■ HIP

Radiological findings that may indicate a prior silent slipped capital femoral epiphysis in a cohort of 2072 young adults

T. G. Lehmann,
I. Ø. Engesæter,
L. B. Laborie,
S. A. Lie,
K. Rosendahl,
L. B. Engesæter

From Haukeland University Hospital, Department of Orthopaedic Surgery, Bergen, Norway

The reported prevalence of an asymptomatic slip of the contralateral hip in patients operated on for unilateral slipped capital femoral epiphysis (SCFE) is as high as 40%. Based on a population-based cohort of 2072 healthy adolescents (58% women) we report on radiological and clinical findings suggestive of a possible previous SCFE. Common threshold values for Southwick's lateral head–shaft angle (≥ 13°) and Murray's tilt index (≥ 1.35) were used. New reference intervals for these measurements at skeletal maturity are also presented.

At follow-up the mean age of the patients was 18.6 years (17.2 to 20.1). All answered two questionnaires, had a clinical examination and two hip radiographs.

There was an association between a high head–shaft angle and clinical findings associated with SCFE, such as reduced internal rotation and increased external rotation. Also, 6.6% of the cohort had Southwick's lateral head–shaft angle ≥ 13°, suggestive of a possible slip. Murray's tilt index ≥ 1.35 was demonstrated in 13.1% of the cohort, predominantly in men, in whom this finding was associated with other radiological findings such as pistol-grip deformity or focal prominence of the femoral neck, but no clinical findings suggestive of SCFE.

This study indicates that 6.6% of young adults have radiological findings consistent with a prior SCFE, which seems to be more common than previously reported.

Cite this article: *Bone Joint J* 2013;95-B:452–8.

Slipped capital femoral epiphysis (SCFE) is one of the most common hip disorders in adolescents,[1] typically diagnosed between 11 and 15 years of age.[2] Known risk factors are male gender, high body mass index (BMI), endocrine disorders such as hypothyroidism, hypogonadism or growth hormone supplement, and a family history of SCFE.[3,4] The reported incidence varies from four to 80 per 100 000 according to ethnicity and method of ascertainment.[2,5,6]

The association between SCFE and the development of degenerative changes has been shown in several previous reports.[7-10] Murray[9] stated that even a minor silent slip may lead to tilt deformities presenting as an idiopathic osteoarthritis (OA) later in life. However, his view was opposed by Resnick,[11] who claimed that the tilt deformity occasionally seen in some patients with OA is more likely to be secondary to degenerative change. In a recent study on 67 patients with SCFE,[12] we showed that approximately half had radiological findings suggestive of a bilateral slip, of which more than one-third were asymptomatic. The diagnosis was based on radiological findings, including a Southwick's lateral head–shaft angle ≥ 13°.[13,14] Jerre et al[14] found in a series of 100 patients that up to two-thirds of those with bilateral SCFE had an asymptomatic slip on the contralateral side at later follow-up, based on a slip angle of > 13°.

In this study we report on the prevalence of radiological findings suggestive of a previous SCFE, based on the commonly used cut-off values for Southwick's lateral head–shaft angle[3,14] and Murray's tilt index[9] and also present new reference intervals for measurements commonly used for the diagnosis of SCFE.

Patients and Methods

Between 2007 and 2009, 4006 adolescents born in 1989 were approached by letter and invited to participate in a long-term clinical and radiological follow-up of a randomised hip trial.[15] The initial cohort comprised all 5068 newborns delivered at Haukeland University Hospital, Bergen, Norway, during the year 1989. A total of 1062 subjects were excluded from the follow-up owing to death (n = 61), emigration (n = 256), or because they did not live in the catchment area defined for the study (n = 745). A total of 2081 (52%)

■ T. G. Lehmann, MD, PhD, Resident, Orthopaedic Department
■ I. Ø. Engesæter, MD, Research Fellow
■ L. B. Engesæter, MD, PhD, Professor, Orthopaedic Surgeon
University of Bergen, Department of Surgical Sciences, and Haukeland University Hospital, Department of Orthopaedic Surgery, Jonas Lies vei 65, 5021 Bergen, Norway.

■ L. B. Laborie, MD, Research Fellow
■ K. Rosendahl, MD, PhD, Professor, Radiologist
University of Bergen, Department of Surgical Sciences, and Haukeland University Hospital, Department of Radiology, Jonas Lies vei 65, 5021 Bergen, Norway.

■ S. A. Lie, PhD, Professor
University Research Bergen, Department of Health, Norway.

