample of 858 potential subjects was generated by the random digit dialing screening and we were able to contact 754 (87.9%). Of those, 254 (33.7%) did not provide data: 41 were ineligible, 66 not interested, 84 not available, 53 declined for other/unknown reasons, and 10 were excluded due to incomplete data. Thus, data were obtained for 500 subjects, of whom 64% (unweighted percentages) were female, 68% were ages 40–49 years, 44% had a college education, 21% had a body mass index (BMI) ≥30, and 5% reported a hip injury in the past (Table 1).

The weighted mean alpha angle was 54.7° (95% confidence interval [95% CI] 53.7–55.8, median 53) on the left side and 54.1° (95% CI 53.1–55.0, median 52) on the right side.

The mean LCE angle was 34.3° (95% CI 33.7–34.9, median 34) on the left side and 34.6° (95% CI 34.0–35.2, median 34) on the right side (Table 2). Figure 1 shows the weighted distributions of the 2 angles. For the alpha angle, the distribution was strongly skewed and possibly bimodal. The LCE angle distribution was symmetric. Weighted mean scores for HAGOS scales ranged from 80.1 (95% CI 77.2–83.0, median 78.7) for physical activity to 93.6 (95% CI 92.3–94.9, median 96.0) for ADL. HAGOS scores did not differ significantly between groups classified according to alpha angle ≤60° versus >60° and LCE angle ≤40° versus >40° (Table 3).

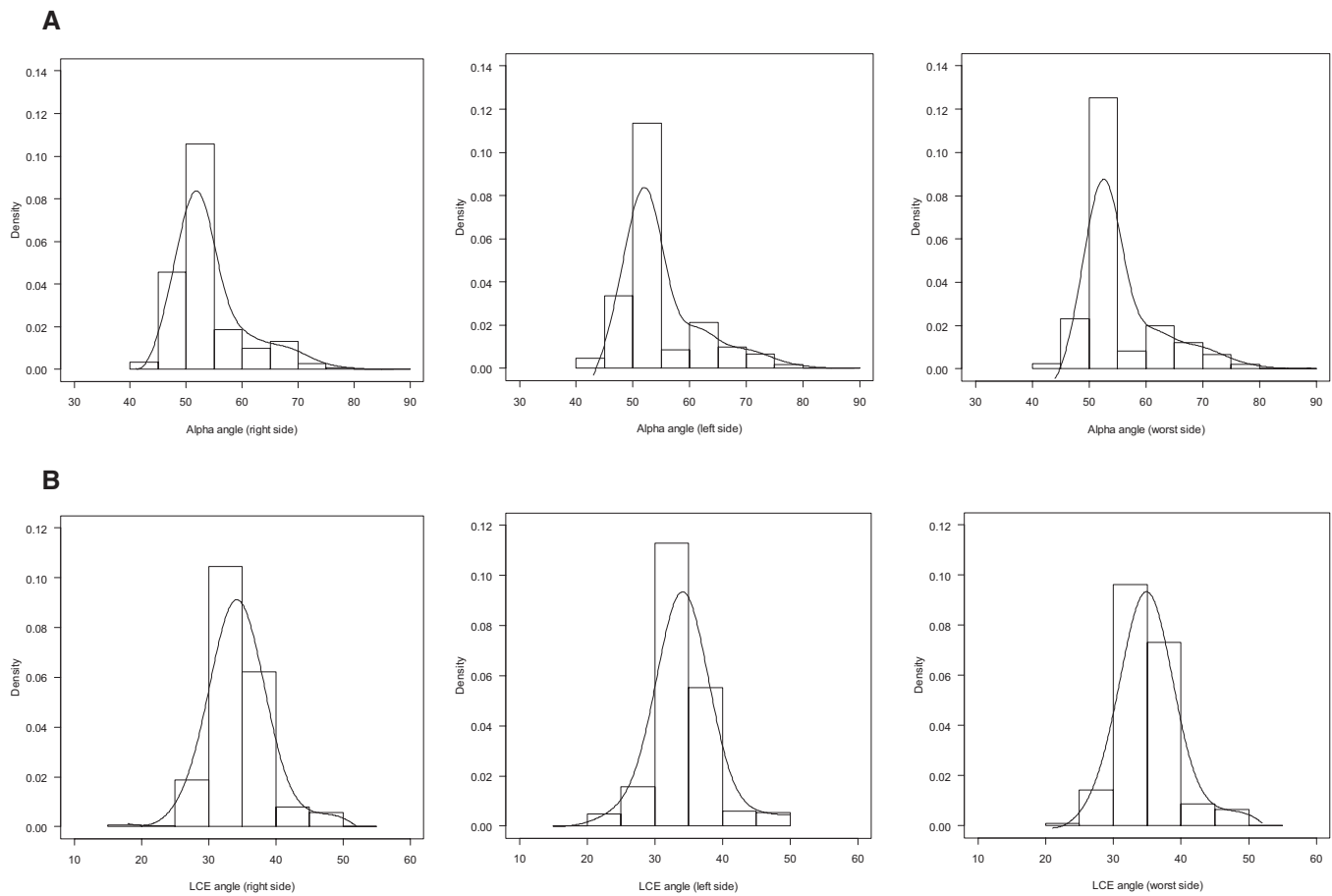
In the restricted cubic spline analysis, the relationship between the alpha angle and HAGOS scales was nonlinear. The shapes of the curves were similar for all scales (see Supplementary Figure 1, available on the *Arthritis Care & Research* web site at <http://onlinelibrary.wiley.com/doi/10.1002/acr.23774/abstract>). Among those with an alpha angle >60°, the graphs showed HAGOS scores to be worse for higher alpha values. Statistically significant nonlinear associations (*P* < 0.05) were identified for the symptoms, sports, and QoL scales (Figure 2). No association was found between the LCE angle and any of the HAGOS scales (data not shown).

