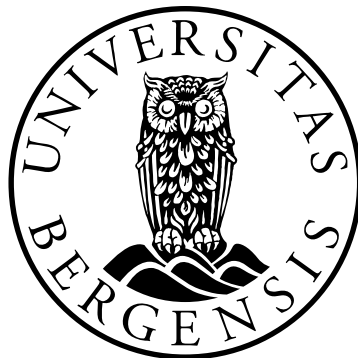


Slipped capital femoral epiphysis

Diagnostics, treatment and long-term outcome

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Dissertation for the degree of philosophiae doctor (PhD)
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Scientific environment

This study is based on data from patients with Slipped Capital Femoral Epiphysis (SCFE) operated at the Department of Orthopaedic Surgery, Haukeland University Hospital (HUS), Bergen, data from the Norwegian Arthroplasty Register and data drawn from an extensive follow-up of a previous randomized hip-trial. I began my work on this study in 2004 as a medical student and later as a PhD fellow and as a resident in the Department of Orthopaedic Surgery at HUS.

The follow-up of the large hip trial was carried out at the Department of Paediatric Radiology, HUS, in collaboration with Ingvild Øvstebø Engesæter and Lene Bjerke Laborie (both MDs and PhD fellows in the same project) and supervised by Professors Lars Engesæter and Karen Rosendahl.

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Finally, I would like to send a thought to my two beautiful children, Malin and Jonas, who give me inspiration and joy every day. They are really marvellous.

2. List of abbreviations

AMH	Anne Marte Haukom
ANOVA	analysis of variance
AP	anteroposterior
AVN	avascular necrosis
ATD	articulotrocanter distance
BMI	body mass index
CI	confidence interval
cm	centimetre(s)
DDH	developmental dysplasia of the hip
EQ-5D	EuroQol five-dimensional questionnaire
FAI	femoroacetabular impingement
HUS	Haukeland University Hospital
IØE	Ingvild Øvstebø Engesæter
JIA	juvenile idiopathic arthritis
JSW	joint space width
KR	Karen Rosendahl
LBE	Lars Birger Engesæter
LBL	Lene Bjerke Laborie
mm	millimetre(s)
MRI	magnetic resonance imaging
n	number
NAR	Norwegian Arthroplasty Register
NARA	Nordic Arthroplasty Register Association
NPR	Norwegian Patient Register

NV	Nils Vetti
OA	osteoarthritis
OR	odds ratio
RA	rheumatoid arthritis
SAL	Stein Atle Lie
SCFE	slipped capital femoral epiphysis
SD	standard deviation
SSB	Statistics Norway
TGL	Trude Gundersen Lehmann
THA	total hip arthroplasty
UK	United Kingdom

3. Abstract

Slipped capital femoral epiphysis (SCFE) is one of the three most common hip disorders in children, together with developmental hip dysplasia and Perthes' disease. The incidence of SCFE varies according to race, ethnicity and the method of ascertainment. The aetiology is unknown, but several risk factors have been identified, such as male gender, overweight, endocrinopathies and treatment with ionising radiation in children with cancer. Patients typically present with a limp and pain at age 11-14 years. The diagnosis is based on clinical examination and hip radiographs, and the treatment is surgery to prevent further slip and later degenerative change. Even though different techniques are reported, the basic principles are the same. During recent years, methods of open surgical dislocation of the hip with femoral neck osteotomy, to restore the anatomy in the hip, have been presented.

The aim of this thesis was to study SCFE in the Norwegian population. By using different data sets, we have reported on prevalence, accuracy of the imaging techniques used and the short-term and long-term results of treatment.

In Paper I we report on long-term results of a new surgical technique as described by Prof. Engesæter, using partly threaded Steinmann pins. This technique was simple, had few acute or late complications and hardware removal was relatively easy.

Furthermore, the long-term results were favourable regarding function and quality of life. As opposed to several other techniques, ours allowed for further growth within the growth plate, thus reducing leg length discrepancy, but without increasing the risk of further slipping. Due to the low complication rate and a high rate of silent slips of the contralateral hip, we changed our treatment to also include prophylactic pinning of the contralateral hip.

In Paper II we used data from the Norwegian Arthroplasty Register on patients reported with a primary total hip arthroplasty under the age of 40 years. The reported diagnoses were validated against hospital records, and found to be correct in 91% of cases. Patients with a total hip arthroplasty after SCFE had no significant decrease in quality of life compared to reference populations without THA from Sweden and the

UK. A better outcome was found for patients with THA after SCFE compared to patients with THA due to developmental dysplasia of the hip (DDH) or Perthes' disease.

In Paper III we investigated the prevalence of radiological markers of a possible previous SCFE in a population based cohort of 2072 Norwegian 19 year olds. Based on the Southwick's head-shaft angle with the commonly used cut-off value of 13°, 6.6% of these teenagers tested positive, suggestive of a previous undiagnosed slip. A high Southwick's head-shaft angle was associated with reduced internal rotation of the hip, and increased body mass index (BMI) in males, both being known factors associated with SCFE. About 20% of males and 6% of females had a high Murray's tilt-index representing a pistol-grip deformity of the femoral neck. We found no association between this tilt deformity, clinical findings of SCFE or radiographic markers of a high head-shaft angle.

In Paper IV we performed intra- and inter-observer studies on different radiographic measurements used for diagnosing a SCFE in skeletally mature adolescents, namely Southwick's head-shaft angle (frog-leg view), the head-neck angle (frog-leg view) and the tilt-index (AP view). The mean difference for each of the three measurements was small both within (intraobserver) and between the two observers (interobserver). However, the 95% limits of agreement were relatively high, in particular for the angular measurements, underscoring the need for thorough standardisation prior to measurement. Of the angular measurements, the variation of the head-shaft angle was smaller than that of the head-neck angle, with 95% limits of agreement of ± 7.5 and ± 5 for intra- and inter-personal variation, respectively.

4. List of publications

This thesis is based on the work in the following papers, referred to in the text by their Roman numerals:

- I Lehmann TG, Engesæter IØ, Laborie LB, Rosendahl K, Lie SA, Engesæter LB. **In situ fixation of slipped capital femoral epiphysis with Steinmann pins** – 67 patients followed for 2-16 years. Acta Orthop 2011;82 (3):333-338

- II Lehmann TG, Engesæter IØ, Laborie LB, Rosendahl K, Engesæter LB. **Total hip arthroplasty in young adults with focus on Perthes' disease and slipped capital femoral epiphysis**. Acta Orthop 2012;83(2):159-64

- III Lehmann TG, Engesæter IØ, Laborie LB, Lie SA, Rosendahl K, Engesæter LB. **Radiographic findings which may indicate an undergone, silent slipped capital femoral epiphysis in a cohort of 2072 young adults**. Submitted JBJS Br. 25.04.12. Accepted for publication 28.12.12

- IV Lehmann TG, Vetti N, Laborie LB, Engesæter IØ, Engesæter LB, Rosendahl K. **Intra- and inter-observer repeatability of radiographic measurements for previously slipped capital femoral epiphysis at skeletal maturity**. Submitted Acta Radiol 31.08.12. Accepted for publication 19.12.12

5. Background

5.1 What is Slipped Capital Femoral Epiphysis?

Slipped capital femoral epiphysis (SCFE) is a disorder of the hip where the femoral head slips in relation to the femoral neck (Figure 1). It typically presents at puberty, with an insidious onset of hip pain and a limp. Overweight males are most commonly affected. Clinically, there is reduced hip movement, particularly internal rotation. Treatment is by surgical fixation, but the preferred technique varies between centres. Patients having undergone a SCFE experience a higher risk for later degenerative hip disease.

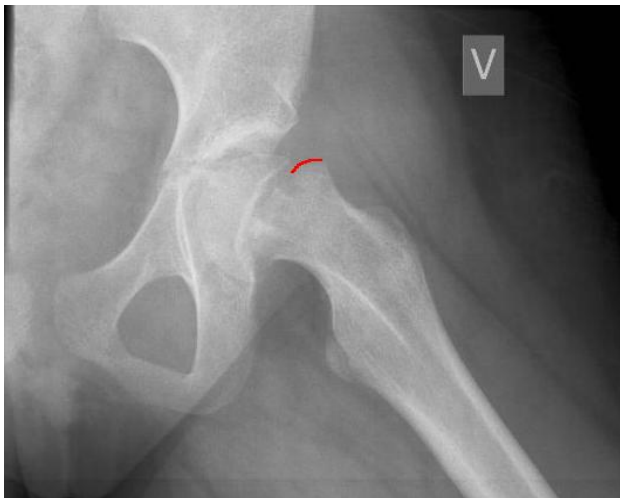


Figure 1. SCFE in a 13-year-old boy. A frog-leg radiograph showing displacement of the capital femoral epiphysis relative to the metaphysis (red line).

5.1.1 Anatomy of the proximal femur

At birth, the proximal femur epiphysis consists of cartilage. At around 3-4 months a secondary ossification centre becomes visible radiographically. Between the secondary ossification centre and the metaphysis, a plate-like structure, the growth plate, or physis, occurs (Figure 2). It accounts for the growth of the femoral neck, and for about 30% of the longitudinal growth of the femur (1).

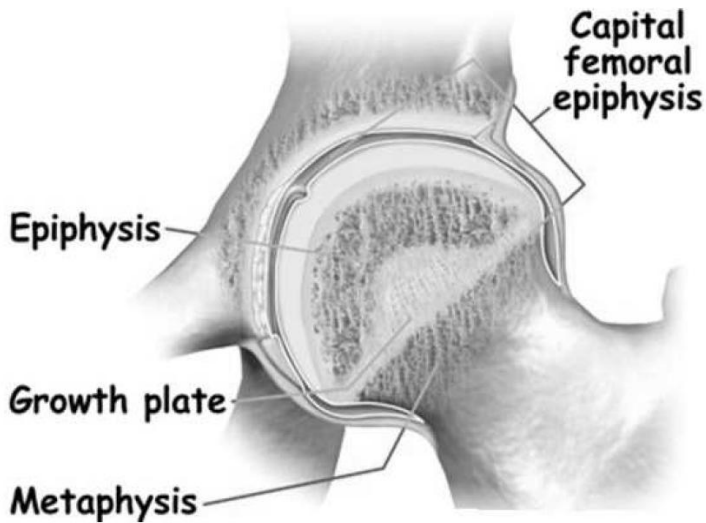


Figure 2. Anatomy of the proximal femur

The blood supply to the femoral head (Figure 3) is mainly from the medial circumflex femoral artery which separates into several branches (the lateral epiphyseal artery and superior and inferior metaphyseal arteries). The ascending cervical vessels also called retinacular vessels account for about 2/3 of the supply to the femoral head. The area around the central fovea is supplied by the medial epiphyseal artery, which is a branch of the ligamentum teres artery from the obturator artery.

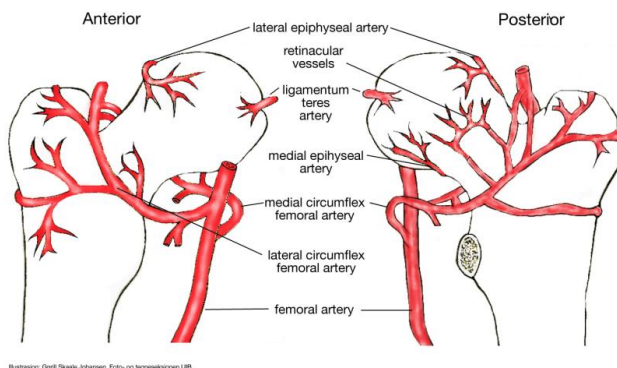


Figure 3. Blood supply to the proximal femur at skeletal maturity, anterior and posterior view

Between the age of 4 months and 7-8 years the ligamentum teres artery is of little importance for the blood supply to the femoral head, except for a small segment of the cartilage adjacent to the attachment of the ligamentum teres. After the age of 14-18 months the cartilaginous growth plate acts as a barrier to the supply from the metaphyseal arteries and the retinacular vessels are then the most important source of blood supply to the femoral head (2). They enter the hip capsula and crosses the physis at the surface of the head before entering and supplying the epiphysis. The epiphyseal and metaphyseal systems are therefore separate until complete closure of the growth plate at late puberty (3).

The oblique proximal femoral growth plate is subjected to stress forces. In pubertal adolescents the hormonal changes make the growth plate thicker and weaker with increased risk of a slip (4, 5). The femoral head is displaced in relation to the femoral neck (Figure 1), and the slip is most commonly posterior and inferior (6). When the femoral head is displaced in relation to the metaphysis, the joint capsule with the blood vessels may shrink on the posterior side of the femoral neck over time and there is a possibility of damage to the blood supply of the femoral head if forceful reduction is performed during surgery. At the end of puberty the growth plate closes, and there is no further risk of slipping.

5.1.2 Epidemiology

The incidence of SCFE varies according to the studied population, method of ascertainment and type of study. A Japanese study reported a incidence of 0.2 per 100.000, compared to 2.13 per 100.000 in southern USA, 10.1 per 100.000 in northern USA and in Sweden calculated as an attack rate (the sum of the annual incidence rates for every age group over the age period of risk) of 1 per 1200 (7, 8). Another Swedish study estimated the incidence of a slip to be 6.1 per 10.000 in males and 3.0 per 10.000 in females in the period of growth (9). A publication by Krauspe (10) reports an incidence of 4-5 per 100.000. The occurrence in the Norwegian population has not previously been reported. Boys are more affected than girls and several studies report about 60% boys affected (7, 11-14). Left hip is more commonly affected than right hip

(2:1) (12, 14-19). Mean age at diagnosis is different for girls and boys and is reported to be 12 years for girls and 13 years for boys (7, 15, 17, 20-23) with a range from 9 to 17 years both in Europe and USA (20, 24, 25).