Correspondence should be sent to Mrs T. G. Lehman; e-mail: trude.gundersen.lehmann@helse-bergen.no

©2013 The British Editorial Society of Bone and Joint Surgery
doi:10.1302/0301-620X.95B4.29910 $2.00

Bone Joint J
2013;95-B:452–8.
Received 24 April 2012; Accepted after revision 28 December 2012

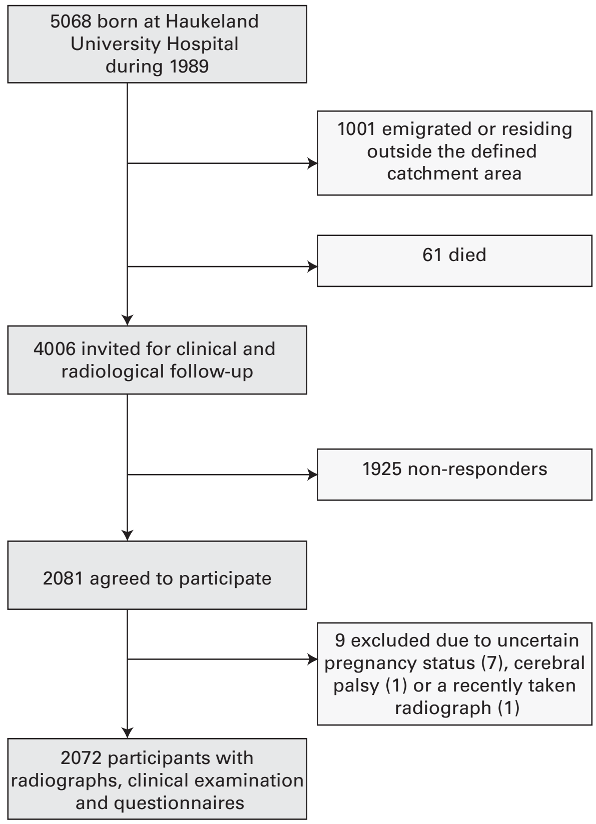

Fig. 1

Flow of participants in the study.

agreed to participate, of whom 1207 (58%) were women. However, seven women were excluded because of uncertainty about their pregnancy status, one woman because of a subluxed hip related to severe cerebral palsy, and one man because of recently taken pelvic radiographs (Fig. 1).

The follow-up at 18 to 20 years of age included two questionnaires, two hip radiographs and a clinical examination.

Questionnaires. The first questionnaire addressed hip problems in parents and siblings; the second included data on hip pain, walking disabilities, training habits, quality of life according to the EuroQol EQ-5D self-reported assessment,[16] and the Western Ontario and McMaster Universities (WOMAC) osteoarthritis index.[17] The EQ-5D scored mobility, personal hygiene, usual activities, pain/discomfort, and anxiety/depression on a three-level scale (no problem, some problems and severe problems). The resulting scores were translated into an EQ-5D index, with a maximum score of 100. Death scores 0 and conditions worse than death yield a negative score (EQ-5D index < 0).

The WOMAC index is a three-dimensional patient-centred health status questionnaire designed to capture elements of pain, stiffness and physical disability in patient with OA of the hip. The index is calculated from 24 five-level questions, giving a score between 0 (high achiever) and 96 (poor achiever).

For physical exercise the subjects were asked to estimate hours a week with activity that made them sweat or breathless (none, half an hour, one hour, two to three hours, four to six hours or > six hours).

Radiographs. All examinations were performed at the Radiological Department, Haukeland University Hospital, using a low-dose technique (Digital Diagnost System v1.5; Philips Medical Systems, Eindhoven, The Netherlands). Two views were obtained, an erect anteroposterior (AP) view (feet pointing forward, neutral ab-/adduction position of the hips)[18] and a frog-leg view, using a film–focus distance of 1.2 m and centred at 2 cm proximal to the pubis. All examinations were performed by the same, specially trained radiographer according to a standardised protocol. The images were analysed by one observer (LBL) measuring the lateral head–shaft angle (frog-leg view)[19] (Fig. 2) and Murray's tilt index (AP view)[9] (Fig. 3), and new reference intervals were established based on the upper 95% reference interval (representing 1.96 standard deviations (SD) from the mean) of our cohort. In order to examine prevalences of radiological findings suggestive of a previous slipped epiphysis, we used cut-off values of 13° for the head–shaft angle[13,14] and 1.35 for the tilt index[9] according to the literature. In a separate session, the radiographs were