**Sensitivity analyses.** In an analysis among individuals reporting hip pain, the alpha angle in the worst hip was statistically significantly associated with the symptoms, pain, sports, and QoL scales (see Supplementary Figure 2, available on the *Arthritis Care & Research* web site at <http://onlinelibrary.wiley.com/doi/10.1002/acr.23774/abstract>). A nonlinear association was identified for symptoms only, though the slopes of the

**Table 2.** Weighted radiographic measurements and HAGOS scores in the study population\*

| Variable              | Mean (95% CI)    | Median (95% CI)  |
|-----------------------|------------------|------------------|
| Radiographic, degrees |                  |                  |
| Alpha angle left hip  | 54.7 (53.7–55.8) | 53 (52–53)       |
| Alpha angle right hip | 54.1 (53.1–55.0) | 52 (52–53)       |
| Alpha angle worst hip | 55.4 (54.4–56.4) | 53 (53–54)       |
| LCE angle left hip    | 34.3 (33.7–34.9) | 34 (34–35)       |
| LCE angle right hip   | 34.6 (34.0–35.2) | 34 (33–35)       |
| LCE angle worst hip   | 35.3 (34.7–35.9) | 35 (34–36)       |
| HAGOS scale scores    |                  |                  |
| Symptoms              | 86.8 (85.2–88.5) | 89.9 (87.5–91.7) |
| Pain                  | 91.5 (89.9–93.1) | 97.7 (96.4–98.0) |
| ADL                   | 93.6 (92.3–94.9) | 96.0 (95.5–96.6) |
| Sports                | 91.3 (89.8–92.9) | 97.0 (95.6–97.5) |
| PA                    | 80.1 (77.2–83.0) | 78.7 (73.4–85.0) |
| QoL                   | 88.4 (86.4–90.4) | 95.3 (92.5–96.0) |

\* HAGOS = Copenhagen Hip And Groin Outcome Score; 95% CI = 95% confidence interval; LCE = lateral center edge; ADL = activities of daily living; Sports = physical function in sport and recreation; PA = participation in physical activities; QoL = hip and/or groin-related quality of life.



**Figure 1.** Weighted distributions of **A**, alpha angle and **B**, lateral center edge (LCE) angle in the study population for the left hip, right hip, and worst hip.

curves for alpha >60° appeared steeper than those observed in the weighted pain and nonpain combined analyses.

**DISCUSSION**

The purpose of this study was to assess the association between radiographic measurements of hip morphology (cam and pincer) and patient-reported hip-related outcomes in individuals ages 20–49 years, selected from the general population. The

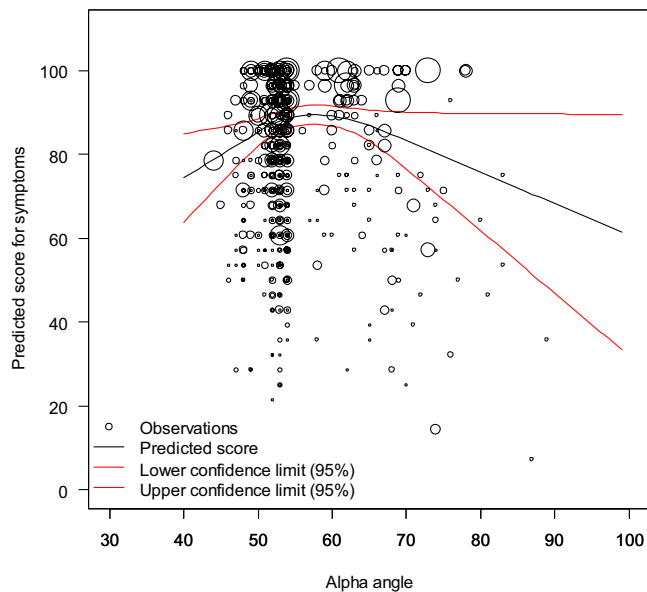
mean alpha and LCE angles in our study were similar to those reported by Frank et al for asymptomatic hips (25). In a systematic review of cam and pincer morphology prevalence studies, these authors found mean values of 54.1° and 31.2° for alpha and LCE angles, respectively.