5.1.3 Aetiology of SCFE

The aetiology of SCFE is unknown; however, both mechanical and biological factors may play a role. The slip occurs through a wider hypertrophic zone within the growth plate which is weaker due to altered chondrocyte maturation and degeneration and inhibited endochondral ossification (4). Testosterone is shown to reduce the strength of the physis, whereas oestrogen narrows the width of the growth plate and makes it stronger (5, 8). Of mechanical factors obesity (12, 25), reduced femoral anteversion, increased physeal obliquity (26) and increased femoral head coverage (27) are associated with a slip. 50-80% of children with a SCFE are reported to have a BMI above the 95th percentile (12, 15, 25, 28). Obese adolescents are also more prone to have decreased femoral anteversion (29). The increased body mass increases the stress over the physis and may result in a slip. Poussa et al. have reported increased weight also during childhood of patients with a SCFE (30). A slip most often occurs at puberty when multiple hormonal changes occur together with rapid longitudinal growth. The disorder is related to the endocrine function and it is stated that hypothyroidism, hypopituitarism and hypogonadism increase the risk of a SCFE. In these patients the slip is often present at an earlier age, and more often bilateral (31). Children with Down's syndrome are also more disposed, and have a less favourable prognosis for reasons not fully understood. Some cases of familial SCFE have been reported (32, 33), suggesting there can also be a hereditary factor involved. Radiation therapy against malignant disease in the pelvic region is also reported to predispose to a slip (34). These children often present at an earlier age than the typical SCFE patient.

5.2 Diagnosis

5.2.1 Symptoms

The most frequent presentation is a painful hip, pain in the groin and a limp. In addition knee pain may also be seen and some only report referred pain to the knee (35, 36). Out-toeing or gait abnormality may have been observed by the parents. The presentation is often gradual in onset, and the symptoms have often been explained as growth pain or some kind of muscular trauma. Initially, pain is intermittent and normal activities such as football or running are possible, though with pain. The time from first symptom until diagnosis is often 3 to 5 months (13, 23, 36-39). Less frequently, the condition presents with a sudden onset related to a trauma or acute event of the hip. Usually, the slip is unstable in these occasions and the patient is unable to bear weight on the affected leg, and may be suspected of having a fracture in the proximal femur (15, 35).

Several authors (13, 16, 37, 40, 41) have reported on the correlation between duration of symptoms and severity of the slip. Severe slips have a longer duration of symptoms before diagnosis. A delay of diagnosis is also seen in patients only presenting with knee or distal thigh pain.

5.2.2 Clinical examination

An analysis of the gait is important and it is important to look for signs of out-toeing of the affected side and leg length discrepancies. Some patients are not able to bear weight and gait observation is therefore not possible. The most important examination is the range of motion of the hips. In a unilateral slip, this can be compared to the unaffected hip. In all patients the internal rotation is decreased, some may even present with an external rotation contracture (6, 10, 24, 42). The best way to examine the rotation of the hip is with the patient prone with 90 degree flexion in both knees (43). An increased external rotation compared to the contralateral hip may also be seen. The abduction is often reduced, but not as often as the internal rotation. Some patients may

have a positive Drehmann sign where the hip will externally rotate when flexion of the hip is performed (10).

5.2.3 Imaging

In most centres, the diagnosis of SCFE is confirmed by conventional radiography, and the degree of slip is measured. Routinely, two radiographs are obtained; an anteroposterior (AP) and a frog-leg view. AP radiographs are obtained with the patient supine, with toes internally rotated to have the femoral neck parallel to the table. A frog-leg view is obtained with the patient supine and with externally rotated and abducted hips, flexed knees and foot soles together. A horizontal ray lateral view may be obtained if the patient is in too much pain to be positioned in a frog-leg position. A study by Loder (44) demonstrated that the frog-leg view gave the most precise measurement of slip angle in all positions of rotation when the external rotation was less than 30°, and recommended this view for the presentation of the slip.

There are several different ways of measuring a slip; angulation in degrees, displacement in mm, or in percentage of the femoral head in relation to the femoral neck. When using angular measurements it is common to classify slips < 30° as mild, between 30 and 50° or 60° as moderate and > 50° or 60° as severe slips (45). In using the proportion of displacement, the amount of slipping according to the diameter of the femoral neck is measured and it is common to classify mild displacement as < 1/3, moderate between 1/3-1/2 and severe as > 1/2 of the width of the femoral neck (45, 46). The classification of slip severity gives valuable information on the long-term prognosis, where a more severe slip has a higher risk of later development of osteoarthritis (OA) (16, 40, 45, 47, 48).

Several measurements have been used to examine the degree of the slip, of which **Southwick's head-shaft angle** (lateral epiphyseal-shaft angle) is commonly used (8, 12, 16, 38, 49-51). The angle is calculated by drawing a line connecting the anterior and posterior end of the epiphysis and one line along the femoral diaphysis. A third line perpendicular to the epiphyseal line will intersect the diaphyseal line and give the Southwick's head-shaft angle (Figure 4a). The angle can be measured on both the AP

view or frog-leg view, the latter being the most common. The measured angle can be used directly (49) to give the slip angle or can be used subtracting the head-shaft angle on the contralateral hip, when this is unaffected (37, 51). When the patients have a bilateral slip this method is of no use. Since small slips may only be discovered in the lateral or frog-leg view, it is most common to measure the slip angle in this view. In publications by Billing and Jerre a special lateral view was used (52-54). In this case, the leg is externally rotated and elevated 25° with the knee flexed in 90° thus enabling a true lateral view of the physis in a standardised manner. The slip angle is then calculated in almost the same way as the head-shaft angle except that it is the angle between a line perpendicular to the epiphyseal line and a bisector between a line through the axis of the diaphysis and a line through the femoral neck. The femoral head in normal hips is usually perpendicular to the femoral neck. In some studies, the angle between a line perpendicular to the epiphyseal line and through the axis of the femoral neck has been used, the femoral **head-neck angle** (Figure 4b).

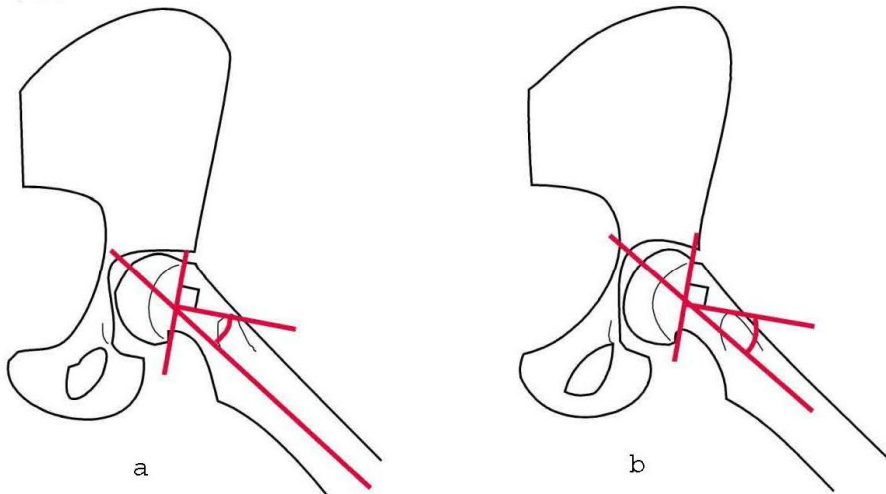


Figure 4. Measurement of a) Southwick's lateral epiphyseal-shaft angle and b) femoral head-neck angle in frog-leg view.

A more crude method of determining the presence of a slip is to draw **Klein's line** (39, 55). In this method a line is drawn along the lateral or superior border of the femoral

neck. In every radiographic view this line should intersect a part of the epiphysis (Figure 5a).

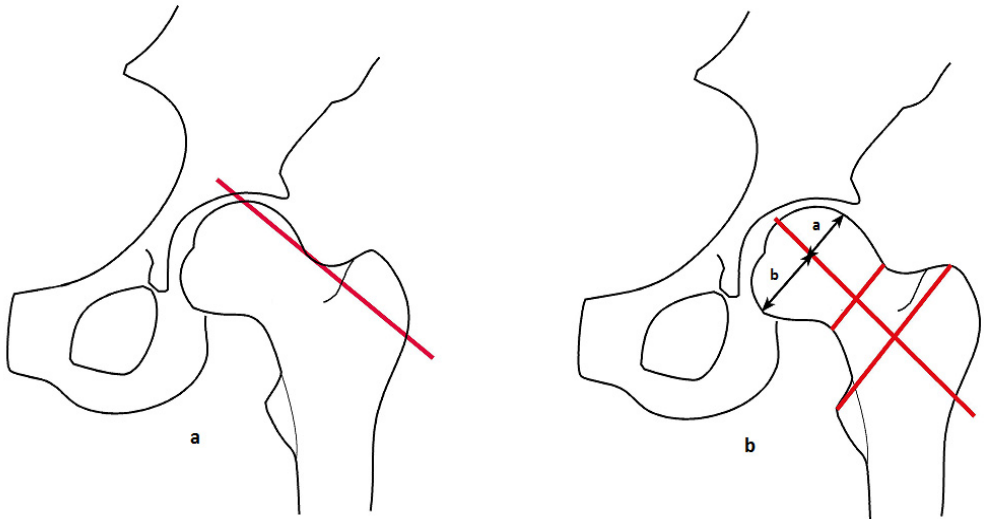


Figure 5. Measurements of a) Klein's line and b) Murray's femoral head ratio, b/a

This method does not allow for measurement of the severity of the slip, merely revealing whether it is small or large. If the line intersects the femoral head a slip is not present, but if only a small part of the head is intersected one should nevertheless suspect a small slip. A study by Loder in 2008 also reported findings of an intersecting Klein's line both in AP and frog-leg view in patients diagnosed with a SCFE. Of 97 reported slips, 39 had a normal Klein's line in AP view and 3 had a normal line in frog-leg view (39). There was a positive correlation between severity of slip and positive Klein's line.

For long-term studies the commonly used measurements of slip can be more challenging. Except for Klein's method they all rely on a visible physis. In skeletally mature persons the physis is not always distinguishable from the rest of the femoral head, and common angular measurements may be difficult. For this purpose Murray has proposed a **femoral head ratio** as a measure of the tilt deformity of the femoral head in relation to the femoral neck, to find patients with markers suspicious of a previous SCFE. In this work the measurement is referred to as the tilt-index. This

index is a measurement of how much of the femoral head is superior and how much is inferior to a line representing the centre of the femoral neck. The central line is found using a line between the tip of the trochanter major and trochanter minor and a line through the narrowest part of the femoral neck. The central line runs through the midpoint in these two lines (Figure 5b) (56).

Radiographic assessment of the hip with anteroposterior and lateral views remains the gold standard for diagnosing SCFE. Additional modalities, such as magnetic resonance imaging (MRI) may play a role in the differentiation between a stable and an unstable, reducible slip, and for the assessment of later cartilaginous damage. It is also more accurate in assessing the severity of the slip. If choice of treatment is dependent on the stability or severity of the slip, MRI will better classify it preoperatively (57).

Ultrasound and computed tomography (CT), on the other hand, are of less value to diagnosis and follow-up of SCFE.

5.2.4 Classifications

Slipped capital femoral epiphysis is classified both according to clinical and radiological findings. Clinically, the time from first symptom until diagnosis is important. A **chronic slip** is by far the most common one, and accounts for about 75-90% of all SCFE (14, 16, 17, 38). The pain in a chronic slip is present for more than 3 weeks (43, 45), and may range from months to years. Usually the pain is intermittent in the start with minor exacerbations. An **acute slip** (10-15%) is a sudden onset pain arising within the last three weeks prior to diagnosis. Normally a minor trauma precedes the pain, and weight bearing is usually difficult. In an **acute-on-chronic slip**, symptoms have been present for more than 3 weeks, with a marked aggravation within the last 3 weeks. In some papers a **pre-slip** has been included in the classification. This applies to adolescents with typical symptoms of a SCFE, but without radiographic findings of a slip. This is most often encountered in patients who have already had a slip in the contralateral hip.

Several authors (13, 16, 37, 40, 41) have reported on the correlation between duration of symptoms and severity of the slip. The more severe slips often have a longer

duration of symptoms before diagnosis. Patients with only knee or distal thigh pain also have longer duration of symptoms before being diagnosed than those with hip or proximal thigh pain. The duration of symptoms can therefore be a predictor of the severity of the slip.

Another clinically important classification is an evaluation of the stability of the physis. If the child is able to bear weight on the affected leg, with or without crutches, it is a **stable slip**. It is considered an **unstable slip** if the child is unable to bear weight (58). An unstable slip has a high risk of avascular necrosis (8, 15, 16, 59), most likely due to damage to the arterial supply at the time of the displacement.