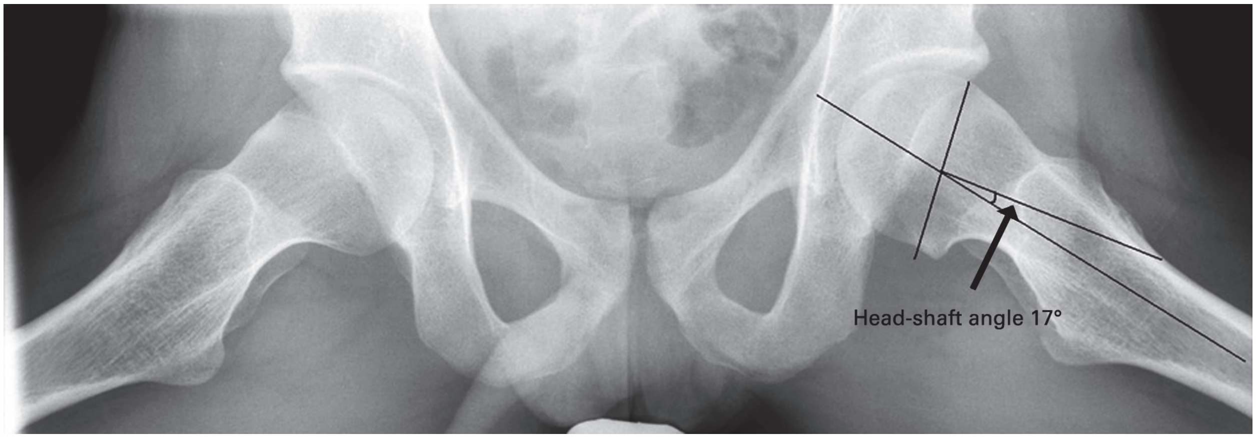

Fig. 2

Frog-leg radiograph showing the measurement of Southwick's lateral head–shaft angle.

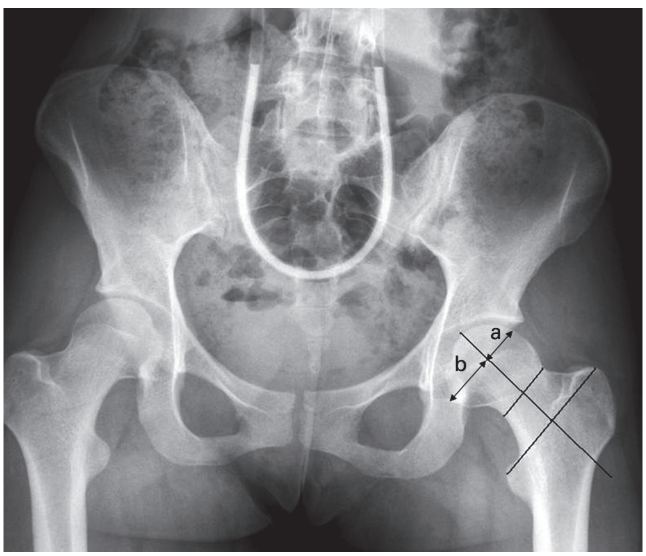

Fig. 3

Anteroposterior radiograph showing the measurement of Murray's tilt index, defined by the ratio b/a.

analysed subjectively by one experienced radiologist (KR). The following features suggestive of SCFE were assessed by gross visual inspection: pistol-grip deformity, focal prominence of the femoral neck, and flattening of the lateral aspect of the femoral head. In a third session, all examinations were measured by one of three observers (TGL, IØE or LBL) using a digital program, including three measurements of the joint space width: medially, in the middle and laterally.[20,21] A joint space width ≤ 2.0 mm was suggestive of degenerative changes.[22]

Clinical examination. The clinical examinations, which were performed by one of five specially trained physicians, included height, weight, leg length differences, hip mobility, Beighton's hypermobility score,[23] range of movement of the hip and an impingement test in flexion, adduction and internal rotation. All physicians standardised their examination technique prior to the study.

Ethics. The procedures followed were approved by the Regional Committee for Medical and Health Research Ethics and the Norwegian Data Inspectorate. Written informed consent was obtained from all the participants. A total of nine participants were scheduled for immediate follow-up by a senior radiologist (KR) and a senior orthopaedic surgeon (LBE) because of clinical or radiological findings related to the hip, pelvis or lumbosacral spine.

Statistical analysis. Data were summarised using mean and range. Continuous variables were compared using independent samples *t*-tests and chi-squared and Fisher's exact tests for categorical variables. A significance level of $p < 0.05$ was decided beforehand, and all the reported p-values were two-tailed. Associations between different radiological findings were analysed by calculating the odds ratio (OR) with 95% confidence intervals (CI) between each of the features separately, with an OR > 2.0 considered to indicate a clinically relevant association. In order to examine for significant differences in BMI by head–shaft angle, BMI was dichotomised as overweight (≥ 25 kg/m^2) or not.

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,[24] based on data from the Medical Birth Registry of Norway. Different sets of probability weights were made for each of the prevalence calculations, owing to slight differences in missing values between the measures. The statistical package PASW Statistics 18 (SPSS Inc., Chicago, Illinois) was used for the statistical analyses, and the survey tools in Stata Statistical Software: Release 11 (StataCorp, College Station, Texas) was used to calculate the prevalence estimates.

Table I. Radiological hip measurements in a population-based cohort of 2072 18- to 20-year-olds by gender

Hip measurements	Males (n = 873)	Females (n = 1199)	p-value*	Total (n = 2072)
Mean head–shaft angle (°) (range)				
Right hip (n = 1798)†	1.4 (-21 to 23)	0.6 (-22 to 20)	0.010	0.9 (-22 to 23)
Left hip (n = 1712)†	0.5 (-23 to 22)	-1.2 (-27 to 21)	< 0.001	-0.6 (-27 to 22)
Mean tilt index (range)				
Right hip (n = 2037)	1.1 (0.7 to 1.9)	1.0 (0.6 to 1.8)	< 0.001	1.1 (0.6 to 1.9)
Left hip (n = 2042)	1.1 (0.6 to 2.1)	1.0 (0.5 to 1.7)	< 0.001	1.0 (0.5 to 2.1)

* independent sample *t*-test
† number of successful measurements

Table II. Prevalence of radiological findings believed to be associated with a prior asymptomatic slipped capital femoral epiphysis in 2072 18- to 20-year-old healthy adolescents by side. Numbers were adjusted for non-responders (CI, confidence interval)

	Prevalence (%, 95% CI)				
Radiological findings	Right hip	Left hip	Left or right hip	Bilateral	Total
All participants					
Head–shaft angle ≥ 13°	3.9 (2.9 to 4.9)	3.1 (2.2 to 3.9)	4.2 (0.33 to 0.52)	1.0 (0.5 to 1.4)	6.6 (5.3 to 7.9)
Tilt index ≥ 1.35	8.9 (7.5 to 10.2)	6.6 (5.4 to 7.8)	10.5 (9.1 to 11.9)	2.4 (1.7 to 3.1)	13.1 (11.6 to 14.7)
Male participants					
Head–shaft angle ≥ 13°	4.4 (2.8 to 6.0)	3.4 (2.0 to 4.7)	4.7 (3.2 to 6.2)	1.1 (0.3 to 1.8)	7.6 (5.4 to 9.8)
Tilt index ≥ 1.35	13.5 (11.2 to 15.8)	10.5 (8.4 to 12.6)	15.3 (12.8 to 17.7)	4.2 (2.9 to 5.5)	19.9 (17.2 to 22.7)
Female participants					
Head–shaft angle ≥ 13°	3.4 (2.3 to 4.5)	2.7 (1.8 to 3.7)	3.8 (2.7 to 5.0)	1.0 (0.4 to 1.5)	5.5 (4.1 to 6.9)
Tilt index ≥ 1.35	4.0 (2.9 to 5.1)	2.5 (1.6 to 3.4)	5.3 (4.1 to 6.7)	0.5 (0.1 to 0.9)	6.0 (4.6 to 7.3)

Results

A total of 2072 subjects were included in the study, comprising 1199 women and 873 men (Fig. 1). Prevalences were adjusted for non-responders as described in the statistical analysis. The mean age at follow-up was 18.6 years (17.2 to 20.1). It was possible to measure the head–shaft angle in at least one hip in 1925 (93%) of the subjects, and bilaterally in 1588 (77%); the corresponding figures for the tilt index were 2056 (99%) and 2024 (98%), respectively.

The mean head–shaft angle was 0.9° (-22° to 23°) for right hips, -0.6° (-27° to 22°) for left and 0.2° (-27° to 23°) for all hips, with upper 95% reference intervals of 13.9°, 13.3° and 13.8°, respectively. Statistically significant differences were found between men and women (Table I). The mean tilt index was 1.1 (0.6 to 1.9) for right hips, 1.0 (0.5 to 2.1) for left hips and 1.0 (0.5 to 2.1) for both hips (Table I), with upper 95% reference intervals of 1.43, 1.42 and 1.43, respectively.

With prevalences adjusted for non-responders, head–shaft angles ≥ 13° were measured in 7.6% of the men, 5.5% of the women and 6.6% of the entire cohort, whereas a tilt index ≥ 1.35 was found in 19.9% of the men, 6.0% of the women and 13.1% of all (Table II). Only six subjects (four men) tested positive for both markers.

Mean age, BMI and self-reported information on health status, hip problems and exercise at follow-up as well as range of movement of the hip are listed in Tables III and IV. The mean BMI for males and females did not differ ($p = 0.05$), but was significantly higher (23.8 kg/m^2) in those with a head–shaft angle ≥ 13° than in those with lower angles (22.8 kg/m^2) ($p = 0.019$). The difference in BMI remained statistically significant only in men with high angles ($p = 0.035$, independent sample *t*-test), and not in women ($p = 0.13$, independent sample *t*-test). A BMI ≥ 25 kg/m^2 was seen in 32 (32%) of those with a head–shaft angle ≥ 13° *vs* 307 (21%) of those with an angle < 13° ($p = 0.007$, chi-squared test). However, both groups had a mean value below the threshold for overweight, and the clinical importance of this difference in BMI can be questioned. The mean internal hip rotation was decreased by 10° (range of internal rotation 10° to 90°) for persons with a high head–shaft angle compared with those with a low angle ($p < 0.001$, independent sample *t*-test), whereas the external rotation was increased by 7° (range of external rotation 0° to 80°) ($p < 0.001$, independent sample *t*-test). The differences in internal and external rotation remained statistically significant for both genders, except for left hip in men, where the reduction in internal rotation was not statistically significant (Table IV). No differences between groups were found for the remaining hip movements (Table IV), or for the degree of physical exercise undertaken. When based on our new 95% reference intervals for 18- to 20-year-olds, i.e. using a cut-off value of 14° for head–shaft angle, similar differences were noted for BMI ($p = 0.026$), increased external rotation ($p < 0.001$) and reduced internal rotation ($p < 0.001$, all independent sample *t*-tests).

Table III. Age, body mass index and self-reported information on health status, hip problems and exercise in a population-based cohort of 2072 18- to 20-year-olds, by gender. Differences between groups calculated using independent sample *t*-test for continuous variables and chi-squared test for categorical variables

Variable*	Males (n = 873)	Females (n = 1199)	p-value	Total (n = 2072)
Mean age (yrs) (range)	18.6 (17.2 to 20.1)	18.6 (17.2 to 20.1)	0.53	18.6 (17.2 to 20.1)
Mean body mass index (kg/m^2) (range)	23.3 (15.0 to 54)	23.0 (14.2 to 42.5)	0.05	23.2 (14.2 to 54.1)
Mean WOMAC (range)	1.3 (0 to 68)	2.0 (0 to 45)	0.002	1.6 (0 to 68)
Mean EQ-5D (range)	94 (21 to 100)	91 (26 to 100)	< 0.001	92 (21 to 100)
Hip problem ever (n, %)	49 (*5.6*)	153 (*12.8*)	< 0.001	201 (*9.7*)
Physical exercise ≥ two hours/week (n, %)	620 (*71*)	755 (*63*)	< 0.001	1388 (*67*)

* WOMAC, Western Ontario and McMaster Universities osteoarthritis index; EQ-5D, EuroQol five dimensions

Table IV. Mean values (range) for range of movement (ROM) of the hip for participants with head–shaft angle < 13° and ≥ 13°, by gender, presented for right and left hip. Differences between groups calculated using independent sample *t*-test

	Right hip				Left hip			
Mean ROM (°) (range)	Head–shaft angle < 13°	Head–shaft angle ≥ 13°	p-value	Whole cohort	Head–shaft angle < 13°	Head–shaft angle ≥ 13°	p-value	Whole cohort
Males								
Flexion	118 (80 to 150)	118 (100 to 140)	0.82	118 (80 to 150)	118 (80 to 150)	121 (110 to 140)	0.19	118 (80 to 150)
Extension	26 (-10 to 50)	27 (15 to 40)	0.78	26 (-10 to 50)	26 (-10 to 50)	27 (20 to 40)	0.33	26 (-10 to 50)
Abduction	59 (30 to 80)	59 (45 to 70)	0.55	59 (30 to 80)	59 (30 to 80)	60 (50 to 70)	0.29	59 (30 to 80)
Adduction	39 (20 to 60)	39 (30 to 50)	0.79	39 (20 to 60)	39 (20 to 60)	38 (20 to 50)	0.70	38 (20 to 60)
Internal rotation	40 (10 to 80)	33 (10 to 65)	0.002	39 (10 to 80)	40 (10 to 90)	35 (10 to 60)	0.20	39 (10 to 90)
External rotation	56 (10 to 80)	61 (30 to 80)	0.029	57 (10 to 80)	56 (0 to 80)	64 (30 to 80)	0.003	57 (0 to 80)
Females								
Flexion	123 (90 to 160)	122 (100 to 140)	0.36	123 (90 to 160)	123 (90 to 160)	123 (100 to 150)	0.92	123 (90 to 160)
Extension	28 (15 to 50)	28 (15 to 55)	0.94	28 (15 to 55)	28 (15 to 55)	27 (15 to 40)	0.94	28 (15 to 55)
Abduction	62 (40 to 100)	61 (50 to 70)	0.24	62 (40 to 100)	62 (40 to 100)	62 (45 to 80)	0.24	62 (40 to 100)
Adduction	39 (20 to 60)	39 (30 to 40)	0.41	39 (20 to 60)	39 (20 to 60)	37 (20 to 40)	0.10	39 (20 to 60)
Internal rotation	53 (10 to 85)	43 (20 to 75)	< 0.001	53 (10 to 85)	54 (10 to 80)	46 (20 to 70)	0.007	53 (10 to 80)
External rotation	46 (10 to 80)	54 (30 to 75)	< 0.001	46 (10 to 80)	45 (10 to 80)	52 (30 to 80)	0.004	46 (10 to 80)

Table V. Associations among subjectively identified radiological features with head–shaft angle and tilt index

	Head–shaft angle ≥ 13°		Tilt index ≥ 1.35	
Odds ratio of radiological feature (95% CI)	Right (n = 67)	Left (n = 52)	Right (n = 164)	Left (n = 123)
Pistol-grip deformity (n = 387)	0.6 (0.2 to -1.8)	0.6 (0.2 to 2.0)	4.3 (2.9 to 6.4)	3.0 (1.9 to 4.7)
Lateral flattening of femoral head (n = 325)	1.7 (0.8 to 3.7)*	1.5 (0.7 to 3.8)*	2.6 (1.7 to 4.2)	1.5 (0.8 to 2.6)*
Focal prominence of femoral neck (n = 186)	1.1 (0.3 to 3.6)*	0.5 (0.1 to 3.5)*	2.0 (1.1 to 3.8)	3.0 (1.6 to 5.4)*

* no females with both radiological findings

No differences in the mean BMI, mean range of hip movement or physical exercise levels were seen between those with a tilt index < or > 1.35 or 1.43 for either gender.

The relationships between the head–shaft angle and subjectively assessed radiological findings, such as pistol-grip deformity or a focal femoral neck prominence, did not reach significance according to our definition of an OR ≥ 2 (Table V). In contrast, tilt index was associated with a pistol-grip deformity, focal prominence of the femoral neck and lateral flattening (Table V).

No differences were seen in mean joint space width (JSW) between high and low head-shaft angle (mean middle JSW 3.7 mm *vs* 3.7 mm; p = 0.88), or high and low tilt index (mean middle JSW 3.6 mm *vs* 3.7 mm, p = 0.41)

The mean EQ-5D score was 92 (21 to 100) overall; for men alone the mean was 94 (21 to 100) and for women it was 91 (26 to 100) (p < 0.001) (Table III), with no significant differences according to head–shaft angle (p = 0.21) or tilt index (p = 0.63, all independent sample *t*-tests). The mean WOMAC score was 1.6 (0 to 68), with women scoring significantly higher (p = 0.002), but no difference was found with respect to the radiological measurements, high *vs* low head shaft angle (p = 0.17) or high *vs* low tilt index (p = 0.27, all independent sample *t*-tests). A total of 99 (4.9%) of the participants reported some problems with walking, but no relationship was found with high or low head–shaft angle (p = 0.81) or tilt index (p = 0.73, both Fisher's exact test).

A clicking sensation, stiffness, or pain in the hip was reported by 109 participants (5.4%) during the three months prior to review, but this was not associated with any radiological findings.

Discussion

In this cohort of healthy 18- to 20-year-old Norwegians we found an association between Southwick's head–shaft angle ≥ 13° and clinical findings common in patients with SCFE, such as reduced internal rotation, increased external rotation and a high BMI. Based on a cut-off value for head–shaft angle of ≥ 13°, 6.6% of the cohort (7.6% of men and 5.5% of women) had radiological findings indicating a previous slip. A high tilt index (≥ 1.35) demonstrated in 13.1% of the cohort was associated with additional radiological but no clinical findings suggestive of SCFE. With regard to BMI, both groups had a mean value below the limit of overweight, and the clinical relevance should be interpreted with care.

Our new reference intervals (of 1.96 SD from the mean) for the head–shaft angle and the tilt index in 18 to 20-year-olds support the commonly used cut-offs of 13° and 1.35, respectively.[13,14] The cut-off of 13° is based on studies addressing radiological findings of SCFE and not on population-based cohorts. For the purposes of comparison, we performed analysis based on commonly used cut-offs, and also searched for associations between known risk factors for, and clinical findings in keeping with, SCFE and the newly established values. The results from the two sets of analyses did not differ substantially.

Several authors have used the difference in head–shaft angle between pathological and healthy hips in the diagnosis of SCFE.[25-28] This approach may be flawed, as up to 60% of those suffering SCFE have bilateral involvement.[12,29,30] Of the different radiological measurements used to diagnose SCFE,[3,9,19,31] none of the measurements has proved superior with regard to intra- and inter-repeatability measurements.[32-34] Carney and Liljenquist[34] found the intra-observer variability of the head–shaft angle to be ±6° in a study including 108 hips, while Loder et al,[33] in a study of 48 hips, found it to be ±12°. They also tested the variability of several other measurements and concluded that the head–shaft angle classified into discrete categories as mild, moderate and severe slip might increase the accuracy.

The tilt index, including the commonly used cut-off of 1.35, was initially proposed by Murray.[9] Based on 100 controls and 200 patients with primary OA, he set the critical value at 1.35, above which a slip was likely. His findings have not been reproduced by others. However, our upper 95% reference interval of 1.43 does not differ substantially.

Typical characteristics of patients with established SCFE are male gender, overweight, and a reduced range of hip movement, especially internal rotation, flexion and abduction.[35] Our findings support these associations, as men with high head–shaft angles had a higher mean BMI, lower internal rotation and higher external rotation than the rest of the male cohort. Except for the higher BMI, similar associations were seen for women.

Corresponding associations were not found for the tilt index. In a previous study[12] including 67 children and adolescents with an established SCFE, only around 25% had a tilt index > 1.35, particularly those with the more severe slips, suggesting that the tilt index is a poor marker for milder degrees of SCFE. On the other hand, a high tilt index was associated with a pistol-grip deformity, lateral flattening of the femoral head and a focal prominence of the femoral neck. These features have also been associated with femoroacetabular impingement, causing groin pain during movement. Murray[9] suggested that the pistol-grip deformity may be caused by a previous slip, but our results lend no support to this theory. Further, Resnick[11] proposed that in elderly patients with OA the pistol-grip deformity or tilt index was due to degenerative changes. However, our study indicates that the tilt deformity is present long before any signs of OA have emerged. In our cohort the number of participants with a high tilt index corresponds well with reports addressing impingement.[22,36,37] About 20% of young men and 3% to 4% of young women are thought to have a pistol-grip deformity that in time may give rise to cam impingement.

We acknowledge some limitations to our study. For instance there was some difficulty associated with measuring some of the radiographs, particularly with regard to the head–shaft angle. However, these radiographs were randomly distributed among the participants and should not cause any selection bias. Another source for selection bias, when estimating prevalence, was the moderate attendance rate of 52%. One might speculate that teenagers with ongoing hip problems would be more prone to participate. However, no differences in subjectively reported hip problems were found between participants with high tilt indices or head–shaft angles compared to those with lower values. Prevalences were adjusted for non-responders based on observed covariates such as gender, birth-weight, maternal age, marital status, parity, foetal position and multiple births, to reduce the possibility that the calculated prevalences were a result of selection bias. Nevertheless, the results must be generalised with care. Finally, there is the possibility that bony remodelling before skeletal maturity may have masked a previous slip.[38,39]

The strengths of the study include the population-based design, including analysis of non-responder data from the Medical Birth Registry of Registry, the large number of participants and the standardised clinical examination, imaging and interpretation.

A high number of radiological findings associated with possible previous slips were found in our cohort, far higher than found in clinical studies of patients treated for SCFE.[6,30] However, a study by Goodman et al[40] found post-slip morphology in 8% of the male and 6% of female skeletons. Bilateral findings were present in 57%. They also found a correlation between post-slip morphology and the development of OA. These prevalences correspond well with the numbers found in this study, and our findings may indicate that asymptomatic slips may occur more frequently than previously reported.

In summary, about 6.6% of participants in a large population-based cohort of 18 to 20-year-olds had a head–shaft angle above the previously reported cut-off of 13°. A high head–shaft angle was associated with clinical findings for SCFE, such as reduced internal rotation and higher BMI.

The authors would like to thank A. M. Haukom MD, M. Olsen BSc, Department of Orthopaedics Surgery, and S. Tufta BSc, Department of Radiology, Haukeland University Hospital, Bergen, Norway, for their help during the data collection period.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primary edited by G. Scott and first-proof edited by D. Rowley.

References

1. **Lehmann CL, Arons RR, Loder RT, Vitale MG.** The epidemiology of slipped capital femoral epiphysis: an update. *J Pediatr Orthop* 2006;26:286–290.
2. **Krauspe R, Seller K, Westhoff B.** Epiphyseolysis capitis femoris. *Z Orthop Ihre Grenzgeb* 2004;142:R37–52 (in German).
3. **Barrios C, Blasco MA, Blasco MC, Gascó J.** Posterior sloping angle of the capital femoral physis: a predictor of bilaterality in slipped capital femoral epiphysis. *J Pediatr Orthop* 2005;25:445–449.
4. **Murray AW, Wilson NI.** Changing incidence of slipped capital femoral epiphysis: a relationship with obesity? *J Bone Joint Surg [Br]* 2008;90-B:92–94.
5. **Gholve PA, Cameron DB, Millis MB.** Slipped capital femoral epiphysis update. *Curr Opin Pediatr* 2009;21:39–45.
6. **Jerre R, Karlsson J, Henrikson B.** The incidence of physiolysis of the hip: a population-based study of 175 patients. *Acta Orthop Scand* 1996;67:53–56.
7. **Carney BT, Weinstein SL, Noble J.** Long-term follow-up of slipped capital femoral epiphysis. *J Bone Joint Surg [Am]* 1991;73-A:667–674.
8. **Abraham E, Gonzalez MH, Pratap S, et al.** Clinical implications of anatomical wear characteristics in slipped capital femoral epiphysis and primary osteoarthritis. *J Pediatr Orthop* 2007;27:788–795.
9. **Murray RO.** The aetiology of primary osteoarthritis of the hip. *Br J Radiol* 1965;38:810–824.
10. **Solomon L.** Patterns of osteoarthritis of the hip. *J Bone Joint Surg [Br]* 1976;58-B:176–183.
11. **Resnick D.** The 'tilt deformity' of the femoral head in osteoarthritis of the hip: a poor indicator of previous epiphysiolysis. *Clin Radiol* 1976;27:355–363.
12. **Lehmann TG, Engesaeter IO, Laborie LB, et al.** In situ fixation of slipped capital femoral epiphysis with Steinmann pins. *Acta Orthop* 2011;82:333–338.
13. **Billing L.** Roentgen examination of the proximal femur end in children and adolescents; a standardized technique also suitable for determination of the collum-, anteversion-, and epiphyseal angles; a study of slipped epiphysis and coxa plana. *Acta Radiol Suppl* 1954;110:1–80.
14. **Jerre R, Billing L, Hansson G, Karlsson J, Wallin J.** Bilaterality in slipped capital femoral epiphysis: importance of a reliable radiographic method. *J Pediatr Orthop B* 1996;5:80–84.
15. **Rosendahl K, Markestad T, Lie RT.** Ultrasound screening for developmental dysplasia of the hip in the neonate: the effect on treatment rate and prevalence of late cases. *Pediatrics* 1994;94:47–52.
16. **The EuroQol Group**. EuroQol: a new facility for the measurement of health-related quality of life. *Health Policy* 1990;16:199–208.
17. **Bellamy N.** Osteoarthritis: an evaluative index for clinical trials [MSc thesis]. McMaster University: Hamilton, Canada, 1982.
18. **Jacobsen S.** Adult hip dysplasia and osteoarthritis: studies in radiology and clinical epidemiology. *Acta Orthop Suppl* 2006;77:1–37.
19. **Southwick WO.** Osteotomy through the lesser trochanter for slipped capital femoral epiphysis. *J Bone Joint Surg [Am]* 1967;49-A:807–835.
20. **Pedersen DR, Lamb CA, Dolan LA, et al.** Radiographic measurements in developmental dysplasia of the hip: reliability and validity of a digitizing program. *J Pediatr Orthop* 2004;24:156–160.
21. **Engesæter IØ, Laborie LB, Lehmann TG, et al.** Radiological findings for hip dysplasia at skeletal maturity: validation of digital and manual measurement techniques. *Skeletal Radiol* 2012;41:775–785.
22. **Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A.** Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. *J Bone Joint Surg [Am]* 2010;92-A:1162–1169.
23. **Beighton P, Horan F.** Orthopaedic aspects of the Ehlers-Danlos syndrome. *J Bone Joint Surg [Am]* 1969;51-A:444–453.
24. **Cole SR, Hernán MA.** Constructing inverse probability weights for marginal structural models. *Am J Epidemiol* 2008;168:656–664.
25. **Aronson DD, Carlson WE.** Slipped capital femoral epiphysis: a prospective study of fixation with a single screw. *J Bone Joint Surg [Am]* 1992;74-A:810–819.
26. **Boyer DW, Mickelson MR, Ponseti IV.** Slipped capital femoral epiphysis: long-term follow-up study of one hundred and twenty-one patients. *J Bone Joint Surg [Am]* 1981;63-A:85–95.
27. **Rao SB, Crawford AH, Burger RR, Roy DR.** Open bone peg epiphysiodesis for slipped capital femoral epiphysis. *J Pediatr Orthop* 1996;16:37–48.
28. **Tokmakova KP, Stanton RP, Mason DE.** Factors influencing the development of osteonecrosis in patients treated for slipped capital femoral epiphysis. *J Bone Joint Surg [Am]* 2003;85-A:798–801.
29. **Jerre R, Billing L, Hansson G, Wallin J.** The contralateral hip in patients primarily treated for unilateral slipped upper femoral epiphisis: long-term follow-up of 61 hips. *J Bone Joint Surg [Br]* 1994;76-B:563–567.
30. **Loder RT, Aronsson DD, Dobbs MB, Weinstein SL.** Slipped capital femoral epiphysis. *Instr Course Lect* 2001;50:555–570 .
31. **Billing L, Bogren HG, Wallin J.** Reliable X-ray diagnosis of slipped capital femoral epiphysis by combining the conventional and a new simplified geometrical method. *Pediatr Radiol* 2002;32:423–430.
32. **Zenios M, Ramachandran M, Axt M, et al.** Posterior sloping angle of the capital femoral physis: interobserver and intraobserver reliability testing and predictor of bilaterality. *J Pediatr Orthop* 2007;27:801–804.
33. **Loder RT, Blakemore LC, Farley FA, Laidlaw AT.** Measurement variability of slipped capital femoral epiphysis. *J Orthop Surg* 1999;7:33–42.
34. **Carney BT, Liljenquist J.** Measurement variability of the lateral head-shaft angle in slipped capital femoral epiphysis. *J Surg Orthop Adv* 2005;14:165–167.
35. **Katz DA.** Slipped capital femoral epiphysis: the importance of early diagnosis. *Pediatr Ann* 2006;35:102–111.
36. **Reichenbach S, Jüni P, Werlen S, et al.** Prevalence of cam-type deformity on hip magnetic resonance imaging in young males: a cross-sectional study. *Arthritis Care Res (Hoboken)* 2010;62:1319–1327.
37. **Laborie LB, Lehmann TG, Engesæter IØ, et al.** Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. *Radiology* 2011;260:494–502.
38. **Bellemans J, Fabry G, Molenaers G, Lammens J, Moens P.** Slipped capital femoral epiphysis: a long-term follow-up, with special emphasis on the capacities for remodeling. *J Pediatr Orthop B* 1996;5:151–157.
39. **Clarke NM, Harrison MH.** Slipped upper femoral epiphysis: a potential for spontaneous recovery. *J Bone Joint Surg [Br]* 1986;68-B:541–544.
40. **Goodman DA, Feighan JE, Smith AD, et al.** Subclinical slipped capital femoral epiphysis: relationship to osteoarthrosis of the hip. *J Bone Joint Surg [Am]* 1997;79-A:1489–1497.