In an analysis using restricted cubic splines, we have found a relationship between HAGOS scores and the alpha angle, but not the LCE angle. The general shape of the relationship was similar for all 6 HAGOS scales and consistently

**Table 3.** Weighted mean HAGOS scores according to alpha angle and LCE angle (worst hip)\*

| HAGOS scale | Alpha ≤60°<br>(n = 413) | Alpha >60°<br>(n = 87) | LCE ≤40°<br>(n = 457) | LCE >40°<br>(n = 43) |
|-------------|-------------------------|------------------------|-----------------------|----------------------|
| Symptoms    | 86.5 (84.8–88.3)        | 88.0 (83.4–92.6)       | 86.8 (85.1–88.5)      | 87.1 (79.1–95.1)     |
| Pain        | 91.6 (89.9–93.2)        | 91.3 (86.9–95.8)       | 91.5 (89.9–93.2)      | 91.4 (83.7–99.0)     |
| ADL         | 93.5 (92.2–94.8)        | 94.0 (90.4–97.7)       | 93.7 (92.5–95.0)      | 92.2 (84.4–100.0)    |
| Sports      | 91.3 (89.7–92.9)        | 91.4 (87.2–95.5)       | 91.4 (89.8–92.9)      | 90.4 (82.2–98.6)     |
| PA          | 80.5 (77.4–83.6)        | 78.7 (70.9–86.4)       | 79.8 (76.8–82.9)      | 83.8 (73.3–94.4)     |
| QoL         | 88.0 (85.8–90.2)        | 89.9 (85.1–94.6)       | 88.2 (86.2–90.3)      | 89.9 (82.1–97.7)     |

\* Values are the Copenhagen Hip And Groin Outcome Score (HAGOS) (95% confidence interval). LCE = lateral center edge; ADL = activities of daily living; Sports = physical function in sport and recreation; PA = participation in physical activities; QoL = hip and/or groin-related quality of life.



**Figure 2.** Relationship between the alpha angle and the Copenhagen Hip And Groin Outcome Score symptoms scale. The figure shows the predicted symptoms score and its 95% confidence interval for a man age 42 years (worst hip) from a restricted cubic spline regression analysis, using 3 knots at the 5th, 50th, and 95th percentiles. The size of the observations reflects their corresponding sample weight.

indicated a negative correlation (a higher alpha correlated with a worse score) for alpha  $>60^\circ$ . The slope of the curve was significantly different from the null for 3 scales: symptoms, sports, and QoL. This finding may be due to discrepancies in how different outcomes are measured and related to CPM. For example, the pain questions in HAGOS ask about the frequency of hip/groin pain, pain on walking on various surfaces, pain on walking up/down stairs, standing, sitting, and lying, as well as bending and straightening the hip. These normal activities may be less likely to cause pain as a result of hip morphology. Furthermore, the physical activity scale has only 2 items and is the least reliable of the HAGOS scales (22). In contrast, other HAGOS scales ask about difficulty in performing more specific movements, for example, “stretching your legs far out to the side” (symptoms), more demanding activities, such as “running as fast as you can” (sports), and their impact on QoL. Such questions may be more sensitive to the effect of cam morphology, and if so, our results are plausible and consistent with the current concept of FAIS.

The graphic representation of the nonlinear relationship between alpha angle and HAGOS scores can be used to assess the clinical importance of the effect observed. For example, the predicted symptoms score for a man age 42 years with an alpha angle of approximately  $80^\circ$  would be close to 75 (of 100), compared with a score close to 90 for alpha  $55\text{--}60^\circ$ . This difference would be considered large and clinically important. On the other hand, as shown in Table 3, the difference in symptoms scores

between those with alpha scores  $>60^\circ$  versus  $\leq 60^\circ$  is only 1.5, i.e., very small and clinically insignificant.

Our sensitivity analysis generally confirmed the results observed in the main analysis. The relationship appeared stronger when the analysis was restricted to individuals reporting any hip pain. While this result is not generalizable to the population at large, it is plausible. We would expect the association of alpha angle with hip function and pain to be stronger and easier to detect in this group, compared to a general population sample in which most subjects report no hip pain.

Both in clinical settings and epidemiologic studies, various cutoff values for the alpha angle have been proposed to determine whether cam morphology is present and to diagnose FAIS (3). The cutoff values for the alpha angle in published studies varied from  $50^\circ$  to  $83^\circ$  and none of the published studies was truly population-based (11). Owing to differences in populations, definitions, and methods of assessment, the prevalence of cam morphology has been difficult to determine. In our study, the population (weighted) proportions of individuals ages 20–49 years with cam morphology (worst side) ranged from 87.3% for alpha  $>50^\circ$  to 24.6% for alpha  $>55^\circ$ , 20.4% for alpha  $>60^\circ$ , and 10.4% for alpha  $>65^\circ$  (Figure 1). In their analysis of data from the Chingford and the Cohort Hip and Cohort Knee studies, Agricola et al (7) suggested alpha  $>60^\circ$  as the best cutoff point to define cam morphology, based on the bimodal distribution they observed. In our data, a greater alpha score was associated with lower patient-reported outcomes scores when the alpha was above  $60^\circ$ , which would support this cutoff.

Our data may also show a negative impact on hip outcomes at lower alpha values (alpha  $<50^\circ$ ). This possibility should be treated with caution, because our data in this range were sparse, and we are not aware of other studies showing a similar association (although a nonlinear relationship between the alpha angle and radiographic OA risk was reported by Thomas et al [5]).

We have found no association between HAGOS scores and the LCE angle. This result is unlikely to be due to sample size or other methodologic aspects of the study. The LCE distribution in our study was symmetric, with a mean similar to that found in other studies (25). In a previous study, we reported unweighted prevalence of pincer morphology (LCE angle  $>40^\circ$ ) to be 8% in subjects with pain and 9% in asymptomatic controls (20). To our knowledge, no study has shown a significant association between hip symptoms, function, or OA and isolated pincer morphology or a high LCE angle. On the other hand, a low LCE angle, indicative of hip dysplasia, may be associated with OA (26). It is possible that the LCE angle is not an optimal measure of pincer morphology; however, another common measure, the crossover sign, has been criticized for low specificity in assessing retroversion of the acetabulum (27) and therefore was not used in the current analysis. In a recent review of the criteria for the surgical treatment of FAIS, Peters et al (28) reported that the LCE angle was used in approximately half of the studies.



Our data suggest that the methods for determining pincer morphology and its relationship with hip symptoms and OA require further study.

Several limitations of the study need to be acknowledged. First, the association between alpha angle and HAGOS scores that we found in a cross-sectional observational study does not necessarily imply causation. In theory, the results may be due to confounding by unmeasured risk factors for hip-related outcomes that are correlated with alpha angle. BMI was not related to the alpha or LCE angle, and adjusting for BMI did not change the results. We did not adjust for hip OA because OA can be a mediator of the association under study. Second, the possibility of other biases, and specifically, measurement, selection, or reverse causality bias, also needs to be recognized. Despite our use of valid and reliable measures of the key variables, some degree of error in measuring alpha angle and self-reported outcomes is inevitable. Such errors would be unlikely to be differential, because the subjects were unaware of their radiograph findings and our radiograph readers were unaware of the questionnaire data. Nondifferential errors would dilute the correlations and make them less statistically significant. Selection bias could occur if participation in the study was related to both hip morphology and outcomes. This possibility seems unlikely, because subjects were unaware of their radiograph findings at the time of recruitment. Third, the confidence bands for the restricted cubic splines curves were relatively wide. Thus the lack of statistical significance for some HAGOS scales does not imply that a relationship does not exist. Since the general shape of the relationship was similar across the scales, the weaker associations could become significant in a larger study.

Our study had some methodologic strengths that are worth noting. The study was carried out in a stratified random population sample, and the data were properly weighted to be representative of the general white population of metro Vancouver. As a result, generalizability of the findings is high. We used the Dunn view for assessing the alpha angle; this method is considered more precise than the anteroposterior view employed in most published studies (3). The ICC for alpha angle was 0.97, indicating almost perfect interrater reliability. Rather than using an arbitrary cut point, we analyzed the alpha angle and LCE angle as continuous variables using modern statistical methods (restricted cubic splines). For measuring hip outcomes, we employed the best measure currently available, the HAGOS questionnaire. This instrument has been recommended for research on FAIS (3). Finally, where comparable data were available, our findings were consistent with the literature.

In conclusion, we have for the first time demonstrated the association of cam morphology with poor patient-reported outcomes, such as hip symptoms, limitations in sports activities, and QoL, in a general population sample. We have also shown that this relationship is limited to an alpha angle above 60°, which sup-

ports previous recommendations to use this cutoff for the diagnosis of FAIS.

## AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Kopec had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Study conception and design.** Kopec, Cibere, Li, Ratzlaff, Forster, Esdaile.

**Acquisition of data.** Cibere, Li, Barber, Pric, Zhang, Ratzlaff, Forster.

**Analysis and interpretation of data.** Qian, Wong.

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