5.3. Treatment of Slipped Capital Femoral Epiphysis

The goal of treatment of patients with a SCFE is to restore hip function and prevent further slipping of the epiphysis. The long-term goal is to reduce the risk of developing degenerative joint disease. It is well known that the subsequent function of the hip is related to the severity of the slip (16, 40, 45, 47, 48), and that even minor slips may play a role in long-term outcome (13). A study performed by Carney and Weinstein (60) on the natural history of untreated chronic slips showed that mild slips had a favourable outcome. Patients with moderate and severe degree had a significantly lower hip rating and more radiographic signs of degenerative disease than those with mild slips. The treatment of choice for at least the last 50 years has been to prevent further slip by surgical intervention.

5.3.1 Surgery

Although the benefits of stabilizing surgery are undisputed, opinions on the degree of urgency, type of fixation, reduction or not, and fixation of the contralateral hip vary significantly. However, there is some agreement that in situ fixation of a slip provides the best functional results and a lower risk of complication (8, 15, 45, 61, 62) and that perioperative forceful reduction may increase the risk of avascular necrosis (16, 48, 63). In situ fixation can be performed as 1) a permanent epiphysiodesis (64) or 2) only

a stabilisation of the physis that allows for further growth until the physal closure (65, 66) depending on which hardware is used. The advantage with an epiphysiodesis is a fused physis and no risk of further slip of the epiphysis or failure of hardware (15, 62). However, this early fusion may lead to leg length discrepancy, especially in younger patients, and decreased possibility of remodelling of the proximal femur. Also an overgrowth of the trochanter may lead to Trendelenburg gait and impingement (67). Others favour implants that allow for further growth of the femoral neck (10, 65, 66, 68), but with the risk of further slipping and withdrawal of pins/nails. This continued growth may favour remodelling; of course less remodelling is possible in a teenager almost at skeletal maturity compared to a younger patient. Also, when allowing for further growth the leg length discrepancy is smaller. Some difference in leg length is common after a SCFE, irrespective of the kind of treatment, and is related to the slip itself as the physis slips posteriorly and inferiorly.

When providing stabilisation with continued growth, several different screws (69), hook-pins (65), specially constructed screws (66) and pins (70) are used. To allow for continued growth the threads or anchoring device must pass medially through the physis, and not bridge it (Figures 6a and b). When the threads are placed over the physis, most likely an epiphysiodesis will occur. The number of nails/screws/pins to insert is also a point of discussion. The risk of penetration of the femoral head increases with the number of nails (71), but slip progression has been encountered after placing only one screw/nail (49, 72). Also, one screw/pin may not provide rotational stability of the epiphysis.



Figure 6a. Steinmann pin (diameter 2.3 mm) with threads in the 8 mm distal end



Figure 6b. Special screw with short threads used in Oslo University Hospital (Published with permission from the Hospital). Both a and b allow for continued growth when all the threads are placed medially to the growth plate for anchoring in the epiphysis.

The agreement on in situ fixation applies to cronical slips of mild and moderate severity. For the more severe slips different osteotomies are performed such as subcapital, lateral femoral neck osteotomy or intertrochanteric or subtrochanteric osteotomies. Long-term results show, however, that nailing/pinning in situ is most successful regardless of the slip severity (16, 40). For the acute slips, it is possible to try a gentle reduction on the operation table but it is important to know that it is not an acute-on-chronic slip. No force should be applied. In acute slips the posterior joint capsule and blood vessels are not shortened as in a chronic slip, and it is possible to reduce the slip without doing any damage to the important blood vessels to the femoral head. For chronic slips the risk of damage to the vessels is more pronounced when reduction is performed, and should be avoided. It is however important to remember that the blood vessels may have been damaged during the slip itself and not always as a result of forceful reduction. In the last decade more extensive surgery has been proposed by some authors. Series of 30 and 40 patients (73, 74) with both acute and chronic slips of moderate and severe type have been operated with an open dislocation of the hip and subcapital correction osteotomy. Yet this is not widely performed due to the demanding technique involved and the risk of damaging the blood supply resulting in an AVN. The presented series have no reported cases of AVN but this surgery is performed only at specialized institutions. The authors argue that the best long-term outcomes are expected from methods that allow for restoration of the normal anatomy in the proximal femur, and refer to studies performed in which also patients with mild

slips had damage in the acetabular cartilage due to femoroacetabular impingement (75). The technique of surgical dislocation was first described by Ganz (76). After the extensive surgery the patients are not allowed to bear any weight for the first 8-12 weeks. Patients operated in this manner are still young and the long-term results of this technique are unknown. Also further studies are needed to establish which patients can benefit from this surgery rather than in situ fixation, and if the same excellent results can be reproduced when it is not performed in a highly specialized institution.

5.3.2 Complications

When treating patients with SCFE, the risk of severe complication is always present. Known complications are avascular necrosis (AVN) of the femoral head, chondrolysis, slip progression, leg length discrepancy, fractures and infection. Depending on type of fixation some will experience pain laterally due to the protrusion of pins/nails/screws. Some of the complications are related to the disease itself, while others are clearly related to the treatment.

The most feared complication is avascular necrosis of the femoral head. The risk of AVN differs between studies, within the range of 0 to 50% depending on the severity and stability of the slips investigated and type of treatment (10, 15, 16, 40, 73, 77). The most important blood vessels to the femoral head run on the posterior surface of the femoral neck (Figure 3). These may be damaged when the slip occurs or may be harmed during operative procedures including reduction. Acute, unstable slips and forceful reduction of a chronic slip are known to increase the risk of necrosis in the femoral head. Also a higher frequency of AVN is reported after proximal femoral osteotomies (16), but it must be noted these were generally performed in the most severe cases. The symptoms and radiological signs of AVN develop several months after treatment; the patient complains of groin and/or knee pain and reduced range of motion in the hip. Kalamchii and McEwan state that AVN can be classified according to the proportion of the femoral head involved (78). Unfortunately, the new bone formation/reossification seen in Perthes' disease is usually not seen in AVN after SCFE. The treatment is symptomatic and may end in a total hip arthroplasty (THA) when the hip is painful and the range of motion severely limited.

Chondrolysis is an acute dissolution of the articular cartilage defined as a reduction of the joint space on radiographs of more than 50% compared to the unaffected hip, or alternatively a joint space of less than 3 mm (59). Symptoms are joint stiffness and pain. The aetiology for chondrolysis is not fully understood, but several factors may play a part. Pin penetration into the joint is proven to increase the risk of chondrolysis (43), together with severe slip and prolonged symptoms. The prevalence of this complication is reported to be between 0-16% (16, 40, 79).

Infection is rarely a problem and most common is a superficial wound infection treated with oral antibiotics.

Leg length discrepancy after a SCFE may occur for several reasons. Firstly, depending on the severity of the slip, the slip itself may inflict a difference in leg length as the femoral head slips posteriorly and inferiorly in relation to the femoral neck. The inferior slip leads to a shortening of the leg itself. Secondly, depending on the fixation technique, an epiphysiodesis in the proximal femur leads to increasing leg length discrepancy during growth of the patient. The younger the patient when an epiphysiodesis is performed, the greater the leg length discrepancy.

5.3.3 Prophylactic nailing of contralateral hip

When a patient is diagnosed with a SCFE there is an increased risk of having a slip at the contralateral hip. The risk of contralateral slip is reported to be from 20-60%, and Castro et al. reported that adolescents with a unilateral slip had an over 2000 times greater risk of developing a slip in the contralateral hip than healthy children (17). Other papers have reported asymptomatic slips in about 40% of patients. Several studies have attempted to identify risk factors for a contralateral slip. Patients with endocrinopathies have a much higher risk than others. Young age at first slip is also associated with increased risk of a subsequent slip (80, 81). Different strategies are used to deal with this risk. Some authors advocate close follow-up including radiographs to identify a slip if it appears (17, 54). Others have concluded that prophylactic nailing is advantageous (13, 82-84). When the rate of contralateral slip is high and close follow-up is not feasible, one should consider prophylactic nailing (18, 84). Jerre et al. advocate radiological and clinical examination every three months. In

contrast, Hägglund et al. recommend prophylactic nailing since at close follow-up they found the prevalence of contralateral slip to be 60% and the risk of OA to be 25% for patients with a slip only recognised at late follow-up. In favour of prophylactic pinning is the fact that the leg length discrepancy will be less marked, if the method of operating is an epiphysiodesis of the proximal femur. Important factors when deciding about prophylactic nailing are that the operation performed must have low risk of complication and little risk of sequela after surgery. The results in the literature differ, and there is no consensus as to whether to use prophylactic nailing or to perform close follow-up.

5.4. Long-term outcome

Several studies of long-term follow-up of treatment for SCFE have been performed. Carney et al.(16) reported on 155 hips in 124 patients with a mean follow-up of 41 years. 42% of the slips were mild, 32% moderate and 26% severe. Reduction was done in 39 hips and realignment in 65. 25% had only been treated symptomatically, 30% with a spica cast, 24% with pinning in situ and 20% with an osteotomy. The results of this study showed increased risk of degenerative joint disease depending on the severity of the slip. Worse results were found in groups with attempts at reduction or realignment procedures. This was also the true for complications such as AVN or chondrolysis, which were more prevalent in patient who had undergone reduction and realignment. Pinning in situ provided the best results regardless of the severity of the slip and provided the best delay of degenerative arthritis. Another study from Hansson et al.(79), comprising 43 patients with 59 hips operated with in situ nailing, found that 20% of mild slips had developed mild OA and 1 case of severe OA after a follow-up of 44 years. Of patients with moderate slips, 33% and 17% developed mild and severe OA, respectively. The Harris hip score was above 90 for all but 7% with mild slips and for 78% with moderate slips. The authors concluded that the long-term results were excellent for mild slips, and that long-term outcome was unrelated to slip severity at surgery. Hägglund et al. (13) reviewed 260 patients of whom 104 were diagnosed with a contralateral slip at late follow-up. Of these, 25% had developed OA compared to 9% of those without a contralateral slip. Of the contralateral hips diagnosed and

stabilised, there were none with degenerative joint disease. Wensaas et al. (85) reviewed 66 patients with a mean follow-up of 38 years and concluded that in situ fixation gave good long-term results, but poorer results for patients with acute slips and more severe slips. Corrective osteotomy of the femoral neck and intertrochanteric osteotomy did not improve the outcome of severe slips. 14 had received a THA and 1 had had a hip arthrodesis.

A recent study from the New Zealand Joint Registry (86) compared the results of THA performed due to SCFE and primary OA where they found no difference in postoperative Oxford hip score or revision rates between the two groups. This study concludes that THA after SCFE is a good management of the degenerative arthritis, and there were even trends in the data, although not significant, that patients with SCFE had better results after THA than patients with THA due to primary OA.

In conclusion, the long-term studies performed support in situ fixation of at least mild and moderate slips. Even when optimal treatment is performed, some will develop degenerative disease in the hip. THA is then the choice of treatment and although few, the existing papers report good results after prosthesis for SCFE patients.

6. Aims of the studies

The main objective of this thesis was to increase current knowledge on the epidemiology of slipped capital femoral epiphysis, treatment with partly threaded Steinmann pins and the long- term results of treatment.

The specific aims of the 4 papers were:

- I.** To present the clinical and radiological results of SCFE operated with 2 or 3 partly threaded Steinmann pins to allow for further growth of the femoral neck after stabilization of the physis. (Paper I)

- II.** To validate the diagnoses reported on total hip arthroplasty to the Norwegian Arthroplasty Register for young patients, and to assess the quality of life following hip replacement for patients operated due to paediatric hip disease with a special focus on patients with SCFE and Perthes' disease. (Paper II)

- III.** To examine the prevalence of radiographic and clinical findings suggestive of a previous SCFE in a population based cohort of Norwegian adolescents born in 1989. (Paper III)

- IV.** To assess the accuracy of radiographic measurements commonly used for diagnosing a previous SCFE at skeletal maturity. (Paper IV)

7. Patients and Methods

This thesis is based on three different data sets: 1) data from patients with SCFE, followed at the Department of Orthopaedic Surgery (Paper I), data from the Norwegian Arthroplasty Register (Paper II) and data drawn from an extensive follow-up of a previous randomised hip trial (Papers III and IV).

7.1 Patients operated for SCFE (Paper I)

This is a retrospective study comprising all patients operated for slipped capital femoral epiphysis (SCFE) at Haukeland University Hospital during the period 1990-2007 (n=67). During this period, only one surgical technique was used for SCFE, namely in situ fixation with 2 or 3 partly threaded Steinmann pins. None were treated with other techniques. After the introduction of this technique in 1990, all surgeons on call at the Department of Orthopaedic Surgery performed the operations. No forceful reduction was allowed. Pins were placed using fluoroscopic guidance. Patients were allowed partial weight bearing on the operated leg for the first 6 weeks and then full weight bearing. None were operated prophylactically in the contralateral hip. Pins were routinely removed at skeletal maturity. A clinical and radiological follow-up was performed after pin removal during the years 2004-2007 and patients answered two questionnaires, EQ-5D to evaluate quality of life and WOMAC to address specific hip problems. Range of movements in the hips was tested and leg-leg discrepancy measured. Medical records were used to find information on potential complications. Severity of slip and slip progression were evaluated using Southwick's head-shaft angle (51). To evaluate the growth of the femoral neck after fixation, we constructed a ratio between the length of the pin and the length of the femoral neck. A paired sample t-test was used to compare the ratio postoperatively to the ratio at skeletal maturity.

7.2 Young adults with THA after SCFE (Paper II)

The Norwegian Arthroplasty Register (NAR) has collected data on total hip arthroplasties inserted in Norway since 1987 (87). Although reporting is not compulsory, the register includes data on 98% of all total hip replacements (88). The registration form is filled in by the surgeon immediately after the operation and includes information on date of surgery, underlying hip disorder classified into 1 of 9 categories, type of surgery and whether the operation is primary or a re-operation .

Based on the information in NAR a questionnaire was sent to all patients (n=713) younger than 40 years (i.e. born after 1st January 1967 when the Medical Birth Registry of Norway was established). This questionnaire contained questions regarding diagnoses, including whether they agreed with the reported diagnosis or not. If not, they were asked to fill in the one they considered correct. They were also asked about quality of life (EQ-5D) and for permission for further data collection from their hospital records. Data from the medical records were either collected directly from the 14 hospitals performing 5 THAs or more or received by post from the remaining 34 hospitals. This provided us with all necessary data for validation of the reported diagnosis in 500 patients. Data on quality of life was compared to reference data on age-matched populations from Sweden and Great Britain. Independent sample t-tests were used. Baseline characteristics between responders and non-responders were compared to avoid selection biases.

7.3 The 1989 Hip Project (Papers III and IV)

Paper III is a prospective study of teenagers born in 1989 at Haukeland University Hospital, who took part in a randomized hip trial on different screening strategies for developmental dysplasia of the hip (DDH) during 1988-1990 (89).

Between 2007 and 2009, a cohort drawn from this trial, namely all those born during 1989, was invited to participate in a long-term follow-up (n=4006). Excluded were those living outside the catchment area of Haukeland University Hospital and those

who had emigrated (n=1062) (Figure 7). For the purpose of the present study, we included eligible adolescents born during 1989 (n=2081). The invitation letter included a questionnaire on previous hip problems and hip problems in siblings and parents. 2081 (51%) met for a follow-up at the Department of Paediatric Radiology at HUS. Upon arrival, they filled in a new questionnaire including hip problems, neck and back pain, training habits, the WOMAC hip-specific questionnaire and a quality of life (EQ-5D) questionnaire. Nine participants were excluded due to uncertain pregnancy status or suboptimal radiographs.

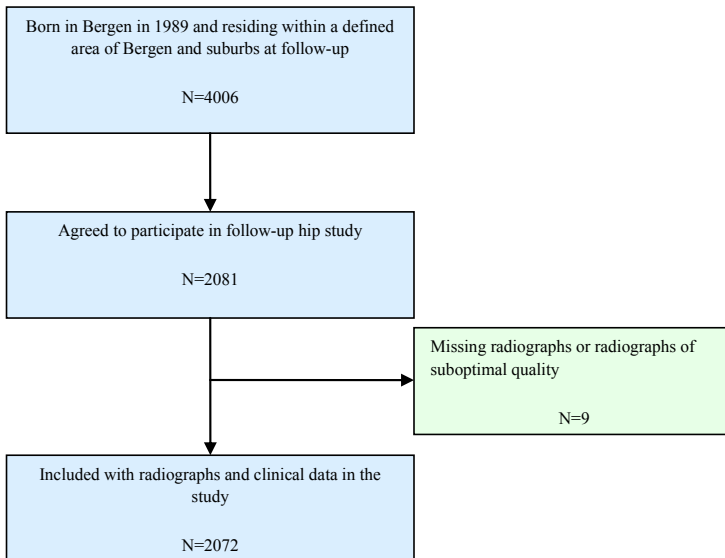


Figure 7. Flow of participants in the Hip 1989 Project.

Radiographic examination

Two radiographs were performed: one standing AP pelvic radiograph with feet pointing forward (90°) and one supine frog-leg radiograph with a 45° pillow under the thighs (Figures 8a and b). All radiographs were performed by 1 specially trained radiographer according to a specific protocol.

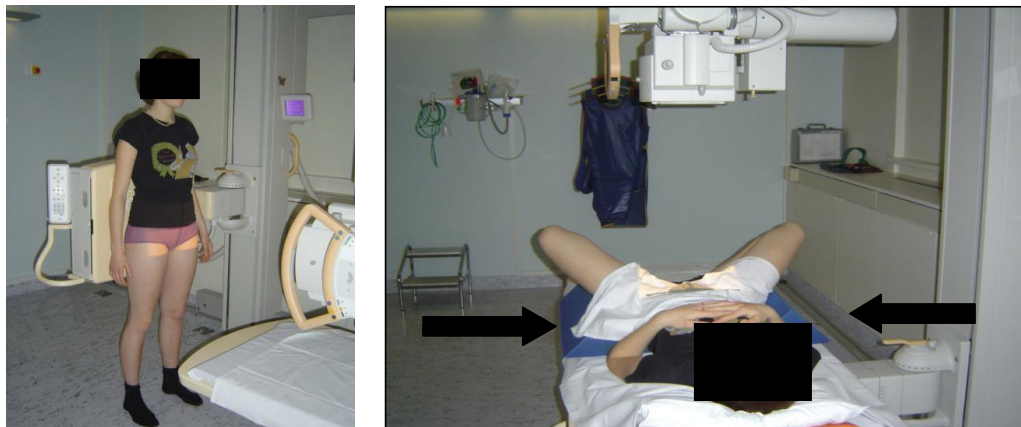


Figure 8. Radiographs of standing AP pelvic and supine frog-leg view.

All radiographs were scored subjectively for pistol grip deformity, lateral flattening of the femoral head and femoral neck bump by a radiologist (KR). The images were also read in a digital measurement programme, DDH Adult (91, 92), by one of three different observers (IØE, LBL, TGL) and finally measured manually according to Southwick's head-shaft angle, femoral head-neck angle and Murray's tilt-index by one observer (LBL).

Based on the literature, cut-off values for possible SCFE were set to ≥ 13 degrees for head-shaft angle (52, 53) and ≥ 1.35 for tilt-index (56). Joint space width (JSW) was measured medially, in the middle and laterally and $JSW \leq 2.0$ mm was suggestive of OA (93). In addition we calculated the 95% reference interval for this cohort to compare with the previously reported cut-off values.

A clinical examination was performed by 1 of 5 physicians (LE, IØE, LBL, AMH and TGL). The examination included height, weight, the Beighton hypermobility test ((94), range of hip motion and an impingement test of the hips (flexion, adduction and internal rotation).

Associations among different radiographic findings were analysed by calculating the odds ratio (OR) between each of the features separately, and an OR greater than 2.0 was considered to indicate a relevant association. 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 of the mother, parity, foetal position, and multiple births as covariates (95). Different sets of probability weights were made for each of the prevalence calculations, due to slight differences in missing values between the measures (STATA).

To examine inter- and intra-observer reliability of radiographic measurements used to diagnose and grade SCFE (Paper IV), we included a subset of radiographs from the 1989 Hip Cohort and radiographs from patients included in Paper I. One hundred randomly selected radiographs from the cohort study were mixed with 28 radiographs of clinical patients operated for SCFE at follow-up (Paper I). Two observers (KR and NV) measured the radiographs twice with an interval of three months, masked to previous readings or other findings. Intra- and inter-observer variation for each of the measurements was assessed using the mean difference, with its 95% limits of agreement (96). For the graphical presentation we plotted the differences against the mean measurements in Bland-Altman plots. Since the results were the same for both right and left hips, we presented only the results for the left hip.

7.4 EQ-5D

To assess quality of life in patients in the different studies we used EQ-5D (www.euroqol.org). This is a standard health-related quality of life questionnaire (97). The subject is asked one question on 5 dimensions (mobility, personal hygiene, usual activities, pain/discomfort, and anxiety/depression) and each dimension has 3 possible responses (no problem, some problems and severe problems). The result of each dimension gives a state of health that is translated to an EQ-5D index, where 0 is dead and 100 is the best possible health. A score below 0 is ranked as a situation worse than death. Reference populations in different age categories from different countries are collected (98), enabling a possible basis for comparison with other patient categories. The most comparable populations to Norwegians were Swedish and UK populations.

7.5 WOMAC

WOMAC (Western Ontario and McMaster Universities Arthritis Index) is a well-known tool to assess the hip pain related to osteoarthritis (99). The WOMAC Osteoarthritis Index (www.womac.org) is a three-dimensional patient-centred health status questionnaire designed to capture elements of pain, stiffness and physical disability. The index is calculated from 24 five-level questions, giving a score between 0 (high achiever) and 96 (poor achiever). The 3 categories of questions are pain in the hip, stiffness in the hip and functional limitations due to pain in the hip, all during the past 48 hours.

8. Summary of Papers I-IV

Paper I

Trude G. Lehmann, Ingvild Ø. Engesæter, Lene B. Laborie, Karen Rosendahl, Stein Atle Lie, Lars B. Engesæter. **In situ fixation of slipped capital femoral epiphysis with Steinmann pins** - 67 patients followed for 2-16 years. *Acta Orthop* 2011; 82 (3): 333–338

Background and purpose Slipped capital femoral epiphysis (SCFE) is often treated by surgical fixation; however, no agreement exists as to technique. We analyzed the outcome of in situ fixation with Steinmann pins.

Patients and methods All 67 subjects operated for slipped capital femoral epiphysis at Haukeland University Hospital during the period 1990-2007 were included. All were treated by in situ fixation with 2 or 3 parallel Steinmann pins (8mm threads in the medial end). The follow-up evaluation consisted of clinical examination and hip radiographs. Radiographic outcome was based on measurements of slip progression, growth of femoral neck, leg length discrepancy, signs of undergone avascular necrosis and chondrolysis.

Results 67 subjects (41 males) were operated on due to unilateral (n=47) or bilateral slips (n=20). Mean age at time of diagnosis was 13(7.2 -16) years. Mean age at follow-up was 19 (14-30) years, with a mean postoperative interval of 6.0 (2-16) years. The operated femoral neck was 9% longer at skeletal maturity than at surgery, indicating continued growth of the femoral neck. At skeletal maturity, 12 subjects had radiographic features suggestive of a previous asymptomatic slip of the contralateral hip. The total number of bilateral SCFEs was 32, i.e. 48% of the children.

Three subjects needed additional surgery and mild avascular necrosis of the femoral head was seen in one patient. None had slip progression or chondrolysis.

Interpretation In situ pinning of SCFE with partly threaded Steinmann pins appears to be a feasible and safe method with few complications. The technique allows for further growth of the femoral neck.

Paper II

Trude G. Lehmann, Ingvild Ø. Engesæter, Lene B. Laborie, Stein Atle Lie, Karen Rosendahl, Lars B. Engesæter. **Total hip arthroplasty in young adults, with focus on Perthes' disease and slipped capital femoral epiphysis** - Follow-up of 540 subjects reported to the Norwegian Arthroplasty Register during 1987-2007. *Acta Orthop.* 2012;83(2):159-64

Background and purpose Paediatric hip diseases account for 9% of all primary hip arthroplasties in the Norwegian Arthroplasty Register. We wanted to validate the diagnosis as reported to the register and to assess the quality of life of these patients after hip replacement.

Patients and methods 540 patients agreed to participate in this follow-up study (634 hips). All were less than 40 years of age and had been reported to the Norwegian Arthroplasty Register as having undergone a primary total hip arthroplasty (THA) between 1987 and 2007. The underlying diagnosis, age at diagnosis, and type of treatment given prior to the hip replacement were recorded from the original hospital notes.

Results The diagnoses reported to the Norwegian Arthroplasty Register were confirmed to be correct in 91% of all cases (538/592). For the 94 hips that had been treated due to Perthes' disease or slipped capital femoral epiphysis (SCFE), the diagnosis was verified in 95% of cases (89/94). The corresponding proportion for inflammatory hip disease was 98% (137/140) and it was only 61% for primary osteoarthritis (19/31). The self-reported quality of life (EQ-5D) was poorer for these young patients with THA than for persons in age-matched cohorts from Great Britain and Sweden, except for those with an underlying SCFE.

Interpretation The diagnoses reported to the Norwegian Arthroplasty Register as the underlying cause of THA were correct in 91% of cases. Individuals who undergo THA before the age of 40 reported a reduced quality of life, except for those requiring a hip replacement because of SCFE.

Paper III

Trude G. Lehmann, Ingvild Ø. Engesæter, Lene B. Laborie, Stein Atle Lie, Karen Rosendahl, Lars B. Engesæter. **Radiographic findings which may indicate an undergone, silent slipped capital femoral epiphysis in a cohort of 2072 young adults.** Submitted JBJS Br. 25.04.12. Accepted for publication 28.12.12

Background, Patients and Methods Up to 40% of patients operated for unilateral slipped capital femoral epiphysis (SCFE) are reported to have an asymptomatic slip of the contralateral hip. Based on a large population based cohort of 2072 healthy adolescents (58% females) we here report on radiographic and clinical findings suggestive of a possible previous SCFE based on commonly used cut-off values for Southwick's lateral head-shaft angle ($\geq 13^\circ$) and Murray's tilt-index (≥ 1.35). We also present new reference intervals for these measurements at skeletal maturity.

Results At follow-up the mean age was 18.6 (17.2-20.1) years. All subjects 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, increased external rotation and a higher BMI in males. When using a cut-off of $\geq 13^\circ$, 6.6% of the cohort had findings suggestive of an undergone slip. A high tilt-index (≥ 1.35) was demonstrated in 13% of the cohort, predominantly in males in whom this finding was associated with additional radiographic findings, but no clinical findings, suggestive of SCFE.

Conclusion This study may indicate that a mild, asymptomatic SCFE is more common than previously reported. Long-term follow-up is necessary to examine the potential clinical significance these findings.

Paper IV

Trude G. Lehmann, Nils Vetti, Lene B. Laborie, Ingvild Ø. Engesæter, Lars B. Engesæter, Karen Rosendahl. **Intra- and inter-observer repeatability of radiographic measurements for previously slipped capital femoral epiphysis at skeletal maturity**

Submitted Acta Radiol 31.08.12. Accepted for publication 19.12.12

Background Recent studies suggest that even a mild slip of the capital epiphysis may lead to later degenerative changes when undiagnosed. However, little has been written on the accuracy of radiographic measurements used to diagnose a slip at skeletal maturity.

Purpose To assess the accuracy of radiographic measurements commonly used for assessment of previously slipped capital femoral epiphysis (SCFE) at skeletal maturity.

Material and Methods All children born at our hospital during 1989 (n=4006) were invited to participate in a follow-up hip trial at age 18-19 years. Erect pelvic anteroposterior and supine frog-leg radiographs were obtained in a standardised fashion. For the purpose of this study, we selected a subset of 100 radiographs. To balance the dataset, we added another 28 radiographs from skeletally mature patients diagnosed and operated for SCFE. Two observers independently measured Southwick's head-shaft angle, Murray's tilt-index and the femoral head-neck angle. Intra- and inter- observer variation was assessed using the mean difference, with its 95% limits of agreement.

Results A high percentage of the images, particularly for the measurement of Southwick's head-shaft angle (40%), were judged immeasurable by at least one observer. Mean head-shaft angle was 11.0° (SD=17.0), head-neck angle was 8.0° (SD=12.0) and Murray's tilt-index 1.18 (SD=0.4). For the head-shaft angle, the mean difference between measurements (Observer 2) was 0.8° (SD=2.7°, 95% limits of agreement -4.5° to 6.1°), while the corresponding figures for the Murray's tilt-index were 0.02 (SD=0.08, 95% limits of agreement -0.18 to 0.14) and for the

head-neck angle 0.9° (SD=4.0, 95% limits of agreement of -6.9° to 8.7°). Slightly higher variance was seen for Observer 1 and between the two observers.

Conclusions Common radiographic measurements for the assessment of a previous SCFE are relatively inaccurate in skeletally mature adolescents, in particular between observers (inter-observer), but also for the same observer (intra-observer). Our results underscore the importance of thorough standardization for both image and measurement techniques when used in a clinical setting.

9. General Discussion

9.1 Methods

9.1.1 Study design

In conducting clinical research, the gold standard of study design is the randomised controlled trial (RCT) (100), which can be both expensive and time-consuming, but has the advantage of controlling for all biasing and confounding factors and provides the highest level of evidence. However, conducting a RCT is not possible for all research questions, and may not always be necessary. As for SCFE, the incidence as well as the complication rates is low. Moreover, the surgical techniques used throughout Norway are relatively similar, in situ fixation with pins or screws being the procedure of choice. It is therefore reasonable to believe that a RCT addressing complication rates and long-term outcomes of different surgical techniques for SCFE would require relatively high numbers in order to reach statistical significance.

An observational study is a study in which inferences are drawn or hypotheses tested through observational methods. Its evidence level is lower than that of a RCT, and the design has been criticized of errors due to confounding. However, to some extent, potential confounders can be controlled for and it has been shown that observational studies can provide high quality results similar to those of RCTs (101). The external validity of observational studies is often better than that of RCTs as they are performed in a real world setting and in a larger population. In this manner it is possible to have longer observational periods, infrequent adverse effects may be identified and small differences in more common complications may be addressed (102).

Observational studies can be performed using a prospective or a retrospective design. The advantages of a prospective design include decisions on inclusion criteria, definitions for disease, standardisation of examination and imaging methods used, but again, for rare diseases, it is time consuming. In retrospective studies, the cohort studied is decided and data collected from medical journals after the exposure studied, like surgery for this manner. It is easy to conduct; the time consumed is limited and

also reflects the results without the surgeon or the patient aware of being studied. It has been demonstrated that health care professionals perform better when they know they are participating in a study (42). A potential problem in observational studies is the selection bias; if the participants differ from those who refuse to participate, this may affect the results. While being aware of this possible bias, one may adjust for the differences between responders and non-responders using logistic regression models.

Paper I was performed by first using a retrospective design, collecting data on all patients having had surgery for SCFE during 1990- 2007. The data were collected from medical records and the classification was based on radiographs performed at diagnosis, postoperatively and at skeletal maturity. Unfortunately, for some of the older patients the initial radiographs were unavailable, and a radiological classification done by others was used. This may have introduced an information bias, but was only the case for a few patients (n=21). Secondly, we performed a questionnaire and a clinical and radiological follow-up using a prospective design. The questionnaire included details on current physical function thus recall bias was not a problem. The clinical examination was performed by one of two physicians after standardisation sessions to minimise the differences. Only four patients did not agree to attend the follow-up, three males and one female, thus, loss to follow-up was negligible. We hypothesise that they would have been more interested in participating if they had experienced any problems, so their inclusion might have improved the results.

Paper II was also a retrospective cohort study with a cross-sectional follow-up of all patients under the age of 40 reported to the Norwegian Arthroplasty Register. The non-responders in this study differed from the responders regarding gender, which has also been demonstrated for other studies (103). Females are more prone to participate than males. However, they did not differ in diagnosis or age, so the selection bias should be minimal. Data on reported diagnoses were controlled both by asking the patients and by collecting old medical records. We were confident that the patients received the correct diagnosis in the follow-up and since we had information from medical records on duration of symptoms, age at diagnosis and prior treatment, the recall bias from the participants were minimized. There might however be a possibility that they also had

received treatment at other hospitals than reported by the patients, but as we had medical records both from the hospitals performing the THA and treating the paediatric hip disease we believe the likelihood of missed treatment to be low.

Paper III is based on a large population based study, on data drawn from a previous RCT on developmental dysplasia of the hip (DDH). A follow-up was performed at age 18-19. For the purpose of DDH the study can be regarded as a prospective cohort study, but not when studying SCFE (Paper III). The cross-sectional design is however the best in determining prevalences, but has the limitation of being unable to reveal any information about the cause-effect relationship. The response rate was 52%, 58% for females and 42% for males. To adjust for the non-responders in the calculation of prevalences, logistic regression was used based on information from the Medical Birth Registry on all invited participants such as gender, birth weight, maternal age, marital status, parity, foetal position and multiple births. Since we know from clinical studies that SCFE is more common in males, it was important to adjust for the fact that more females than males participated in the follow-up.

Answers collected from the questionnaire on previous hip disease and hip problems may be affected by recall bias. At age 18-19 it may be difficult to remember if there were any transient episodes of hip pain during puberty. This recall bias may have underestimated the association between radiographic findings and subjectively reported hip pain in puberty. To reduce this bias, we mailed the questionnaire to the participants together with the invitation in the hope that parents would help them recall whether any hip problems had occurred.

Paper IV was performed with data drawn from the same population as Study III. The aim of the study was to test inter- and intra-repeatability for known markers for SCFE in skeletally mature persons. The radiographs had been scored a priori with respect to pistol grip deformity and femoral neck irregularities to include both normal and subjectively assessed pathological hips. To obtain a balanced dataset we also included radiographs from 28 patients previously operated for SCFE. This was done to ensure that we had measurements of normal hips, borderline cases and hips with a diagnosed

slip. We were then to test the repeatability for both low and high values of the measurements.

All radiographs were performed by one specially trained radiographer using a well-defined protocol. The radiographs were measured twice by two musculoskeletal radiologists, one with 25 years of experience and one with 5 years. Measurement landmarks were standardized prior to the study, using 20 radiographs not included in the study. All radiographs were re-read by both observers after a period of three months, masked to previous findings.

9.1.2 Estimation of longitudinal growth of the femoral neck after fixation

To estimate the longitudinal growth of the femoral neck after fixation, we constructed a ratio between the length of the Steinmann pin and the length of the femoral neck parallel to the pin as measured on the AP pelvic radiograph (Figure 9).



Figure 9. Method of calculating ratio between length of femoral neck and pin. a= length of femoral neck, b= length of Steinmann pin. Ratio: a/b

We were not able to measure the exact length of either the pin or the neck due to different magnifications in the radiographs and small differences in positioning on the different radiographs. The ratio was calculated on the first postoperative radiograph and the last radiograph before pin removal. The mean difference in ratio was calculated.

In a study by Wensaas and Svenningsen (66) this longitudinal growth of the femoral neck was measured as the length of the screw protruding at the lateral cortex in addition of direct measurement of the femoral neck. They found a positive correlation for both findings but as the radiographs were viewed retrospectively they could not control for difference in projections. In our study we had to construct the ratio since small rotational differences between the radiographs revealed no meaningful relationships regarding growth of the femoral neck. Hägglund et al. (21) in their study on 6 boys operated with the hook-pin (65) inserted tantalum balls into the epiphysis, the base of the femoral neck and the top of the greater trochanter. The patients were followed until closure of the growth plate and evidence was found of continuous growth of both the femoral neck and the greater trochanter. This study showed no significant difference in growth between the hip with prophylactic nailing and the one with a slip. On the basis of the retrospective design of our study we were unable to perform this kind of roentgenstereophotogrammetric study, but instead found evidence for the longitudinal growth in an increase in the ratio at skeletal maturity compared to the ratio on first postoperative radiographs.

9.1.3 Validation of diagnosis in NAR

Several countries have established nationwide arthroplasty registers (86, 104-107) and many publications have been based on the data reported to these registers. The diagnoses reported to the Danish Arthroplasty Register were validated in 2004 (106) and we have published a report on validation of diagnosis for DDH (108). Apart from these, the only papers on data collection for the registers concern completeness (88, 109) or validation of other reported information such as date, index hip or reoperation rate (109). For this reason, we wished to validate the diagnoses reported to the NAR.

Due to our interest in paediatric hip disease we selected patients born after 1967, when the Medical Birth Registry of Norway was established, and registered as having a primary total hip replacement in the Norwegian Arthroplasty Register (NAR) during the period 1987-2007. From the databases in NAR we had access to the reported diagnoses on each patient. To validate the diagnoses we asked the patient whether the reported diagnosis was correct and also consulted medical records both from the hospital performing the THA and from the hospital(s) treating the paediatric hip disease. When comparing to the validation done in the Danish Register, they also included access to radiographs but unfortunately, Norwegian legislation only permits radiographs to be kept for 10 years if no new ones are performed. Thus many of the radiographs were missing and could not be used in the validation. However, we feel that our rigorous data collection from old medical records ensured the correct diagnoses. Only patients 40 years of age and under were included. This is an advantage in validation work as secondary degenerative changes tend to obscure underlying pathologies and make it difficult to assess an underlying diagnosis in older age groups. Since our main objective was validation of the reported diagnosis, and not to validate whether the diagnosis decided by the surgeon was the correct one, we believe that the results are valid also for the other age groups reported to the NAR.

9.1.4 Calculation of incidence of SCFE in Norway

In Paper II one of our aims was to estimate the annual incidence of SCFE in Norway in order to compare the data with data on Perthes' disease. For Perthes' disease the incidence was found in a nationwide randomized study during 1995-2000 where all children in Norway with Perthes' disease were included (110). An annual incidence of Perthes' disease of 9.2 per 100.000 was found in subjects below 15 years of age. For SCFE no such incidence has been established. We used the Norwegian Patient Register (NPR) (111) and Statistics Norway (112) to try to estimate an incidence. However, there are several limitations to the calculations. We collected information about number of patients reported to the NPR from 2000-2009 with an ICD-10 diagnosis code M93.0 and with a primary operation code for the proximal femur. One problem was that until 2007 the data in the NPR was anonymous, so we could not

ascertain whether the same person was reported twice due to bilateral affection. Hence, we had to adjust the annual reported number of patients with SCFE in line with the expected number of bilateral slips, and according to the literature and results from Paper I we reduced the calculated incidence by 25% (9, 12). Data from Statistics Norway was used to find out the number of children in Norway below the age of 16. The method described only gives an estimated annual incidence and hopefully the establishment of the National Children's Hip Registry will reveal the true incidence of SCFE in Norway.

9.1.5 Radiographs of healthy teenagers

The 1989 Hip Project was conducted in accordance with the ethical standards of the Regional Committee for Medical and Health Research Ethics. The research protocol was approved by the Committee according to standard regulations. The teenagers were invited to participate in a voluntary study and of course it was naturally necessary to minimize the radiation. Since the participation required two radiographs of their pelvic region, we focused strongly on minimizing the radiation exposure. First of all, it was vital to have one specially trained radiographer, who performed all the radiographs. She was instructed to adapt the radiation doses to each participant to make them as low as possible without compromising the quality of the radiographs. Participants were all explained the importance of lead protection and males were offered suitable protection when possible. All radiation doses were recorded and the mean doses in the AP view were 0.09 mSv and in the frog-leg view 0.06 mSv, giving a total radiation dose of 0.15 mSv for each participant. Measurement values from Radnett for natural radiation in Norway vary from 0.05 μ Sv/h to 0.20 μ Sv/h which is equivalent to an annual dose of 0.4 to 1.8 mSv (113). The general population receives an annual radiation dose of approximately 3.5 to 4.5 mSv and half of this is from radon radiation in people's homes. In plane travel the estimated radiation dose for a flight is 0.02-0.05mSv, approximately half of the dose of a chest radiograph (114). The annual threshold of exposure for health workers is 20mSv (115). This demonstrates that the teenagers in our study were exposed to a low level of radiation, similar to 15-20 days of natural radiation, which is not expected to involve any health risk.

9.1.6 Measurements of SCFE, lacking a gold standard

Different radiological measurements for SCFE exist and there are also differences in the way papers present the same measurements. Prior to the work on this thesis an extensive literature search was performed to try to find the most commonly used or best documented method. The head-shaft angle proposed by Southwick stood out as being most used (8, 12, 16, 38, 49-51), but this was also used in different manners. Some papers measured the angle on the AP view, which may lead to an underestimation of both numbers and severity of slips, due to the fact that minor slips may only be visualised in the lateral view. Others tend to use the head-shaft angle in the lateral view, calculating the slip angle as the head-shaft angle in the affected side minus the head-shaft angle in the opposite hip. Since we know from other studies that up to 60% of SCFE patients have bilateral slips it seems inappropriate to use the contralateral hip as a reference for normality. For Papers I, III and IV in this thesis the lateral head-shaft angle is measured directly without comparing it with the opposite side. Several other measurements are based on the same principles, but conducted with minor differences i.e. the Billing technique or head-neck angle.

Measurements of slip angle have also been used in the long-term follow-up of SCFE patients to look for undiagnosed bilateral slips or progression of slips. However, it has been difficult to find a minimum value of what to diagnose as a slip. Jerre et al. have used $>12^\circ$ as a limit of pathology (54) based on previous study by Billing which found the mean angle of healthy controls to be 0° and a critical value at 12° (116). They even suspected a slip between $7-12^\circ$ if there were other signs to suggest this. Barrios et al. (28) proposed pinning of all patients bilaterally if the posterior sloping angle was $>12^\circ$ in the asymptomatic hip. They showed in a study of 36 normal hips and 47 contralateral hips of patients with unilateral affection the mean posterior sloping angle of healthy individuals was 5° , whereas for contralateral hip in SCFE patients this angle was 12° . In an abstract presented on the annual meeting of the Norwegian Orthopaedic Society in 2007 we performed an ROC analysis to try to find the best cut-off between the first 305 participants in the 1989 Hip Project and patients from Paper I (117). In

these analyses we found that the best cut-off value to differentiate a healthy hip from a slipped hip was between 13-14°.

Since there were few studies to support the lower cut-off value of a SCFE, we calculated the 95% reference intervals (mean \pm 2SD) for the cohort including 2072 teenagers in Paper III to compare this to the commonly used cut-off values. Also in Paper III we used Murray's tilt-index as a marker of a previous slip. No papers have used this measurement in diagnosing slips in skeletally immature patients, but it has been proposed for use in follow-up studies of patients with OA scheduled for a THA to diagnose missed SCFE (56). Since our population based cohort comprised skeletally mature persons with no previous history of a slip we used several radiographic markers. No study was found dealing with slips in previously undiagnosed teenagers.

Clinical findings are of course also important when making a diagnosis of SCFE. Typical characteristics of patients with established SCFE are male sex, overweight, and a reduced range of hip motion (24). Especially the internal rotation is reduced, and some may have an increased external rotation explained by the posterior slipping of the femoral head. However, no single clinical finding alone is diagnostic of SCFE, and to date, no composite SCFE score has been proposed to help diagnose a previous, "silent" slip. Thus, our results must be interpreted with care. Although 6.6% tested positive for an undergone slip based on the commonly used cut-off of 13° for Southwick's angle, a slightly higher cut-off would have provided quite different results.

9.1.7 Intra- and inter-observer repeatability

When conducting studies on SCFE we are dependent on radiological measurements. Since there is no "gold standard" of measurement, we selected three different known markers with the aim of testing the repeatability of these when used in skeletally mature persons. When calculating the repeatability we used the method of Bland and Altman (96) in plotting the mean of two measurements against the difference between the measurements (Figure 11). The agreement between observers was calculated as the 95% limits of agreement. However, it is important to emphasize that the intra-class

correlation coefficient is also often used in studies when calculating the reliability of a measurement. The agreement parameters (the Bland-Altman method) are more related to the measurement instrument itself and assess closeness of repeated measurement scores. The reliability parameter (intra-class correlation coefficient) is related to how well different measurements can be distinguished from each other. A good correlation will for instance be seen for any two methods designed to measure the same parameter and does not automatically imply that there is a good agreement (118). In general, the Bland-Altman approach, analyzing the difference between measurements by two observers on each subject, is the preferred method for analysing agreement on continuous data.

9.2 Results

9.2.1 Operation with 2 Steinmann pins

In Paper I we found that in situ pinning of slipped capital femoral epiphysis with partly threaded Steinmann pins (diameter 2.3mm) is a feasible and safe technique with few perioperative and postoperative complications, and with good clinical and radiographic long-term outcome. The technique enables further growth of the femoral neck, with an acceptable leg length discrepancy at skeletal maturity.

All children admitted to our hospital with SCFE since 1990 have been operated with this method (Figure 10). None of the subjects were prophylactically pinned in the contralateral hip. The mean age at diagnosis for boys and girls was 13 and 12 years respectively. 49% of the slips were mild, 32% moderate and 16% severe. 2 were not classified. Duration of symptoms were positively related to severity of slip, where mild slips had a mean duration of symptoms of 3.2 months and severe slips a symptom duration of 8.4 months ($p=0.004$). This finding is in accordance with other studies (23, 37, 39, 41). We also found that females had longer duration of symptoms and more cases of moderate and severe slips than males. One could speculate on a diagnostic delay leading to a more severe slip in girls, since doctors are more prone to consider SCFE as a possible diagnosis in males. The mean operating time was 40 min (range 10-105) which is in accordance with others using in situ fixation (70). The mean time

from primary operation until removal of pins was 3.3 years. Since our method allows for further growth in the proximal femur, pins could not be removed until skeletal maturity. This period of time is distinctly longer than for methods favouring epiphysiodesis (15).



Figure 10. Surgery for SCFE in a 12 year old male. The pins are inserted into the femoral neck via a drill sleeve.

During the entire time of growth there is a possibility for slip progression or pin displacement. In our study we had no cases of slip progression but 1 that needed re-fixation due to displacement of the pins. This was a patient with bilateral slips. Slip progression after stabilization with a single screw has been reported by several authors (16, 43, 49, 72). Carney et al. found in 2003 that 20% suffered a slip progression of 10° or more when operated with a single cannulated screw. The idea that double screw fixation is more likely than a single screw to provide torsional stability in non-reduced slips has been verified in artificially created slips in bovine femurs (119). Others have used multiple Kirschner wires to fixate the femoral head. In a study of 29 patients, a repeated transfixation was judged to be necessary in 7 of the cases as the wires lost contact with the femoral head during growth (68). We believe that our favourable results may be due in part to the threads at the end of the pins, securing sufficient anchorage within the femoral head during the residual growth.

A mild AVN with partial involvement of the femoral head was seen in one male with a severe slip. He also suffered a leg length discrepancy of 2.5 cm and was subsequently treated with a leg lengthening procedure. Carey et al. (1987) reviewed 60 patients operated with threaded pin fixation. At follow-up of 4 to 13 years after primary surgery, 8 patients had findings consistent with AVN (15). Carney et al. (1991) reported on 155 operated hips with a mean follow-up of 41 years. AVN was diagnosed in 12% of the subjects, and was more frequent in those with severe slips (16). They also found a positive association between AVN and penetration of a pin into the joint. AVN was not seen in any of the three subjects in our study who had pin penetration to the joint and neither resulted in a chondrolysis.

Remodelling after SCFE results from bone deposition anteromedially and absorption posterolaterally. Several authors claim that remodelling also results from reduced Southwick's head-shaft angle (120). In theory, this reduced angle may be due to further asymmetric growth of the femoral neck. Our results indicate that stabilization of the epiphysis from further slip is possible without stopping the longitudinal growth of the femoral neck. This may lead to better biomechanics, improved remodelling, and reduced leg length discrepancy.

Fifty-two of the 67 patients answered a questionnaire at mean age of 20 years and they had a mean EQ-5D index of 89 (33-100). This was compared to an age-matched population of Sweden with an index of 84 ($p=0.06$). When answering the WOMAC questionnaire, 21 reported no problems at all, 19 complained of morning stiffness and 14 reported some problems with heavy everyday activities. Thirty-eight patients exercised more than two hours per week at an intensity which produced breathlessness or sweating and physical exercise was performed at a mean of 4.3 hours per week.

Until 2011 operation with Steinmann pins was the only method of treatment of SCFE in our clinic for mild, moderate and severe slips. However, since then we have operated a 15 year old boy with a severe slip and symptom duration of more than one year with subcapital correction osteotomy with surgical hip dislocation (73). He had an extensive external rotation and severe pain in the hip. In this setting we decided, on the basis of the reports by Leunig et al., to perform the surgical dislocation of the femoral

head combined with the subcapital femoral osteotomy (73). We will follow the reports on this promising procedure and also the long-term results and we acknowledge that this procedure may be a possibility for selected cases of severe SCFE. However, the procedure has a potential risk of severe complications as AVN, although Leunig et al. report no such cases in 30 patients operated. Rebello et al. reported that 2 of 5 patients with SCFE developed a severe AVN after surgical dislocation and femoral neck osteotomy (121). In a survey in 2011 among members of the European Paediatric Orthopaedic Society (EPOS) (122), 90% of the respondents recommended no reduction even in a severe stable slip, but for an unstable slip about 46% recommended reduction under positioning on the table and as few as 11% did an open reduction. These results show that the European surgeons still support the traditional treatment with in situ fixation, and only rarely is a surgical dislocation performed.

9.2.2 Bilateral SCFE

The prevalence of bilateral involvement reported varies between 15 to 80% depending on population studied, classification and measurements used (13, 35, 38, 52, 54, 81, 82, 85). Castro et al reported the risk of a new slip to be 2335 times higher in adolescents with a previous slip than in healthy subjects (17). Bilateral involvement was seen in half of the subjects in our study, and one-third of these cases were undiagnosed until follow-up at skeletal maturity (Paper I). Even small slips may have remodelled, resulting in a head-shaft angle found to be normal at follow-up (120, 123). In a long-term follow-up of 260 patients from 1988, Hägglund et al. found that 61% had bilateral slips at skeletal maturity, of which 104/260 (40%) remained undiagnosed until the long-term follow-up (13). In another study involving 224 children, Loder et al. reported that 37% had bilateral slips (38). In a retrospective study of 100 patients, Jerre et al. found bilateral slip in 59% after 32 years observation (54). Around two-thirds of these were asymptomatic, and 18% were first diagnosed after skeletal maturity. In a report published by Hägglund in 1988, 25% of patients with an undiagnosed slip had OA before the age of 50 (13, 83) compared to 9% of contralateral hips without signs of an asymptomatic slip, and during recent years it has been discussed that even silent slips could lead to femoroacetabular impingement (93,

124, 125). This shows that even the minor slips may give problems later in life, and that preventing a silent slip may be important. Based on information in the literature and on our results, we have now changed the clinical routine in our department to prophylactic pinning of the contralateral hip in children presenting with a unilateral slip. Crucial for this decision was the fact that we had only a small number of complications and were also able to prove the continued growth of the femoral neck.

9.2.3 Validation of diagnoses reported to NAR

In Paper II we found that the underlying cause of a total hip replacement was correctly reported to the NAR in 91% of all subjects < 40 years of age and in 95% of patients operated due to Perthes' disease or SCFE. SCFE and Perthes' disease were reported in the same box in the registration form, and the correct figures for each of these diagnoses could therefore not be distinguished. Our findings regarding validation of diagnoses compare favourably with a study from the Danish hip arthroplasty register comprising 459 patients (106). After having reviewed medical records and preoperative radiographs, the authors found that a reported diagnosis had a positive predictive value of 84%.

Not unexpectedly, primary osteoarthritis was the diagnosis most commonly incorrectly reported. This is because a severe osteoarthritis warranting a THA at this young age tends to obscure a possible underlying diagnosis such as DDH, Perthes' disease or SCFE (56). It is also to be expected that the diagnoses of Perthes' disease and SCFE have a high proportion of correct reports, since these patients are often aware of diagnoses and operations performed and are able to communicate this to the surgeon performing the THA. 56 hips were incorrectly reported to NAR; in 43 of the cases the reporting surgeon had chosen the wrong diagnosis and in 8 cases placed the diagnosis under "other specified diagnoses" even though the patients had diagnoses that corresponded to the alternatives given in the form. This was however not recognized in the registry and in the database these cases figure in the wrong category. Only 3 forms were misclassified by the secretary. The study indicates that the reporting to the register is of high quality and that only minor mistakes are performed during the work

of transferring the data reported in the forms to the databases. However, in order to further improve the quality of the reporting, the surgeons need to be even more precise when filling in the form.

9.2.4 Previous treatment and results of THA secondary to SCFE

Paper II was undertaken with a special interest in THA after paediatric hip diseases. For patients reported to have had a THA secondary to a SCFE, we collected all data available from medical records. All but one had undergone surgery at diagnosis of the slip, at a mean age of 12 years, to prevent further slipping and to prevent or delay degenerative change (16). Initial radiographs at diagnosis were missing for several of the patients due to Norwegian legislation and we had no possibility to classify them according to severity. This could have given us valuable information on who is at risk of developing later degenerative changes, warranting a THA at such young age. Several papers state that the more severe slips have the worst long-term outcome (16, 40, 45, 47, 48). Of those operated with a THA secondary to a SCFE, more than half (16 of 29) were females. This was rather surprising since SCFE is more frequently seen in males (2/3) (8, 42). One explanation may be that girls suffer a more severe slip than boys, as the results in Paper I may indicate. Again, due to unavailable initial radiographs, we could not investigate this in detail. In Paper I we found that female patients had nearly 2 months longer duration of symptoms before diagnosis and nearly 2/3 had a moderate or severe slip compared to 1/3 of the boys. Longer duration of symptoms is known to increase the severity of the slip (50).

Quality of life was assessed for all the patients and compared to healthy age-matched controls. For the group in general (index=71), inferior quality of life was demonstrated ($p<0.001$). These findings have also been reported by Wangen et al. (126) in a study of 49 patients aged 30 or below. They found a mean EQ-5D index of 68, compared to 71 in our study. In comparison, indices from age-matched Swedish or British cohorts have been reported at 85-90 (98). When subdivided into different diagnoses, still patients operated secondary to DDH (index=69) and Perthes' disease (index=74) still had inferior results, but patients operated secondary to SCFE (index=81) had the same

quality of life as the control group from the UK ($p=0.13$). This contradicts the belief that THA after paediatric hip disease is more challenging with poorer results. Also a newly published study from the New Zealand Hip Registry (86) concluded that THA secondary to SCFE and primary OA had the same quality of life, but that there was a tendency for patients with SCFE to report even better results. In a study by Engesaeter et al. on data from the Nordic Arthroplasty Registry Association (NARA), the revision rates for paediatric hip diseases were compared to revision rates for OA (127). They found no overall increased risk. In an analysis of subgroups, DDH had higher revision rates, but there was no statistical difference for Perthes' disease or SCFE. The reasons for this are unclear, but one explanation may be that femoral head alone, and not the acetabulum, is involved in the underlying disease.

In this study all patients but one were diagnosed and operated as teenagers, yet they had a THA before the age of 40. As mentioned earlier we had no possibility to find out about the severity of the slip, and medical notes were not detailed enough provide information about stability. Therefore we do not know if these patients represent the more serious cases of slips, or if any of them presented with a mild slip. However, even though a THA is not desirable at a young age, we have demonstrated that patients with prosthesis secondary to SCFE have good quality of life and other studies have indicated the same revision rates as for primary OA.

9.2.5 Epidemiology of SCFE

The estimated incidence of SCFE in Norway calculated in Paper II reveals about 3 cases per 100.000 children 16 years or below. A slip is rarely encountered before the age of 10 and the incidence for the population at risk could be estimated to be higher at around 10 per 100.000 giving about 38 cases annually in Norway for children between 10-16 years. When comparing incidences it is important to compare with populations genetically similar to our own, since the prevalence varies according to ethnicity (12, 20). The US incidence rate is 10 per 100.000 for children aged 9-16 years (20) and Sweden shows an attack rate of 1 per 1200 and an estimated annual incidence of 7 per 100.000 for children aged 7-17 years (7). Using the roughly estimated incidence for

only children aged 10-16 in Norway, we find the incidences in the two Nordic countries to be fairly similar. However, our estimate of 3 per 100.000 for all children 16 and below compares well with other reports from Europe and USA (8, 10).

It is interesting to compare the numbers of primary THA performed due to SCFE in Norway and in Sweden against the background of the reported incidences. Data from Engesæter et al (127) shows that SCFE/Perthes' disease is the cause of about 1.3% of the primary THA in the Norwegian Register compared to 0.1% in the Swedish Registry. The Swedish Register also presents the figures for SCFE separately, which account for only 0.02% of all primary THA reported. The numbers cannot be compared directly since the Norwegian Register combines the number for Perthes' disease and SCFE, but in Paper II we found the relation between Perthes' disease and SCFE to be 2.3:1. If the calculated incidences are correct, they are quite similar, yet there is a smaller proportion of patients undergoing a THA due to previous SCFE in Sweden than in Norway. We have no good explanation for these differences.

The radiographic findings of possible SCFE in Paper III may indicate that the prevalence of SCFE is higher than reported in clinical studies. We have performed an extensive literature search and found no studies describing findings of slips in population based cohorts of teenagers, but several authors report pistol grip deformity or proximal femoral deformities in patients with degenerative changes as findings suspicious of an earlier, undiagnosed SCFE. Goodman et al. (128) reported findings of post-slip morphology in 2665 human skeletons. They found that 8% of the male skeletons and 6% of the female skeletons had post-slip morphologies. They also found a significant correlation between post-slip morphologies and development of OA. Skeletons with post-slip showed more cases of severe arthritis and in skeletons only affected on one side, the OA was more pronounced on the affected than the unaffected side. Gosvig et al. reported findings of cam deformities in 17% of males and 4% of females, and found no relation to acetabular dysplasia, BMI or findings of degenerative changes. They concluded that this lends support to the fact that cam deformities are a result of a silent SCFE (124). In our study we found 6.6% of all 18-19 year olds, 7.6% of males and 5.5% of females, with a head-shaft angle of $\geq 13^\circ$

more, and 12% with a tilt-index of ≥ 1.35 , which was also more common in males than females at 20% and 6% respectively. The numbers of high head-shaft angles compare well with the study by Goodman and our findings of tilt-deformity with the study by Gosvig. However, there was no association between the findings of a high head-shaft angle and a high tilt-index in our study, and the tilt-index had no association with common clinical findings in patients with SCFE. The tilt-index proposed by Murray (56) may not be a good predictor for a previous slip since there was no association with clinical findings in that case either. On the other hand, a high tilt-index was associated with pistol grip deformity, lateral flattening of the femoral head and a focal prominence of the femoral neck. These features have been associated with femoroacetabular impingement, causing groin pain during movement. Murray suggested that the pistol grip deformity may be caused by a previous slip; however, our results lend no support to this theory. Further, Resneck (129) proposed that the pistol grip or tilt-index was due to degenerative changes in elderly patients with osteoarthritis (OA). However, our study indicates that the tilt deformity is present long before any signs of OA, since there were no differences in the JSW in the groups of low versus high head-shaft angles or low versus high tilt-index. In our cohort the number of participants with a high tilt-index corresponds well with papers presented on impingement (125,130,131). About 20% of young males and 3-4% of young females are thought to have a pistol grip deformity which in time will give rise to a cam impingement (125, 130).

On the basis of our study we are not in a position to conclude that all these teenagers suffered a previous slip. Nevertheless, our study should draw attention to the fact that more teenagers than previously known may have a slip, and hip problems in puberty should warrant hip radiographs to reveal any signs of a slip. All the high head-shaft angles found were within the range of a mild slip, and it is known that the more severe slips lead to a greater risk of developing degenerative changes. However, a study by Hansson et al. (79) found that 20% of patients with a slip below 30° had developed mild OA and one patient severe OA at follow-up 30 years after fixation. Only long-term follow-up of this cohort will demonstrate whether the findings of a head-shaft

angle $\geq 13^\circ$ or a tilt-index ≥ 1.35 have any significance at all and if there is an increased risk of developing degenerative changes compared to lower values.

9.2.6 Repeatability of SCFE measurements

Several papers have presented repeatability measurements for SCFE (132-134). In Paper IV we calculated the intra- and inter-observer repeatability for known SCFE measurements in 100 19 year olds without any previous slip and 28 teenagers previously operated for SCFE. We have shown that common radiographic measurements for the assessment of SCFE are relatively inaccurate, in particular between observers, but also for the same observer. Overall the degree of inter-observer variation was higher than the intra-observer variation for all three markers. In addition the Bland-Altman analysis (96) demonstrated that although the mean difference between the two readers was small the standard deviation was large, with a relatively wide 95% limit of agreement demonstrated by the Bland-Altman plots (Figure 11).

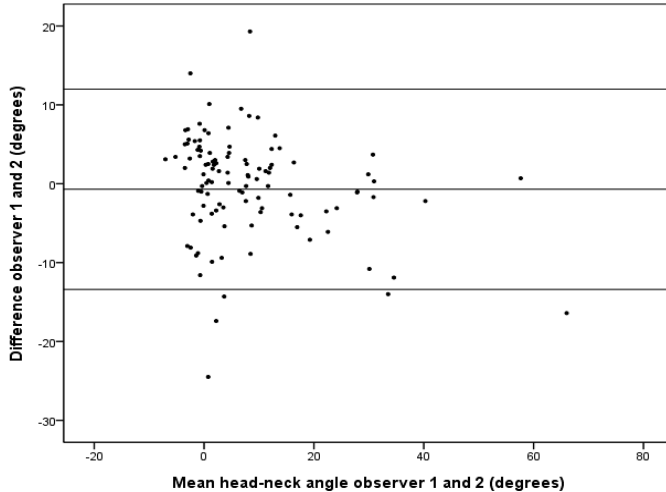


Figure 11. Bland-Altman plot, showing the mean between observers is plotted against the mean difference between observers, with 95% limits of agreement.

Of the angular measurements under investigation, the head-shaft angle appeared to be the more consistent, with relatively low variability both within ($\pm 5^\circ$) and between observers ($\pm 7.5^\circ$), compared to the measurement of the femoral head-

neck angle at $\pm 8^\circ$ and $\pm 12.5^\circ$ respectively for intra- and inter- observer variation. Our results compare well with a study by Loder (132) and colleagues on slip angle in 38 children diagnosed with SCFE. They found that Southwick's head-shaft angle based on a frog-leg view was the more accurate measurement but with a 95% limits of agreement of ± 12 degrees for both intra- and inter-observer variability. They recommended converting into discrete categories to achieve better variability. Another study by Carney and Liljenquist (134) of 108 showed an intra-observer variability for the lateral head-shaft angle of $\pm 5.9^\circ$. Zenios reported on the repeatability of the posterior sloping angle (133). Two senior orthopaedic and two fellows measured the radiographs twice and reported both the intra- and inter-observer reliability using the intraclass correlation coefficient. This makes it difficult to compare directly but they concluded that the inter-observer measurements were excellent or good and the intra-observer measurements varied between excellent for the senior surgeons to good or fair for the fellows.

To our knowledge, the repeatability of Murray's index or the femoral head-neck angle has not been addressed in previous studies. A literature search revealed that Murray's tilt-index has been used as a marker for previous slips at late follow-up only, but not for the assessment of actual slips (56, 135). We found 95% limits of agreement for the tilt-index of ± 0.16 and ± 0.29 for intra- and inter-observer repeatability, respectively.

When the measurements are used in clinical practice, standardization of measurement is important, or alternatively the measurements may be done by a single, experienced observer. This is supported by the study of Zenios (133) where senior surgeons performed better than fellows. Although maybe impractical for daily practice, the small number of cases of SCFE means that it would be possible for a single individual to perform the measurements in each referral centre. Persons using the measurements have to be familiar with the results of repeatability studies and the limitations of the lack of accuracy.

10. Conclusions

Paper I

In situ fixation of slipped capital femoral epiphysis with partly threaded Steinmann pins seems to be a safe procedure with few complications both for primary surgery and for hardware removal. Only 1 of 67 patients experienced a mild AVN and none suffered further slipping.

The results suggest that the applied technique allows for growth of the femoral neck, resulting in little leg length discrepancy at skeletal maturity. Most patients had no specific health complaints at long-term follow-up.

Paper II

Validation of the data reported to the Norwegian Arthroplasty Register on primary THAs for patients 40 years and below reveals good quality, with 91% correctly reported diagnoses. For patient operated due to a previous SCFE or Perthes' disease the correct diagnosis was reported in 95%. All but 1 patient had been diagnosed with SCFE as a teenager and received surgical treatment at the time of diagnosis. A THA before the age of 40 seems to reduce quality of life as assessed by EQ-5D, except for patients needing a hip replacement due to SCFE, who have an EQ-5D score similar to reference persons of the same age.

Paper III

In a cohort of 2072 teenagers aged 18-19 years, 7.6% of males and 5.5% of females had a head-shaft angle $\geq 13^\circ$. This finding was associated with an increased BMI, reduced internal rotation and increased external rotation. In the same cohort 20% of boys and 6% of girls had a Murry's tilt-index ≥ 1.35 . There was no association between a high head-shaft angle and increased tilt-index. None had reduced JSW as an early sign of osteoarthritis. Our findings may indicate that mild slips in teenager are more common than previously supposed.

Paper IV

Southwick's head-shaft angle can be difficult to measure in skeletally mature persons due to difficulties in identifying the physis. When measurable, the variation between observers was relatively large, comparing well with previous reports, while the intra-observer variation was better. Measurement variation was smaller for the head-shaft angle than for the femoral head-neck angle, and relatively small for the Murray's tilt-index. Our results underscore the importance of meticulous imaging techniques and standardisation of measurements. In everyday practice, measurements performed by a single, trained radiologist may improve accuracy.

11. Future research

The treatment of SCFE in Norway is carried out in several different hospitals. There is no agreement on the type of fixation even though there are only about 38 new cases annually. On January 1st 2010 the nationwide Paediatric Hip Registry began registrations. All new cases of DDH, Perthes' disease and SCFE are reported, in addition to reports of each occasion when procedures are performed under general anaesthesia. Radiographs of each subject are collected by the Registry. It is to be hoped that in a few years data will be reported with the same range of completeness as of the other registers (98% for THA and 79% for the hip fracture register) (88, 136). A study of the completeness of the data in the Paediatric Hip Registry can now more easily be performed since the National Patient Register is personally identifiable. When more complete data are available in the Paediatric Hip Registry, we will have a unique possibility to estimate the incidence more precisely and prospectively follow patients with treatment and long-term follow-up.

Regarding the validation of the data in the NAR, we feel confident of the routines performed by the personnel handling the data. To reassure ourselves that the favourable result reported in Paper II applies to the whole register, it would also be of interest to carry out validation for patients above 40 years. In the latest revision of the NAR form, the diagnoses of Perthes' disease and SCFE have been separated. This will enable us to study these groups separately and compare the results.

The 1989 Hip Project has given us a huge amount of data on the hips of Norwegian 18-19 year olds. We hope to follow this cohort for many years to be able to determine the consequences of high head-shaft angles and tilt deformities with regard to the development of degenerative changes and the need of THA for these participants compared to those with lower values. Also in relation to the on-going discussion on cam impingement, it will be of great interest to follow the participants with the findings of a pistol grip deformity. This can give valuable insight in the debate on arthroscopic reshaping procedures performed and the need of these procedures. We

hope to invite the cohort for a new follow-up in 2029, when they are 40 years old, and look for the development of early degenerative changes.

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13. Appendices

Appendix 1 Consent form, Study I

Appendix 2 Patient consent form and questionnaire, NRL follow-up study

Appendix 3 Registration form, Study II

Appendix 4 Registration form THA, Norwegian Arthroplasty Register

Appendix 5 Consent form, Hip 89 study

Appendix 6 Patient questionnaire, Hip 89 Bergen Cohort Study Part 1

Appendix 7 Patient questionnaire, Hip 89 Bergen Cohort Study Part 2

Appendix 8 Clinical examination, Hip 89 Bergen Cohort Study

Samtykke til å delta i Epifysiolyse-studie ved Ortopedisk avdeling, Haukeland Universitetssykehus

Navn:.....

Jeg har mottatt skriftlig informasjon om studien av lidelsen epifysiolyse capitis femoris (glidning av lårhodet på lårhalsen), og sier meg villig til å delta.

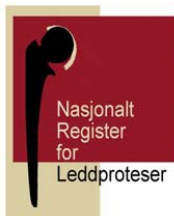
Jeg kan når som helst trekke meg fra deltakelse, uten at dette får konsekvenser for meg.

Medisinsk ansvarlig for studien er assistentlege Trude G. Lehmann og professor Lars B. Engesæter.

Bergen,.....2008 Signatur.....

Dersom du er under 18 år, må en av dine foreldre/foresatte godkjenne at du deltar i studien.

Bergen,.....2008 Foreldre/foresattes signatur.....



Nasjonalt Register for Leddproteser

Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 11
5021 BERGEN
Tlf.: 55 97 64 52
<http://www.haukeland.no/nrl/>

Navn

Kjære

Alle kunstig hofteleddoperasjoner (totalprotese i hofteleddet) i Norge blir rapportert til Nasjonalt Register for Leddproteser. Registreringen startet 15. september 1987 og er godkjent av Datatilsynet. I perioden 1987 – 2007 har ca 110 000 fått innsatt kunstig hofteledd, av disse er 753 innsatt på yngre voksne dvs. personer som er født etter 1967.

I følge Nasjonalt Register for Leddproteser er du en av de yngre voksne som har fått innsatt et kunstig hofteledd. Vi tillater oss derfor å be deg svare på noen spørsmål angående din hoftelidelse. Dine svar vil selvsagt bli behandlet konfidensielt og ingen personidentifiserbare opplysninger vil bli offentliggjort. Studien er godkjent av Datatilsynet og Etisk komité.

Vi ønsker nå å klarlegge funksjonen til unge personer med hofteproteser og om funksjonen er avhengig av lidelsen som førte til hofteoperasjonen. Dette prosjektet er en del av en større studie om kunstige hofteledd hos yngre voksne. Spørsmålene som vi ber deg svare på, er delvis internasjonale standardiserte spørsmål. De består av en generell del om din allmenne helsetilstand og en spesifikk del om din hoftelidelse. Vennligst bare kryss av for ett alternativ for hvert spørsmål. Vi ber deg sende det utfylte skjemaet i retur til oss i den ferdig frankerte svarkonvolutten snarest mulig (NB! Porto er betalt). Det vil ta deg ca. 3 minutter å svare på spørsmålene. Vi håper du tar deg tid til dette.

På forhånd takk for hjelpen!

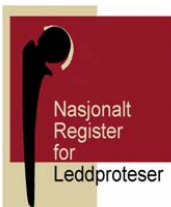
Med vennlig hilsen

Lars B. Engesæter
Professor /seksjonsoverlege i Barneortopedi,
Haukeland Universitetssykehus
Nasjonalt register for leddproteser
E-post: Lars.Engeseter@helse-bergen.no
Tlf: 55 97 56 84

Stein Atle Lie
Statistiker, dr. philos
Nasjonalt register for leddproteser
Haukeland Universitetssykehus

Trude Gundersen Lehmann
Lege
Haukeland Universitetssykehus

Ingvild Øvstebø Engesæter
Stud.med.
Universitetet i Bergen



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Haukeland Universitetssykehus

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PASIENTSPØRRESKJEMA

Navn:

1. Fødselsnummer:

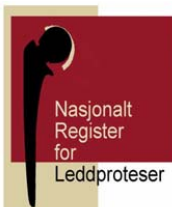
2. Dato for utfylling av skjema: |_|_||_|_||_|_||

3. I Nasjonalt Register for Leddproteser er du registrert med følgende lidelse som bakgrunn for innsettelse av kunstig hofteledd:

- Idiopatisk coxartrose (=slitasjegikt i hoften med ukjent årsak)
- Rheumatoid artritt (=leddgikt)
- Seqv. fraktura colli femoris (=sensskader etter lårhalsbrudd)
- Seqv. dysplasi (=sensskader på grunn av grunne hofteskåler)
- Seqv. dysplasi m/ luksasjon (=sensskader på grunn av grunne hofteskåler med lårhodet ute av ledd)
- Seqv. Perthes/epifysiolyse (=følgetilstand av Calvé-Legg-Perthes eller glidning av lårhodet på lårhalsen)
- Bechterew (=arvelig tilstivning av rygg og hofteledd)
- Annen årsak
- Årsaken mangler

Stemmer denne opplysningen?

- Ja
- Nei. Vennligst angi riktig diagnose:
- Vet ikke



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<http://www.haukeland.no/nrl/>

4. Hvor gammel var du første gang du fikk behandling for din hoftelidelse?

Alder: Vet ikke:

5. Hvor gammel var du da du merket de første symptomene på din hoftelidelse?

Alder: Vet ikke:

6. Ved hvilke(t) sykehus ble du behandlet for din hoftelidelse?

..... Vet ikke:

7. Har du smerter fra den andre hoften?

Ja

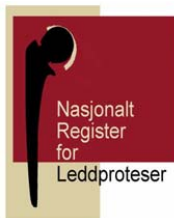
Nei

8. Er det andre årsaker til at du har problemer med å gå?

(For eksempel smerter fra andre ledd, rygg smerter, hjerte-karsykdom eller andre sykdommer som påvirker gangevnen din)

Ja

Nei



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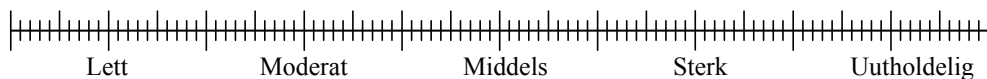
<http://www.haukeland.no/nrl/>

9. Smerte

Sett ett kryss på den streken som du synes tilsvarer din gjennomsnittlige smerteopplevelse fra den aktuelle hoften den siste måneden:

Ingen
smerte

Maksimal
smerte

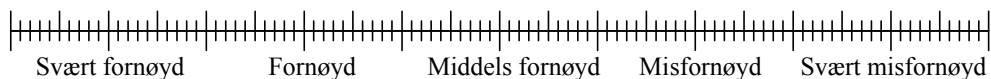


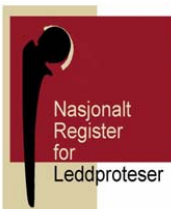
10. Tilfredshet

Sett ett kryss på den streken som du synes tilsvarer hvor fornøyd du er med operasjonsresultatet:

Fornøyd

Ikke fornøyd





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I de neste 5 spørsmålene ønsker vi å vite hvordan livssituasjonen din er i dag (EQ-5D-spørsmålene (<http://www.euroqol.org>):

11. Hvordan opplever du gangevnen din?

- Jeg har ingen problemer med å gå omkring
- Jeg har litt problemer med å gå omkring
- Jeg er sengeliggende

12. Hvordan klarer du personlig stell?

- Jeg har ingen problemer med personlig stell
- Jeg har litt problemer med å vaske meg eller kle meg
- Jeg klarer ikke å vaske meg eller kle meg

13. Hvordan klarer du dine vanlige gjøremål (f.eks. arbeid, studier, husarbeid, familie- og fritidsaktiviteter)?

- Jeg har ingen problemer med å utføre mine vanlige gjøremål
- Jeg har litt problemer med å utføre mine vanlige gjøremål
- Jeg er ute av stand til å utføre mine vanlige gjøremål

14. Smerter eller ubehag?

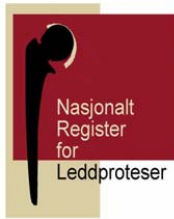
- Jeg har verken smerte eller ubehag
- Jeg har moderat smerte eller ubehag
- Jeg har sterk smerte eller ubehag

15. Angst eller depresjon?

- Jeg er verken engstelig eller deprimert
- Jeg er noe engstelig eller deprimert
- Jeg er svært engstelig eller deprimert

16. Hvordan er din helsetilstand i dag sammenlignet med helsetilstanden like før din (første) hofteproteseseoperasjon?

- Bedre
 - Uforandret
 - Dårligere
-



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17. Din helsetilstand i dag.

For å hjelpe folk til å si hvor god eller dårlig en helsetilstand er, har vi laget en skala (omtrent som et termometer) hvor den beste tilstanden du kan tenke deg er merket 100 og den verste tilstanden du kan tenke deg er merket 0.

Vi vil gjerne at du viser på denne skalaen hvor god eller dårlig helsetilstanden din er i dag, etter din oppfatning. Vær vennlig å gjøre dette ved å trekke en linje fra boksen nedenfor til det punktet på skalaen som viser hvor god eller dårlig din helsetilstand er i dag.

Best tenkelige
helsetilstand



Verst tenkelige
helsetilstand



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<http://www.haukeland.no/nrl/>

Navn

I forbindelse med den videre studien ønsker vi å innhente medisinske opplysninger om din hoftelidelse fra sykehuset/sykehusene som har behandlet deg. På grunn av sykehusene sin taushetsplikt, er vi nødt til å innhente tillatelse fra pasienten for å få utlevert denne informasjonen.

Vi håper du kan gi oss tillatelse til å kontakte sykehuset hvor du ble behandlet for å hente ut medisinske data om din hoftediagnose.

Ja, jeg tillater at dere kan kontakte sykehuset for å hente ut medisinske data om min hoftediagnose.

Signatur:.....

Nei, jeg ønsker ikke at informasjon knyttet til min hoftelidelse skal utleveres og brukes i denne studien.

Ved eventuelle spørsmål, vennligst kontakt professor/seksjonsoverlege i Barneortopedi Lars B. Engesæter på tlf. 55 97 56 84 eller e-post:

Lars.Engeseter@helse-bergen.no

Registreringsskjema

TOTALPROTESE HOS UNGE VOKSNE

Fødselsnummer:
 Navn:
 Sykehus:
 Skjemanummer:

DIAGNOSE I NRL

- Idiopatisk coxartrose
- Rheumatoid artritt
- Sekvele etter FCF
- Sekvele dysplasi
- Sekvele dysplasi med total luksasjon
- Sekv. Perthes/Epifysiolyse
- Mb. Bechterew
- Akutt fraktura colli femoris
- Annet

NRL-DIAGNOSE BEKREFTET MED JOURNALOPPLYSNINGER

- Nei, annen diagnose bekreftet
- Nei, mangelfulle journalopplysninger
- Ja

DIAGNOSEGRUPPE ETTER JOURNALOPPLYSNINGER

- Idiopatisk coxartrose
- Hofteledds dysplasi
- Hofteledds dysplasi med total luksasjon
- Calvé-Legg-Perthes
- Epifysiolyse
- Usikkert

RØNTGENBILDER REGISTRERT

- Nei
- Ja
- Dato for røntgenbilder

FØRSTE LEGEKONTAKT

(Enten ved det aktuelle sykehus eller dokumentert i journalen)

DATO

AKTUELLE SIDE (bilateral opr. = 2 skjema)

- Høyre
- Venstre
- Bilateralt
- Ikke angitt

SYMPTOMER OG FUNN

- Nedsatt abduksjon
- