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■ CHILDREN'S ORTHOPAEDICS

# Prevalence of radiographic findings associated with hip dysplasia in a population-based cohort of 2081 19-year-old Norwegians

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**In Norway total joint replacement after hip dysplasia is reported more commonly than in neighbouring countries, implying a higher prevalence of the condition. We report on the prevalence of radiological features associated with hip dysplasia in a population of 2081 19-year-old Norwegians. The radiological measurements used to define hip dysplasia were Wiberg's centre-edge (CE) angle at thresholds of < 20° and < 25°, femoral head extrusion index < 75%, Sharp's angle > 45°, an acetabular depth to width ratio < 250 and the sourcil shape assessed subjectively. The whole cohort underwent clinical examination of their range of hip movement, body mass index (BMI), and Beighton hypermobility score, and were asked to complete the EuroQol (EQ-5D) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The prevalence of hip dysplasia in the cohort varied from 1.7% to 20% depending on the radiological marker used. A Wiberg's CE angle < 20° was seen in 3.3% of the cohort: 4.3% in women and 2.4% in men. We found no association between subjects with multiple radiological signs indicative of dysplasia and BMI, Beighton score, EQ-5D or WOMAC. Although there appears to be a high prevalence of hip dysplasia among 19-year-old Norwegians, this is dependent on the radiological parameters applied.**

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Hip dysplasia results in altered mechanical conditions that predispose to the development of osteoarthritis (OA) and the subsequent need for a total hip replacement.[1] In Norway, 8% of all primary hip replacements are as a result of hip dysplasia, whereas in the other Nordic countries the corresponding number is about 2%.[2,3] This may indicate a high prevalence of hip dysplasia in Norway, but the true prevalence in skeletally mature Norwegians is unknown. The reported prevalence of adult hip dysplasia varies according to gender, ethnicity or threshold values derived from different radiological measurements. However, in general Caucasians have a prevalence of hip dysplasia in the region of 3% to 4%,[1,4-7] and females have a higher prevalence than males.[8]

Pain and loss of function are commonly reported symptoms for patients with a dysplastic hip and hip OA.[9] This may affect the quality of life, which can be assessed by instruments such as the EuroQol EQ-5D[10] and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).[11] Clinical examination may demonstrate an effect on the range of movement of the hip.

The aims of this study were to report on the prevalence of different radiological findings indicating hip dysplasia assessed at skeletal maturity in the general population in Norway, and to assess associations with clinical findings and self-reported quality of life.

## Patients and Methods

**Study population and design**. Between 2007 and 2009, 4006 19-year-old Norwegians were written to and invited to participate in a long-term clinical and radiological follow-up of a randomised hip study[12] (Fig. 1). The initial cohort for the study comprised all 5068 newborn babies delivered at Haukeland University Hospital during 1989, but 1062 subjects were excluded from the follow-up due to death (n = 61), emigration (n = 256), or because they did not live in the catchment area of our hospital at follow-up (n = 745). Of the 4006 subjects invited for the follow-up, 2081 agreed to participate. A further eight subjects (seven women) were excluded because of missing radiographs, seven because of uncertain pregnancy status, and one because of recently taken pelvic radiographs. A further subject had severe deformities as a result of cerebral palsy, resulting in a radiograph of suboptimal quality. The follow up-study included a clinical examination, two

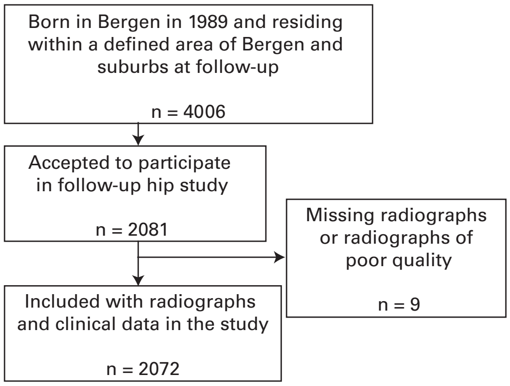



Fig. 1

Flow of participants in the study.

radiographs of the pelvis, two questionnaires and an optional saliva sample for later genetic analysis.

**Radiographs and radiological parameters of hip dysplasia**. The radiological examination was performed at the Department of Radiology, Haukeland University Hospital, by a single specially trained radiographer (ST) using a low-dose digital radiography technique (Digital-Diagnost System v1.5; Philips Medical Systems, Hamburg, Germany). All male participants were offered a gonadal shield. Two standardised views were obtained, one weight-bearing anteroposterior (AP) view and one supine frog-leg view. For this study we used an erect AP pelvic radiograph, taken with the feet pointing forward, in neutral femoral ab-/adduction, at a distance of 1.2 m from the x-ray source to the film and the beam centred 2 cm above the pubic symphysis.

Following several calibration sessions, all radiographs were assessed independently by one of three observers (IØE, LBL, TGL) using a digital measurement program.[13,14] Four measurements commonly used for the assessment of hip dysplasia were taken: Sharp's angle,[15] Wiberg's centre-edge (CE) angle,[16] the femoral head extrusion index (FHEI)[17] and acetabular depth:width ratio (ADR)[18] (Fig. 2). In addition, each hip was subjectively judged as being normal, mildly or moderately dysplastic, based on the outline of the subchondral bone condensation in the acetabular roof, named the sourcil.[19]

The acetabular anatomy was assessed by Sharp's angle and the ADR, and the position of the femoral head relative to the acetabular cavity was described by Wiberg's CE angle and the FHEI[17] (Fig. 2). A Sharp's angle > 45°, an ADR ≤ 250 and a FHEI < 75% were used as cut-off values as described in the literature.[18] For the CE angle cut-off values of < 25° and < 20° were used.[16,18]

**Clinical examination**. The clinical examination was performed by one of five physicians (IØE, LBL, TGL, LBE, AMH), who were blinded to the results of the questionnaires and the radiographs. A protocol including height, weight, assessment of hip range of movement as well as Beighton score[20] for joint laxity was performed. The maximum Beighton score is 9, and ≥ 4 points indicates joint hypermobility.[21] Flexion, abduction and adduction were measured with the subject supine, whereas extension and internal and external rotation were measured prone with 90° of knee flexion.

**Questionnaires**. A questionnaire addressing hip-related problems was completed before the visit to the department, and a second questionnaire was filled in on arrival; this included a question on hip pain during the last three months, the EQ-5D and the WOMAC.

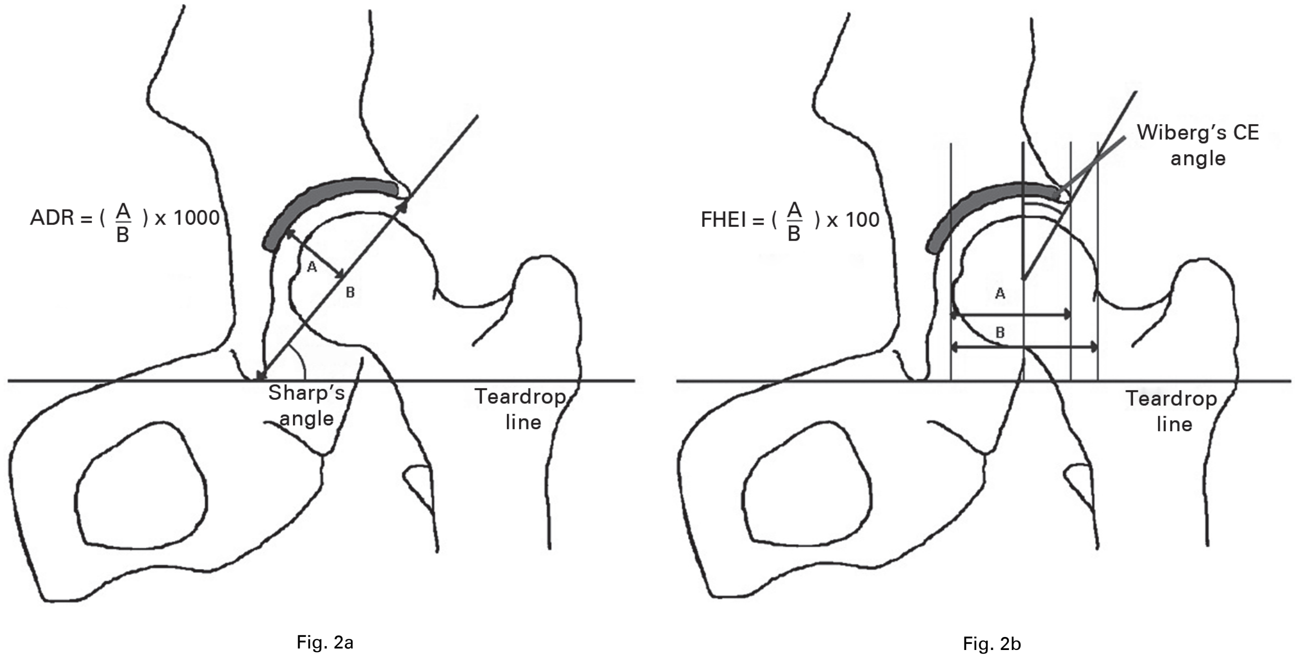
**Ethical approval**. The project was approved by the Medical Research Ethics Committee of Western Region of Norway. All participants provided written informed consent according to the Helsinki declaration. A total of 15 subjects presenting with uncertain or severe clinical and/or radiographic findings related to hip, back or pelvic pathology were immediately scheduled for a radiological review and/or recalled for a consultation.

**Statistical analysis**. Data were summarised using means and ranges. Comparison of mean values was performed using independent samples *t*-tests, and $p < 0.05$ was considered statistically significant. The relationship between different continuous variables was analysed using linear regression with the correlation coefficient R. The chi-squared test was used to compare categorical data within the cohort related to the radiological dysplasia findings or gender. In order to adjust for non-responders in the calculation of prevalences, we calculated inverse probability weights (IPW) based on a logistic regression model including gender, birth weight, maternal age, marital status, parity, fetal position and multiple births as covariates.[22] The statistical package PASW Statistics 18 (IBM, Armonk, New York) for Microsoft Windows (Microsoft Corp., Redmond, Washington) and Stata Statistical Software, release 11 (StataCorp, College Station, Texas) were used for the statistical analysis.

## Results

A total of 2072 subjects (1199 women (58%)) with a mean age 18.6 years (17.3 to 20.2) with radiographs and clinical data were included in the study (Fig. 1). The established threshold values for variables to predict hip dysplasia corresponded well with the 2.5 or 97.5 percentiles found in our population-based cohort (Table I). The prevalence of hip dysplasia varied between 1.7% and 20% according to the radiographic measurements used (Table II). All parameters except the ADR yielded a higher prevalence for females than for males (Table II).

**Radiological findings associated with hip dysplasia**. Acetabular shape was assessed by Sharp's angle and the ADR. A total of 300 left hips (15%) and 316 right hips (15%) were considered abnormal based on at least one of the two measurements (Fig. 3), whereas only 15 left hips (0.72%) and 21 right hips (1.0%) met both criteria (R = 0.019 (left); R = 0.027 (right)).




Diagrams showing the measurement of the radiological parameters. Figure 2a – Sharp's angle is defined as the angle between the horizontal teardrop line and a line through the inferior teardrop point and the lateral rim of acetabulum, and the acetabular depth:width ratio (ADR) as the ratio of the distance between the inferior teardrop point and the lateral acetabular rim, and the depth of the acetabulum. Figure 2b – Wiberg's centre–edge (CE) angle describes the angle between a line perpendicular to the horizontal teardrop line drawn through the centre of the femoral head, and a line from the centre of the head to the lateral edge of the acetabulum, and the femoral head extrusion index (FHEI) assesses the percentage of the femoral head to a line from the medial margin of caput to the lateral acetabular edge.

When based on subjective evaluation of the sourcil shape alone, 27 left (1.3%) and 24 right hips (1.2%) were considered mildly or moderately dysplastic.

Measurements for the position of the femoral head relative to the acetabulum were examined using Wiberg's centre-edge (CE) angle and the femoral head extrusion index (FHEI). Of the women, 276 (23%) had at least one hip with a CE angle < 25°, and 52 (4.3%) had an angle < 20°. Using a cut-off value of 20° for the CE angle, 59 left hips (2.8%) and 94 right hips (4.5%) were judged to be pathological for at least one of the two positional measurements; 41 left hips (2.0%) and 32 right hips (1.5%) met both criteria ($R = 0.839$ (left); $R = 0.873$ (right)) (Fig. 3).

An analysis of the interrelation between the three groups of parameters (measurements describing: 1) the shape of acetabulum; 2) the position of the femoral head with regard to the acetabular cavity; and 3) subjective evaluation of the sourcil, is shown in Figure 3. A moderate to good overlap was seen between parameters describing the position of the femoral head in relation to the acetabulum and the group describing the acetabular shape. Only four of the 2072 left hips and two of the 2072 right hips were judged as dysplastic according to the sourcil shape but they had normal values for both the other parameter groups.

The prevalence of hip dysplasia by the number of criteria met is listed in Table III. In all, 75% of the cohort had normal values for all five dysplasia markers, and 0.45% met all five criteria for dysplasia (0.27% of the men and 0.65% of the women).

**Association between radiological and clinical findings indicating hip dysplasia**. The associations between radiological findings, clinical findings and patients self-reported health problems are presented in Table IV. The range of hip movement was increased for all movements in women compared with men (all $p \le 0.015$), except for external rotation, which was significantly decreased compared with men ($p < 0.001$). Subjects with a pathological Sharp's angle (< 45°) had an increased internal rotation (mean difference 6.1°, $p < 0.001$) and decreased external rotation (mean difference 5.6°, $p < 0.001$) compared with those with a normal Sharp's angle. Similar findings were observed for the CE angle at both thresholds (< 20° and < 25°), and for FHEI (right hip only).

A Beighton score of ≥ 4 indicating joint hypermobility was more common in women (28%) than in men (10%) (chi-squared test, $p < 0.001$). We found no association between Beighton score and the number of radiological dysplasia criteria met (chi-squared test, $p = 0.30$), but participants with a pathological Sharp's angle were more prone to have joint hypermobility than those with a normal Sharp's angle (chi-squared test, $p < 0.001$).

A total of 483 (23%) of the participants were classified as overweight, with a body mass index (BMI) ≥ 25 kg/m$^2$. No differences were found between gender (chi-squared test, $p = 0.33$) and number of radiological criteria for hip dysplasia (chi-squared test, $p = 0.90$).

The EQ-5D quality of life assessments identified women as having a lower mean score than men (91 (26 to 100) *versus*

**Table I.** The cut-off values used as defined in the literature, compared with 2.5 percentiles (centre-edge (CE) angle, acetabular depth-width ratio (ADR) and femoral head extrusion index (FHEI)) or 97.5 percentiles (Sharp's angle) in our cohort

| | Right hip | Left hip | Cut-off value |
|---|---|---|---|
| CE angle (°) | 20.1* | 20.9* | 20.0 |
| Sharp's angle (°) | 46.9† | 47.3† | 45.0 |
| ADR | 233.8* | 234.4* | 250.0 |
| FHEI (%) | 73.7* | 74.9* | 75.0 |

* 2.5 percentile
† 97.5 percentile

**Table II.** Prevalence of the various radiological markers suggestive of hip dysplasia for the whole cohort and for male and female subgroups (CI, confidence interval)

| | Prevalence (%, 95% CI) | | | | |
|---|---|---|---|---|---|
| Parameter* | Right hip | Left hip | Unilateral | Bilateral | Total |
| WHOLE COHORT (n = 2072) | | | | | |
| Sharp's angle > 45° | 7.5 (6.4 to 8.6) | 6.7 (5.7 to 7.8) | 11 (9.8 to 12) | 1.6 (1.1 to 2.1) | 13 (11 to 14) |
| ADR ≤ 250 | 8.3 (7.0 to 9.5) | 7.8 (6.6 to 9.0) | 8.7 (7.4 to 9.9) | 3.7 (2.9 to 4.6) | 12 (11 to 14) |
| CE angle < 20° | 2.3 (1.7 to 3.0) | 1.5 (1.0 to 2.0) | 2.8 (2.1 to 3.5) | 0.5 (0.2 to 0.8) | 3.3 (2.5 to 4.1) |
| CE angle < 25° | 14 (12 to 15) | 12 (10 to 13) | 14 (12 to 15) | 5.9 (4.9 to 6.9) | 20 (18 to 21) |
| FHEI ≥ 25% | 4.0 (3.2 to 4.9) | 2.6 (1.9 to 3.3) | 4.9 (4.0 to 5.9) | 0.8 (0.5 to 1.2) | 5.8 (4.7 to 6.8) |
| Dysplastic sourcil shape | 1.1 (0.7 to 1.6) | 1.2 (0.7 to 1.7) | 1.0 (0.6 to 1.4) | 0.7 (0.3 to 1.0) | 1.7 (1.1 to 2.2) |
| MALE COHORT (n = 873) | | | | | |
| Sharp's angle > 45° | 3.8 (2.5 to 5.1) | 2.9 (1.7 to 4.0) | 6.0 (4.4 to 7.6) | 0.3 (-0.04 to 0.7) | 6.4 (4.7 to 8.0) |
| ADR ≥ 250 | 8.7 (6.7 to 11) | 8.1 (6.2 to 9.9) | 9.3 (7.3 to 11) | 3.7 (2.4 to 5.0) | 13 (11 to 15) |
| CE angle < 20° | 1.6 (0.8 to 2.5) | 1.1 (0.4 to 1.8) | 2.0 (1.1 to 3.0) | 0.3 (-0.05 to 0.8) | 2.4 (1.4 to 3.4) |
| CE angle < 25° | 12 (9.4 to 14) | 10 (7.8 to 12) | 11 (8.7 to 13) | 5.3 (3.8 to 6.8) | 16 (14 to 19) |
| FHEI ≥ 25% | 3.6 (2.3 to 4.8) | 2.4 (1.4 to 3.5) | 4.4 (3.0 to 5.9) | 0.8 (0.2 to 1.4) | 5.2 (3.7 to 6.7) |
| Dysplastic sourcil shape | 0.8 (0.1 to 1.4) | 0.7 (0.1 to 1.3) | 0.7 (0.1 to 1.3) | 0.4 (-0.06 to 0.9) | 1.1 (0.4 to 1.8) |
| FEMALE COHORT (n = 1199) | | | | | |
| Sharp's angle > 45° | 11 (9.6 to 13) | 11 (9.1 to 13) | 17 (14 to 18) | 2.9 (1.9 to 3.8) | 19 (17 to 22) |
| ADR ≤ 250 | 7.9 (6.3 to 9.4) | 7.6 (6.1 to 9.1) | 8.0 (6.5 to 9.6) | 3.7 (2.6 to 4.8) | 12 (9.9 to 14) |
| CE angle < 20° | 3.0 (2.0 to 4.0) | 2.0 (1.2 to 2.7) | 3.6 (2.5 to 4.6) | 0.7 (0.2 to 1.2) | 4.3 (3.1 to 5.4) |
| CE angle < 25° | 16 (14 to 18) | 14 (12 to 15) | 17 (14 to 18) | 6.6 (5.2 to 8.0) | 23 (21 to 26) |
| FHEI ≥ 25% | 4.5 (3.4 to 5.7) | 2.7 (1.8 to 3.6) | 5.4 (4.1 to 6.7) | 0.9 (0.4 to 1.4) | 6.3 (5.0 to 7.7) |
| Dysplastic sourcil shape | 1.5 (0.8 to 2.2) | 1.7 (1.0 to 2.4) | 1.3 (0.7 to 2.0) | 0.9 (0.4 to 1.5) | 2.3 (1.4 to 3.1) |

* ADR, acetabular depth to width ratio; FHEI, femoral head extrusion index; CE angle, Wiberg's centre-edge angle

94 (21 to 100)) (*t*-test, p < 0.001), but we found no association between EQ-5D-score and radiological findings (*t*-test, p = 0.21). The same tendency was seen for the WOMAC score, with women yielding a higher score than men (26 (24 to 69) *versus* 25 (24 to 92); *t*-test, p = 0.015), thereby indicating a poorer level of functioning. A total of 109 participants (5.3%) reported some problems with their right hip in the previous three months, more frequently in women (7.3%) than in men (2.4%) (chi-squared test, p < 0.001).

## Discussion

In a cohort of 19-year-old Norwegians we have shown that the prevalence of hip dysplasia varies between 1.7% and 20% depending on which radiological measurements are used. Women had a more steeply inclined acetabulum and less femoral head coverage than men.

Numerous studies have reported on the prevalence of hip dysplasia,[1,4,6,26] but most have addressed newborn babies and infants. Defining hip dysplasia in adults is difficult when several radiological measurements provide various threshold values (Table V). Our study shows that the prevalence varies greatly according to which parameter is applied. Wiberg's CE angle[16] is one of the most used markers and describes the position of the femoral head with respect to the acetabulum, but cut-off values of 20° and 25° have been used in the literature to describe a hip believed to be dysplastic.[18] In our cohort 3.3% (2.4% men and 4.3% women) had a CE angle < 20°, and as many as 20% (16% men and 23% women) had an angle < 25°. These results compare well with findings of a longitudinal Danish health survey, which included 4151 participants aged between 22 and 93 years[1] (Table V) where the prevalence of Wiberg's CE angle < 20° was 3% to 4% for both males and females. Other studies, using a cut-off of 25°,[4-7,23-28] report a prevalence among Caucasians ranging from 2.4% to 5.6% for females and 1.8% to 4.0% for males. This is markedly less frequent than our findings. Studies on Japanese populations[5,26] report a prevalence from 12% to 19% for


Fig. 3

Diagrams showing the relationships between the different radiological measurements suggestive of hip dysplasia. Sharp's angle and the acetabular depth:width ratio (ADR) describe the shape of the acetabulum and Wiberg's centre-edge (CE) angle and the femoral head extrusion index (FHEI) describe the position of the femoral head with regard to the acetabular cavity.

females and 5% to 16% for males using a cut-off of 25°, which is more comparable with our findings.

Jacobsen et al[1] reported a pathological Sharp's angle (> 45°) in about 8% of females and 3% of males. A slightly increased prevalence was found in our cohort for females (11%), but similar findings were found for males. The ADR and the FHEI prevalence in our study are similar to the Danish study.[1]

An increase in femoral anteversion is commonly seen in dysplastic hips[29] and results in increased internal rotation on clinical examination. This is supported by our findings (Table IV). No clinical differences were found for the other movements. Excessive joint laxity in children with hip dysplasia is described[30] and results in an increased Beighton score. However, this was not confirmed in our cohort where we only found a difference between genders.

We acknowledge some limitations to our study. First, all subjects who took part also participated in a randomised hip study on different screening strategies for hip dysplasia in the newborn.[12] This might influence our results, as it is more likely that persons with previous or present hip

**Table III.** The distribution of the number of dysplasia markers (Wiberg's centre-edge (CE) angle, Sharp's angle, femoral head extrusion index, acetabular depth:width ratio and sourcil shape) in the cohort. The total numbers are based on the worst hip for each patient (CI, confidence interval)

| | Distribution (%, 95% CI) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Males (n = 873) | | | Females (n = 1199) | | | |
| Findings indicating dysplasia of the hip (n) | Right hip | Left hip | Total | Right hip | Left hip | Total | Total |
| 0 | 86 (84 to 89) | 89 (86 to 91) | 80 (77 to 83) | 81 (79 to 83) | 82 (80 to 84) | 70 (68 to 73) | 75 (73 to 77) |
| 1 | 11 (8.8 to 13) | 9.3 (7.3 to 11) | 16 (13 to 18) | 14 (12 to 16) | 15 (13 to 17) | 22 (20 to 25) | 19 (17 to 21) |
| 2 | 1.9 (0.99 to 2.8) | 1.1 (0.37 to 1.8) | 2.6 (1.5 to 3.7) | 2.4 (1.5 to 3.3) | 1.7 (1.0 to 2.4) | 3.6 (2.5 to 4.6) | 3.1 (2.3 to 3.8) |
| 3 | 0.54 (0.06 to 1.0) | 0.79 (0.20 to 1.4) | 1.1 (0.41 to 1.8) | 1.3 (0.68 to 2.0) | 1.0 (0.42 to 1.5) | 2.1 (1.3 to 2.9) | 1.6 (1.0 to 2.1) |
| 4 | 0.33 (-0.05 to 0.70) | 0.22 (-0.09 to 0.52) | 0.44 (0.01 to 0.9) | 0.92 (0.01 to 0.68) | 0.39 (0.05 to 0.74) | 1.0 (0.43 to 1.5) | 0.71 (0.35 to 1.1) |
| 5 | 0.16 (-0.16 to 0.48) | 0.10 (-0.10 to 0.30) | 0.27 (-0.11 to 0.6) | 0.34 (0.01 to 0.68) | 0.39 (0.05 to 0.74) | 0.65 (0.20 to 1.1) | 0.45 (0.16 to 0.75) |

**Table IV.** Mean outcome values related to radiological findings indicating hip dysplasia. Radiological findings of dysplasia were also related to the proportion of the cohort with an increased Beighton score (≥ 4) or body mass index (BMI) > 25 kg/m$^2$. p-values were determined using the chi-squared test for Beighton score, BMI and hip pain last three months, and with the two-sided independent samples *t*-test for all other characteristics

| | Total cohort | | | | Number of radiological dysplasia criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outcome* | All (n = 2072) | Females (n = 1199) | Males (n = 873) | p-value† | 0 (n = 1548) | 1 to 2 (n = 463) | ≥ 3 (n = 61) | p-value‡ | Sharp's angle > 45° (n = 288) | p-value§ | Wiberg's CE angle < 20° (n = 73) | p-value§ |
| Mean EQ-5D (range) | 92 (21 to 100) | 91 (26 to 100) | 94 (21 to 100) | < 0.001 | 92 (30 to 100) | 91 (21 to 100) | 94 (48 to 100) | 0.21 | 92 (21 to 100) | 0.51 | 94 (48 to 100) | 0.093 |
| Mean WOMAC (range) | 26 (24 to 92) | 26 (24 to 69) | 25 (24 to 92) | 0.015 | 25 (24 to 92) | 26 (24 to 74) | 25 (24 to 60) | 0.68 | 26 (24 to 74) | 0.11 | 25 (24 to 60) | 0.33 |
| Beighton score ≥ 4 (%) | 21 | 28 | 10 | < 0.001 | 19 | 25 | 25 | 0.30 | 29 | < 0.001 | 27 | 0.14 |
| BMI > 25 kg/m$^2$ (%) | 23 | 23 | 24 | 0.33 | 24 | 22 | 25 | 0.90 | 21 | 0.22 | 22 | 0.77 |
| Mean ROM (°) (range)¶ | | | | | n = 1727 | n = 305 | n = 40 | | n = 171 | | n = 50 | |
| ROM | 346 (230 to 450) | 352 (265 to 450) | 337 (230 to 420) | 0.015 | 345 (255 to 450) | 349 (230 to 420) | 349 (315 to 390) | 0.26 | 351 (230 to 420) | 0.004 | 350 (310 to 395) | 0.22 |
| Adduction | 39 (20 to 60) | 39 (20 to 60) | 39 (20 to 60) | 0.014 | 39 (20 to 60) | 39 (20 to 50) | 39 (30 to 45) | 0.44 | 39 (20 to 50) | 0.33 | 39 (30 to 45) | 0.47 |
| Abduction | 61 (30 to 100) | 62 (40 to 100) | 59 (30 to 80) | < 0.001 | 61 (40 to 100) | 62 (30 to 80) | 61 (40 to 70) | 0.60 | 62 (30 to 80) | 0.032 | 62 (40 to 80) | 0.41 |
| Flexion | 121 (80 to 160) | 123 (90 to 160) | 118 (80 to 150) | < 0.001 | 121 (80 to 160) | 123 (90 to 150) | 121 (100 to 140) | 0.93 | 124 (90 to 150) | 0.001 | 122 (100 to 140) | 0.84 |
| Extension | 27 (10 to 55) | 28 (15 to 55) | 26 (10 to 50) | < 0.001 | 27 (5 to 55) | 27 (10 to 50) | 29 (20 to 35) | 0.078 | 28 (10 to 50) | 0.10 | 28 (20 to 35) | 0.15 |
| Internal rotation | 47 (10 to 85) | 53 (10 to 85) | 39 (10 to 80) | < 0.001 | 46 (10 to 85) | 49 (20 to 80) | 53 (30 to 70) | 0.002 | 52 (20 to 80) | < 0.001 | 53 (20 to 80) | 0.002 |
| External rotation | 51 (10 to 80) | 46 (10 to 80) | 57 (10 to 80) | < 0.001 | 51 (15 to 80) | 49 (10 to 80) | 46 (20 to 80) | 0.014 | 46 (10 to 80) | < 0.001 | 46 (20 to 80) | 0.013 |
| Hip pain last three months (%)¶ | 5.3 | 7.3 | 2.4 | < 0.001 | 4.9 | 7 .2 | 7.5 | 0.421 | 7.8 | 0.16 | 8.3 | 0.37 |

* EQ-5D, EuroQol 5 Dimensions; WOMAC, Western Ontario and McMaster Universities osteoarthritis index; BMI, body mass index; ROM, range of movement
† females compared with males
‡ 0 radiological criteria *versus* ≥ 3 radiological markers
§ participants with an pathological angle compared with participants with a normal angle
¶ for 'range of movement' and 'hip pain in the last three months' the results are presented for the right hip

problems would participate in a follow-up study. However, the baseline characteristics for the same cohort analysed in a former publication[31] revealed no clinically important differences, however more females responded to this survey.

A second potential limitation is that three independent observers read the radiographs and five independent physicians performed the clinical examinations. Including more observers increases the risk of introducing bias. For the radiological measurements, a detailed calibration process was carried out and the inter- and intra-observer variability demonstrated only minor differences.[13]

In conclusion, our study shows a high prevalence of hip dysplasia among 19-year-old Norwegians, but we found large differences in the prevalence depending on the radiological measurements used. However the inference that prevalence of hip dysplasia is high in Norway is in agreement with findings from the Nordic Arthroplasty Register Association, showing a higher incidence of total hip replacement due to hip dysplasia in Norway than in the other Scandinavian countries.[2,3]

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