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# Prevalence of borderline acetabular dysplasia in symptomatic and asymptomatic populations: A systematic review and meta-analysis

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# Prevalence of Borderline Acetabular Dysplasia in Symptomatic and Asymptomatic Populations

## A Systematic Review and Meta-analysis

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**Background:** Patients with borderline acetabular dysplasia are a controversial patient population in hip preservation, as some have primarily impingement-based symptoms and others have instability-based symptoms. Borderline dysplasia is most commonly defined as a lateral center-edge angle (LCEA) of 20° to 25°. However, its prevalence has not been well established in the literature.

**Purpose:** To (1) define the prevalence of borderline hip dysplasia in the general population as well as in populations presenting with hip pain using a systematic review and meta-analysis of the literature and (2) describe differences between male and female patients as well as differences in prevalence from that of classic acetabular dysplasia.

**Study Design:** Systematic review; Level of evidence, 3.

**Methods:** A systematic review of the literature was performed using search terms to capture borderline dysplasia, or studies reporting prevalence by LCEA. The search yielded 1932 results, of which 11 articles met inclusion criteria and were included in the final systematic review. Studies were grouped by patient cohort as (1) asymptomatic general population, (2) asymptomatic targeted population (eg, athletes in a specific sport), and (3) symptomatic hip pain population. The reporting of prevalence rates by subject or by hip was recorded. In a study, the rates of borderline dysplasia were compared with those of classic acetabular dysplasia (LCEA, <20°).

**Results:** The 11 studies included 19,648 hips (11,754 patients). In the asymptomatic general population, the pooled estimate of the prevalence of borderline dysplasia was 19.8% by subject and 23.3% by hip (range, 16.7%-46.0%). The targeted subpopulation group included 236 athletes with subgroups in ballet, football, hockey, volleyball, soccer, and track and field with prevalence ranging from 17.8% to 51.1%. The prevalence of borderline dysplasia in groups presenting with hip pain was 12.8% (range, 12.6%-16.0%). Borderline acetabular dysplasia was 3.5 times more common than classic acetabular dysplasia in the asymptomatic general population.

**Conclusion:** This study demonstrated a prevalence of borderline dysplasia of 19.8% to 23.3% in the asymptomatic general population. Additionally, an estimated prevalence of 12.8% of hips in symptomatic patients highlights the common decision-making challenges in this population.

**Keywords:** borderline hip dysplasia, acetabular dysplasia, prevalence

Borderline acetabular dysplasia is a controversial topic in hip preservation surgery because of the limited evidence to guide decision making between surgical treatment options in this transitional morphology between instability and impingement. While classic acetabular dysplasia is most commonly defined as a lateral center-edge angle (LCEA) <20°, borderline acetabular dysplasia is most commonly defined as an LCEA of 20° to 25°, and some authors define it as an LCEA of 18° to 25°.[8,50] Some patients in this population have primarily impingement-based symptoms, while other patients have primarily instability-based symptoms.‡ No current gold standard exists for differentiating these subgroups. No direct comparative studies exist comparing these primary treatment approaches (isolated hip

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‡References 8, 13, 18, 19, 24, 31, 41, 46, 52.

arthroscopy vs periacetabular osteotomy [PAO] with or without arthroscopy). The outcomes of these procedures in this population have been good in selected subgroups, but a subset of patients appears to have suboptimal outcomes (up to 30% in some series).[12,37]

The risk of osteoarthritis (OA) has been well established in classic acetabular dysplasia (LCEA, $<20°$)[§] but has been demonstrated to extend into the borderline subgroup as well.[53] Thomas et al[52] reported a linear risk increase for each degree of LCEA $<28°$. This means that patients with borderline dysplasia may have an increased risk of OA compared with those with normal LCEA, but this risk is less than that of classic acetabular dysplasia. Borderline acetabular dysplasia can cause OA due to chronic joint instability leading to chondral surface overload, which can produce irreversible articular cartilage and labral damage, thereby reducing the longevity of the hip joint.[6,7] Many hips with borderline dysplasia have cam-type morphologies of the proximal femur that may lead to femoroacetabular impingement (FAI), which is also well established as a risk factor for hip OA.[1,2,5,21,39,48,49]

Decision making in the setting of borderline dysplasia is a common clinical dilemma. The clinical presentation of borderline hip dysplasia is similar to that of other young adult hip disorders such as FAI or classic acetabular dysplasia.[43] Diagnosis begins with a clinical history, physical examination, and radiographic imaging.[35,40] No agreed-upon current clinical criteria for differentiating impingement and instability in this population exist as multiple factors (femoral and acetabular hip morphology, soft tissue laxity, apprehension testing, range of motion) contribute to an accurate diagnosis in these cases. Different radiographic measurements are used to assess acetabular dysplasia such as the LCEA, anterior center-edge angle, and Tönnis angle/acetabular inclination.[4,7,9,10,30,38]

An important initial step to understanding a condition is to establish its prevalence.[17,45] The prevalence of borderline acetabular dysplasia is currently not well established in the literature. The purpose of this study was to estimate the prevalence of borderline hip dysplasia in the general population, as well as in groups of patients presenting with hip pain. Additionally, we described differences in rates between male and female patients and compared the prevalence with that of classic acetabular dysplasia.

## METHODS

A systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The following question was posed: "What is the prevalence of borderline acetabular dysplasia in hips with and without hip pain?" The published literature was searched using strategies created by an independent medical librarian for measurements of the LCEA in the hip or borderline hip dysplasia. The search strategies were established using a combination of standardized terms and keywords and were implemented in Ovid Medline (1946-2020), Embase (1947-2020), Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, and ClinicalTrials.gov. Full-search strategies are provided in Appendix Table A1. The reference lists of each study that met the eligibility criteria were also reviewed to identify other relevant studies. All searches were completed in February 2020.

There were a total of 1932 results, with 1166 unique results after duplicates were removed. A total of 11 studies[‖] met the inclusion criteria and were included in the final systematic review (Figure 1).

### Eligibility Criteria

Studies were considered eligible if they reported prevalence of borderline acetabular dysplasia in their study cohorts. Only manuscripts written in English were considered, and only cohorts with patients aged $\geq12$ years were included. Exclusion criteria included nonhuman subjects, cadaveric studies, abstracts or unpublished works, imaging technique studies, surgical technique studies, reviews and meta-analyses, case reports, other hip disorders (trauma, avascular necrosis, connective tissue disorders, or other preexisting orthopaedic conditions, soft tissue and joint conditions [eg, slipped capital femoral epiphysis, Legg-Calve-Perthes]), or studies that did not report prevalence of borderline acetabular dysplasia.

### Data Collection

Two blinded reviewers (S.F., L.F.) independently assessed each study title, abstract, and full text, as applicable.. The following variables were extracted from the selected articles: date of study, study type, study country, level of evidence, sex, age, total number of hips in cohort, number of hips with borderline acetabular dysplasia, number of hips

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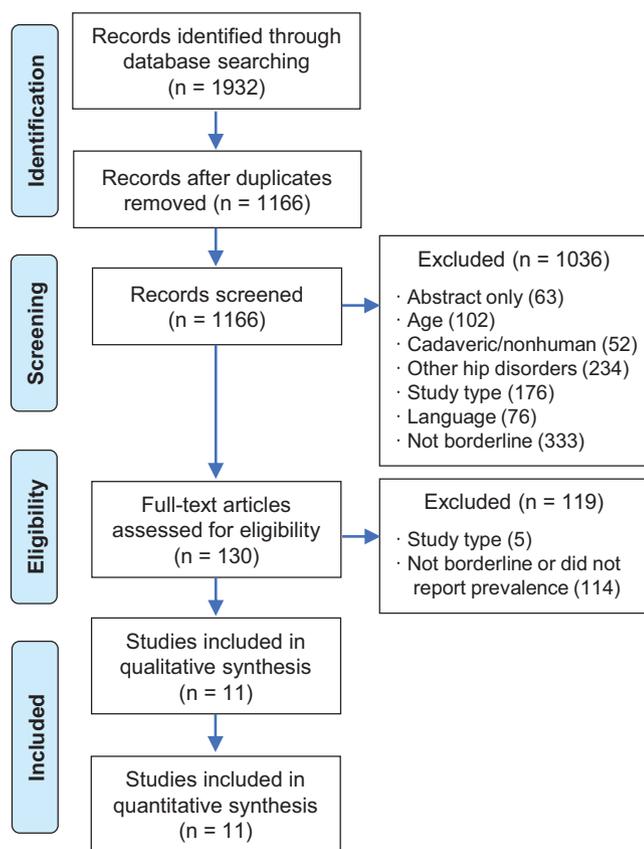[§]References 3, 8, 11, 19, 22, 25, 29, 51, 54.

[‖]References 7, 16, 20, 22, 26–28, 31, 33, 36, 47.

**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) study flow diagram.

with classic acetabular dysplasia, and radiographic definition used to diagnose borderline acetabular dysplasia as well as classic acetabular dysplasia. For 2 included studies,[33,48] prevalence was extracted from figures in the published text, as it was not explicitly stated in the manuscript. The definition of borderline acetabular dysplasia for all papers was an LCEA of 20° to 25°.

### Statistical Analysis

Prevalence of borderline acetabular dysplasia (as well as classic acetabular dysplasia) was broken down into subgroups for further analysis. Studies were grouped by patient cohort as (1) asymptomatic general population, (2) asymptomatic targeted population (such as athletes in a specific sport), and (3) symptomatic hip general population. The reporting of prevalence rates of borderline dysplasia in each study was characterized by subject or by hip. When reported, the prevalence specific to male and female subject was abstracted. Finally, rates of borderline dysplasia were compared with those of classic acetabular dysplasia (LCEA, <20°) in each of these groups.

Statistical analyses were performed to define prevalence estimates and associated 95% confidence intervals for borderline dysplasia in the different populations. A meta-analysis was performed using Stata with *metaprop*

analysis.[44] A random-effects meta-analysis was performed to account for heterogeneity between studies. Confidence intervals were calculated using exact binomial distribution.[42]

### RESULTS

The 11 included studies comprised a total of 19,648 hips in 11,754 subjects. There were 4 level 2 studies[16,22,26,47] and 7 level 3 studies.[7,20,27,28,31,33,36]

### General Population Subgroup

The general population subgroup included 4 studies of 7595 subjects (15,190 hips) with an average age of 40.6 years and 60.2% women (5175 patients) (Table 1). The estimated prevalence of borderline acetabular dysplasia in the general population subgroup was 23.3% by hip and 19.8% by patient (range, 16.7%-46.0%) (Figure 2). In the largest included study, Jacobsen et al[23] reported on a prospective longitudinal cohort study of 3859 asymptomatic subject (7718 hips) from the Copenhagen City Heart Study.[22,23] Overall, 63.0% of the subjects were women, and the cohort had an average age of 61 years. In this study, 19.2% of hips (by hip) were classified as borderline dysplasia, and 3.4% of hips were classified as classic acetabular dysplasia. Engesæter et al[16] reported on a prospective population-based cohort of 2072 asymptomatic 19-year-old Norwegians (4144 hips), with 57.8% of the subjects being women. Overall, 16.7% of the participants were borderline dysplastic, and 3.3% had acetabular dysplasia. Kapron et al[27] reported a cross-sectional study of 63 female athletes (126 hips) participating in National Collegiate Athletic Association Division I collegiate volleyball, soccer, or track and field. Given the broad number of sports involved, this was considered to be relatively representative of the general population. The average age was 19.6 years in this study. Overall, 46.0% of hips were borderline dysplastic, and 20.6% of hips had acetabular dysplasia. Raveendran et al[47] reported on the Johnston County Osteoarthritis Project in the United States. This cohort included 1601 subjects (3202 hips) and allowed calculation of rates by subject and by hip. In this study, the borderline dysplasia rate by hip was 18.8%, while the rate by patient was 25.1% (rate by subject = 1.33 times the rate by hip).

### Targeted Population

The targeted population subgroup included 236 athletes (ballet, football, hockey) (472 hips) from 4 studies (Table 2). This group had an average age of 22.2 years and was 62.3% male, with a pooled prevalence of borderline dysplasia prevalence of 26.4% (range, 10.6%-36.2%). Kapron et al[26] reported on a prospective cohort study of 67 asymptomatic male football players (134 hips) with a prevalence of borderline dysplasia of 19.4%. Harris et al[20] reported a cross-sectional study of 47 consecutive asymptomatic subjects (94 hips) in an international professional ballet company. The cohort had an average age of 23.8 years, with 55.4% of participants being women. Of the 47 patients,

TABLE 1
General Population Studies on Borderline Acetabular Dysplasia Prevalence (N = 7595 Patients; 15,190 Hips; 68.1% Women)[a]

| Lead Author (Year) | Study Type (LOE) | Population | Location | Patients (Hips), n | Age, y | Sex | Definition by Hip or by Patient | Radiographic Technique | LCEA Definition of Dysplasia | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Borderline | Classic |
| Engesæter (2013)[16] | Prospective longitudinal cohort (2) | Invited follow-up of population-based cohort; age, 17-20 y | Norway | 2072 (4144) | 18.6 (17.3-20.2) | 58% female (n = 1199) | By patient | Standing AP pelvis | 20°-24.9° | <20° |
| Raveendran (2018)[47] | Prospective longitudinal cohort (2) | Population-based cohort; age, >45 y; OA exclusion | USA | 1601 (3202) | 63 ± 10 | 57.2% female (n = 1483) | By patient and by hip | Supine AP pelvis | 20°-25° | ≤20° |
| Jacobsen (2005)[22] | Prospective longitudinal cohort (2) | Population-based cohort; no OA exclusion | Denmark | 3859 (7718) | 61 (22-93) | 63% female (n = 2430) | By hip | Standing AP pelvis | 20°-25° | ≤20° |
| Kapron (2015)[27] | Cross-sectional (3) | Female collegiate athletes (volleyball, soccer, and track and field) | USA | 63 (126) | 19.6 ± 1.4 | 100% female | By hip | Supine AP pelvis | 20°-25° | <20° |

[a]Data are shown as mean (range) or mean ± SD unless otherwise indicated. AP, anteroposterior; LCEA, lateral center-edge angle; LOE, level of evidence; OA, osteoarthritis.
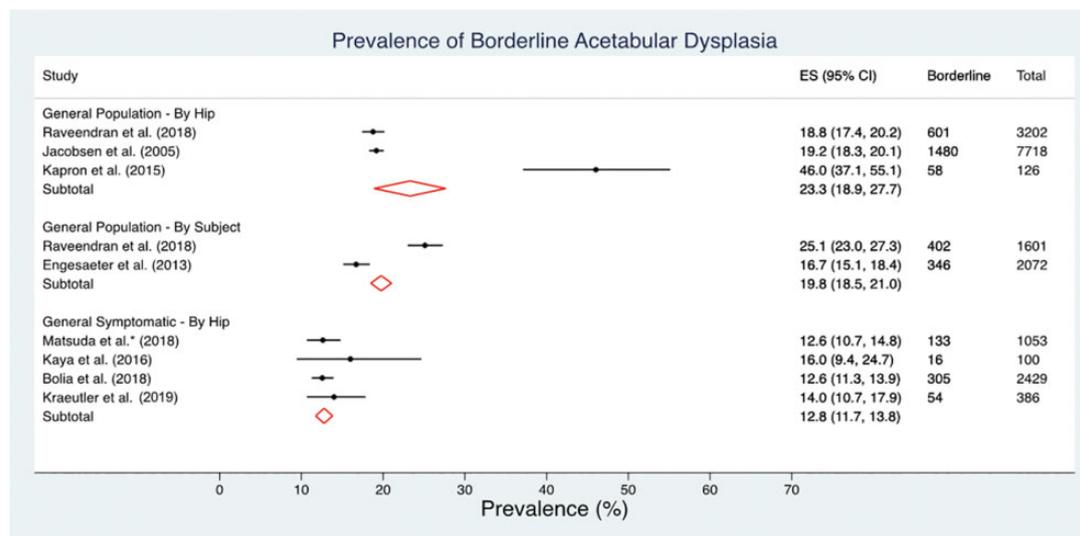


**Figure 2.** Meta-analysis of prevalence of borderline acetabular dysplasia. *Study excluded classic acetabular dysplasia. ES, effect size.

51.1% had borderline dysplasia, and 36.2% had classic acetabular dysplasia. Thus, a total 87.2% of hips in this study had an LCEA <25°. Larson et al[32] reported on a cross-sectional study of 59 male National Hockey League athletes (118 hips) with an average age of 24.2 years. The prevalence of borderline acetabular dysplasia in this cohort was 17.8%. Kapron et al[27] was also included in this subanalysis, as the authors provided a borderline dysplasia prevalence breakdown for individual sports (soccer 50%, track and field 43%, volleyball 46%).

### Symptomatic Population

There were 4 studies reporting the prevalence of borderline dysplasia in the symptomatic population (all reported by hip) (Table 3).[20,26,27,33] These studies evaluated a total of

4018 hips with an average age of 36.5 years, with 54.2% being women (2126 patients). The estimated prevalence of hips with borderline dysplasia in populations presenting with hip pain was 12.8% (range, 12.6%-16.0%).

Among these studies, Kraeutler et al[31] reported a retrospective comparative study including a series of 341 subjects (436 hips; mean age, 33.9 years; 74.1% women) presenting with hip pain to a dedicated hip preservation clinic. The prevalence of borderline dysplasia and classic acetabular dysplasia was 14.0% and 11.7%, respectively. Matsuda et al[36] reported a cohort of 1053 subjects undergoing hip arthroscopy by 7 surgeons. This study only reported prevalence of overall dysplasia (borderline + classic dysplasia; LCEA, <25°) and found a prevalence of 12.6% of hips (133/1053). However, most patients with classic acetabular dysplasia are generally not considered to be appropriately

TABLE 2
Targeted Subpopulation Studies on Borderline Acetabular Dysplasia Prevalence (n = 236 Patients; 472 Hips; 62.3% Men)[a]

| Lead Author (Year) | Study Type (LOE) | Population | Location | Patients (Hips), n | Age, y | Sex | Definition by Hip or by Patient | Radiographic Technique | LCEA Definition of Dysplasia | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Borderline | Classic |
| Larson (2017)[33] | Cross-sectional (3) | Professional hockey players | NHL | 59 (118) | 24.2 (18-36) | 100% male | By hip | AP pelvis | 20°-25° | <20° |
| Kapron (2011)[26] | Prospective cohort (2) | Collegiate American football players | USA | 67 (134) | 21 ± 1.9 | 100% male | By hip | Supine AP pelvis | 20°-25° | <20° |
| Harris (2016)[20] | Cross-sectional (3) | Professional ballet | USA | 47 (94) | 23.8 ± 5.4 (18-39) | 53.3% female (n = 26) | By patient and by hip | Standing AP pelvis | 20°-25° | <20° |
| Kapron (2015)[27] (subgroups) | Cross-sectional (3) | Female collegiate volleyball | USA | 22 (44) | N/A | 100% female | By hip | Supine AP pelvis | 20°-25° | <20° |
| | | Female collegiate soccer | | 28 (56) | | | | | | |
| | | Female collegiate track and field | | 13 (26) | | | | | | |

[a]Data are shown as mean (range) or mean ± SD (range) unless otherwise indicated. AP, anteroposterior; LCEA, lateral center-edge angle; LOE, level of evidence; N/A, not available; NHL, National Hockey League.

TABLE 3
Symptomatic Population Studies on Borderline Acetabular Dysplasia Prevalence (n = 4018 Hips; 54.2% Women)[a]

| Lead Author (Year) | Study Type (LOE) | Population | Location | Patients, n | Age, y | Sex | Definition by Hip or by Patient | Radiographic Technique | LCEA Definition of Dysplasia | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Borderline | Classic |
| Matsuda (2018)[36] | Retrospective cohort (3) | Multicenter, patients with hip arthroscopy | USA | 1053 | 32 ± 13.8 for borderline | 62.7% female | By hip | | <25° | N/A |
| Kaya (2016)[28] | Retrospective cohort (3) | Patients with hip arthroscopy patients | Japan | 100 | 47.2 (18-76) | 66% female | By hip | | 20°-25° | <20° |
| Bolia (2018)[7] | Retrospective cohort (3) | Patients with hip arthroscopy; excluded patients with LCEA <20° and >40° | USA | 2429 | 33 ± 16 for borderline | 51% female | By hip | Supine AP pelvis | 20°-25° | Not included |
| Kraeutler (2019)[31] | Retrospective cohort (3) | Hip preservation clinic (included both hips) | USA | 436 | 33.9 ± 11.4 | 74.1% female | By hip | Standing AP pelvis | 20°-24.9° | <20° |

[a]Data are shown as mean (range) or mean ± SD unless otherwise indicated. AP, anteroposterior; LCEA, lateral center-edge angle; LOE, level of evidence; N/A, not available.

treated with arthroscopic surgery alone so were likely not heavily represented in this study. Bolia et al[7] reported a retrospective comparative study of 2429 patients undergoing arthroscopic FAI surgery. This study excluded subjects with an LCEA <20° and >40°. Average age was 33 years, with 50.8% of the patients being women. The prevalence of borderline dysplasia was 12.6% in this population.

### Borderline Versus Classic Acetabular Dysplasia

Most studies analyzed the prevalence of borderline dysplasia (LCEA, 20°-25°) and acetabular dysplasia (LCEA, <20°) to allow comparison (Table 4). In the general population subgroup, the prevalence of borderline dysplasia was higher than that of classic acetabular dysplasia in the general population group (3.5 times greater by subject, 20.4% vs 5.9%; 4.4 times greater by hip, 19.4% vs. 4.4%) and in the

symptomatic population (1.3 times greater; 14.4% vs 11.3% by hip) (Figure 3).

### Male Versus Female Prevalence

In the general population subgroup, the prevalence of borderline dysplasia was slightly higher in women than men (Table 5). By hip, the prevalence estimate was 23.7% for women and 20.3% for men (Figure 4). By patient, the prevalence estimate was 20.6% for women and 17.9% for men. The prevalence of classic acetabular dysplasia was similar for men and women (men: mean, 4.5% [range, 2.4%-10.1%]; women: mean, 4.5% [range, 3.5%-20.6%]). Two studies in the symptomatic group reported female versus male prevalence (Table 5). Matsuda et al[36] reported that 65.4% (87/133) of the patients with borderline dysplasia and acetabular dysplasia were women. The female prevalence was

TABLE 4
Prevalence of Borderline and Classic Acetabular Dysplasia

| Study[a] | Definition | Prevalence of Acetabular Dysplasia, % (n/N) | | Ratio of Borderline:Classic Dysplasia |
|---|---|---|---|---|
| | | Borderline | Classic | |
| General population | | | | |
| Engesæter[16] | By patient | 16.7 (346/2072) | 3.3 (68/2072) | 5:1 |
| Raveendran[47] | By patient | 25.1 (402/1601) | 9.4 (150/1601) | 2:7 |
| | By hip | 18.8 (601/3202) | 5.9 (190/3202) | 3:2 |
| Jacobsen[22] | By hip | 19.2 (1480/7718) | 3.4 (266/7718) | 5:6 |
| Kapron[27] (women only) | By hip | 46.0 (58/126) | 20.6 (26/126) | 2:2 |
| Pooled | By patient | 20.4 (748/3673) | 5.9 (218/3673) | 3:5 |
| Pooled | By hip | 19.4 (2139/11,046) | 4.4 (482/11,046) | 4:4 |
| Targeted subpopulation | | | | |
| Harris[20] | By patient | 51.1 (24/47) | 36.2 (17/47) | 1:4 |
| Larson[33] | By hip | 17.8 (21/118) | 3.4 (4/118) | 5:2 |
| Kapron[26] | By hip | 19.4 (26/134) | 7.5 (10/134) | 2:6 |
| Symptomatic population | | | | |
| Kaya[28] | By hip | 16.0 (16/100) | 10.0 (10/100) | 1:6 |
| Kraeutler[31] | By hip | 14.0 (54/386) | 11.7 (45/386) | 1:2 |
| Pooled | By hip | 14.4 (70/486) | 11.3 (55/486) | 1:3 |

[a]Does not include studies that did not provide both borderline and classic dysplasia.
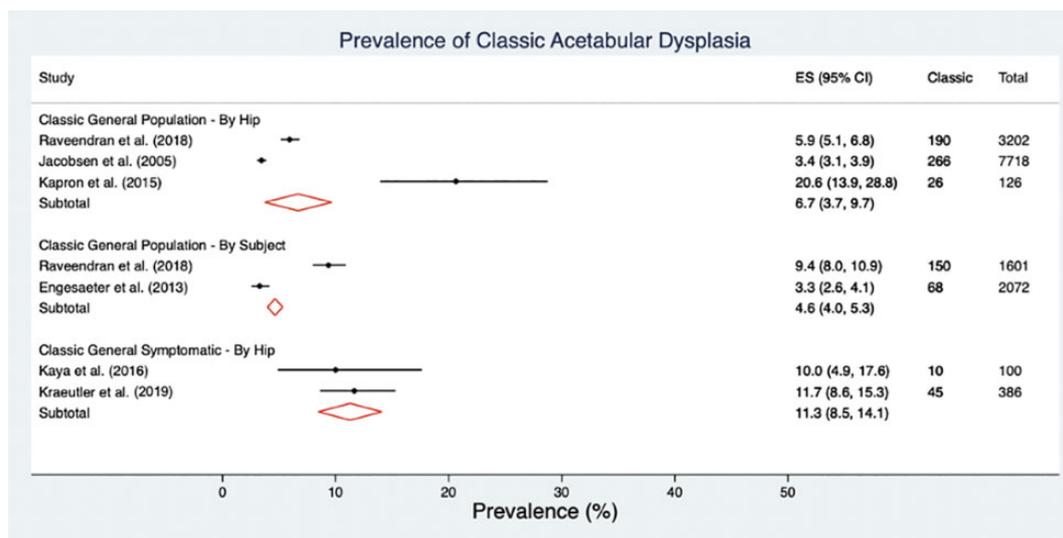


**Figure 3.** Prevalence of classic acetabular dysplasia. ES, effect size.

13.2% (87/659), and the male prevalence was 11.7% (46/394). Bolia et al[7] reported that 51% (155/305) of the patients with borderline dysplasia were women. The female prevalence in this group was 13.9% (155/1114) in comparison with 11.4% (150/1315) in men.

## DISCUSSION

Borderline acetabular dysplasia remains a controversy in the hip preservation field. Yet, even basic characteristics of the condition, including the prevalence, have not been well

established in the literature. This study highlights how commonly borderline dysplasia is present in the general population and symptomatic groups. In this systematic review, 11 studies used AP pelvic radiographs to measure LCEA. These studies most commonly classified borderline dysplasia as an LCEA of 20° to 25° and classic acetabular dysplasia as an LCEA <20°. Four of the studies analyzed the prevalence of borderline dysplasia in patients presenting with hip pain.[7,28,31,36] Four studies[16,22,27,47] analyzed the prevalence of borderline dysplasia in the general population. The pooled estimate of the prevalence of borderline dysplasia was 19.8% by patient and 23.3% by hip in the

TABLE 5
Prevalence of Dysplasia in Male Versus Female Patients[a]

| | Definition | Prevalence of Borderline Dysplasia, % (n/N) | | Prevalence of Classic Dysplasia, % (n/N) | |
|---|---|---|---|---|---|
| | | Female | Male | Female | Male |
| General population | | | | | |
| Engesæter[16] | By patient | 18.7 (224/1199) | 13.6 (119/873) | 4.3 (52/1199) | 2.4 (21/873) |
| Raveendran[47] | By patient | 23.5 (221/939) | 27.3 (181/662) | 8.8 (83/939) | 10.1 (67/662) |
| | By hip | 17.5 (329/1878) | 20.5 (272/1324) | 6.0 (112/1878) | 5.9 (78/1324) |
| Jacobsen[22] | By hip | 18.6 (902/4860) | 20.2 (578/2858) | 3.5 (171/4860) | 3.3 (95/2858) |
| Kapron[27] | By hip | 46.0 (58/126) | — | 20.6 (26/126) | — |
| Targeted population | | | | | |
| Harris[20b] | By patient | 96.2 (25/26) | 81.0 (17/21) | — | — |
| | By hip | 92.3 (48/52) | 73.8 (31/42) | | |
| Kapron[26] | By hip | — | 19.4 (26/134) | — | 7.5 (10/134) |
| Symptomatic population | | | | | |
| Matsuda[36b] | By hip | 13.2 (87/659) | 11.7 (46/394) | — | — |
| Bolia[7] | By hip | 13.9 (155/1114) | 11.4 (150/1315) | — | — |

[a]Studies that did not provide sex-specific prevalence data were excluded. -, not reported/not applicable.
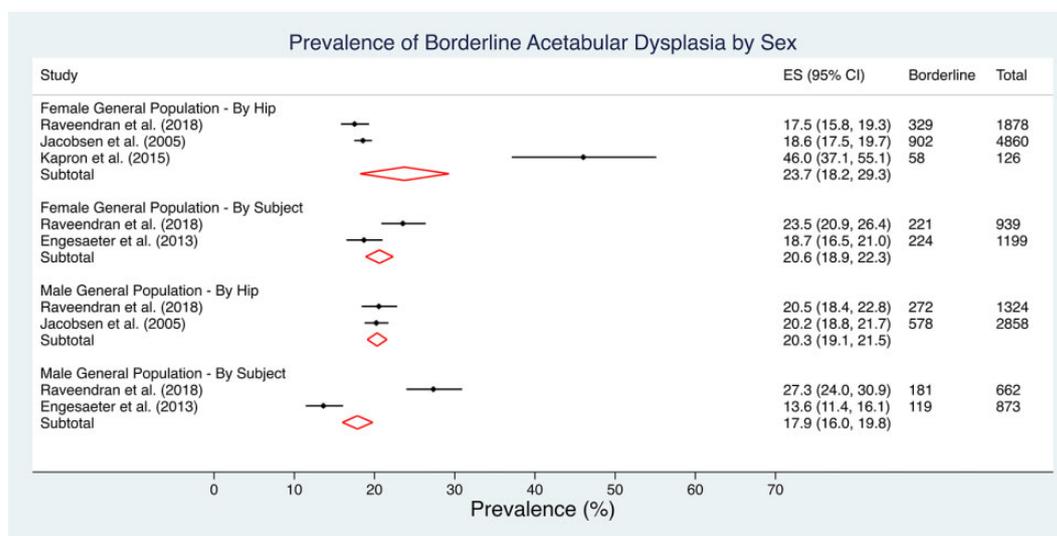[b]Borderline + classic dysplasia (LCEA, <25°).



**Figure 4.** Prevalence of borderline acetabular dysplasia by sex. ES, effect size.

general population compared with 12.8% in symptomatic patients. For comparison, the prevalence of acetabular dysplasia was 4.6% by patient (6.7% by hip) in the general population and 11.3% (by hip) in the symptomatic population.

This study had several limitations. The published literature included patient data from varied populations and demonstrated variability in the reported rates of borderline dysplasia. While not all populations were equally represented in the analyzed studies, the combined analysis of the available studies did provide more generalizable data than a single study. In the symptomatic population studies, only operatively treated patients were generally included. This may have created significant selection bias. Particularly, in hip preservation, many surgeons only performed some types of surgical procedures, which may have excluded patients treated with other methods. While hip arthroscopy is increasingly used as an adjunct treatment in some hips with acetabular dysplasia undergoing PAO, hips with classic acetabular dysplasia were likely underrepresented in these symptomatic cohorts, leading to underestimation of the true prevalence of classic acetabular dysplasia.

Additionally, some studies calculated prevalence by patient, and other studies calculated prevalence by hip. In general, these studies did not provide detailed information to convert between these rates. In theory, if hips were purely independent of each other, the prevalence by patient would be double the prevalence by hip. However, given the genetic and environmental effect on hip development, in

the majority of individuals, hip morphology is relatively similar. In theory, if this similarity were absolute, the prevalence by hip and by patient would be identical. Data from 1 population-based study that allowed conversion reported a 1.33 times higher prevalence by patient.[47] However, given the different characteristics of studies in each group, our estimate for prevalence by hip was actually slightly higher than the estimate by patient. If the 1.33 conversion factor were used, the estimate of prevalence of 23.7% by hip would represent a rate of 31.0% by patient. Thus, 19.8% to 31.0% may represent the best overall estimate of prevalence by patient. Given the potential inaccuracy of this conversion factor, we chose to stratify the estimates by hip or by patient as each study reported in actual data.

Systematic reviews enable comprehensive summary of the literature to assess the available evidence regarding the prevalence of borderline dysplasia in various populations. This review has summarized the findings of each study. The prevalence of borderline dysplasia was found to be higher in the studies looking at the general population compared with the studies looking at symptomatic patients (Figure 2). However, the prevalence of acetabular dysplasia was higher in the symptomatic population than in the general population (Figure 3). This would be consistent with classic acetabular dysplasia's having an increased risk of the development of symptoms compared with borderline dysplasia. This is consistent with findings of Thomas et al,[52] who demonstrated the higher risk of OA in a setting of classic acetabular dysplasia compared with borderline acetabular dysplasia. This equates to a 1.4- to 2.0-times elevated risk of OA in settings of borderline dysplasia compared with a 2.0- to 4.5-times elevated risk of OA from an LCEA of 20° down to an LCEA of 0°.

Female sex is well recognized as a risk factor for acetabular dysplasia.[14,15,34] Loder and Skopelja[34] found that 75.5% of the 9717 acetabular dysplasia cases were in women. Tian et al[53] found that the prevalence of acetabular dysplasia was significantly higher among women than men. These studies agree with our findings that in the general asymptomatic population, women had a higher prevalence of borderline dysplasia (Figure 4). However, in borderline acetabular dysplasia, the difference between women and men was relatively small.

This study demonstrated the high prevalence of borderline dysplasia in subjects presenting with prearthritic hip pain (12.8%). The high proportion of subjects undergoing hip preservation in the setting of borderline acetabular dysplasia underscored the importance of improving the evidence guiding treatment decisions in this common population. Understanding the prevalence of borderline dysplasia in the various patient populations may enable surgeons to better understand the condition, its parameters, and suitable treatment options.

## CONCLUSION

Using a systematic review of the literature and meta-analysis, this study demonstrated a prevalence of borderline dysplasia of 19.8% to 23.3% in the asymptomatic

general population. Additionally, an estimated prevalence of 12.8% of hips in symptomatic patients highlighted the common decision-making challenges in this population.

## ACKNOWLEDGMENT

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APPENDIX

TABLE A1
Search Strings by Database

Ovid Medline (820 results)
  (Exp hip/ OR (acetabular OR acetabulum OR hip OR femur OR femoral).mp.
  AND (Wiberg.mp. OR "Lateral center edge angle".mp. OR "Lateral centre edge angle".mp. OR LCEA.mp. OR "Lateral central edge angle".mp. OR "Lateral central edge angles".mp. OR "Lateral center edge angles".mp. OR "LCE angle".mp.))
  OR
  (Exp hip dislocation/ OR ((acetabular OR acetabulum OR hip) adj7 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)).mp. OR femur head dislocation.mp. OR femur head dysplasia.mp. OR (Exp Developmental bone diseases/ AND hip.mp.) AND (borderline.mp. OR border line.mp. OR (mild* adj2 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)).mp.))
Embase (1076 results)
  (('hip'/exp OR hip: ti, ab, kw, de OR acetabular: ti, ab, kw, de OR acetabulum: ti, ab, kw, de OR femur: ti, ab, kw, de OR femoral: ti, ab, kw, de) AND ('wiberg': ti, ab, kw, de OR 'Lateral center edge angle': ti, ab, kw, de OR 'Lateral center edge angles': ti, ab, kw, de OR 'Lateral central edge angle': ti, ab, kw, de OR 'Lateral central edge angles': ti, ab, kw, de OR 'lateral centre edge angle': ti, ab, kw, de OR 'lateral centre edge angles': ti, ab, kw, de OR 'LCE angle': ti, ab, kw, de OR LCEA: ti, ab, kw, de))
  OR
  (('hip dysplasia'/exp OR ((acetabular OR acetabulum OR hip) near/7 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)): ti, ab, kw, de OR 'femur head dislocation': ti, ab, kw, de OR 'femur head dysplasia': ti, ab, kw, de OR 'congenital hip disease': ti, ab, kw, de) AND ('borderline': ti, ab, kw, de OR 'border line': ti, ab, kw, de OR (mild* near/2 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)): ti, ab, kw, de))
Cochrane Library:
  Cochrane Database of Systematic Reviews (1 result)
  Cochrane Central Register of Controlled Trials (33 results)
  Database of Abstracts of Reviews of Effect (0 results)

  1.  [mh hip] OR hip: ti, ab, kw OR acetabular: ti, ab, kw OR acetabulum: ti, ab, kw OR femur: ti, ab, kw OR femoral: ti, ab, kw
  2.  "wiberg": ti, ab, kw OR "Lateral center edge angle": ti, ab, kw OR "Lateral center edge angles": ti, ab, kw OR "Lateral central edge angle": ti, ab, kw OR "Lateral central edge angles": ti, ab, kw OR "lateral centre edge angle": ti, ab, kw OR "lateral centre edge angles": ti, ab, kw OR "LCE angle": ti, ab, kw OR LCEA: ti, ab, kw
  3.  #1 AND #2
  4.  [mh "hip dislocation"] OR ((acetabular OR acetabulum OR hip) near/7 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)): ti, ab, kw OR femur head dislocation: ti, ab, kw OR femur head dysplasia: ti, ab, kw OR ([mh "Developmental bone diseases"] AND hip: ti, ab, kw)
  5.  borderline: ti, ab, kw OR "border line": ti, ab, kw OR (mild* near/2 (luxation OR dislocation* OR displacement* OR dysplasia OR dysplastic)): ti, ab, kw
  6.  #4 AND #5
  7.  #3 OR #6
Clinicaltrials.gov (0 results)
  Borderline hip dysplasia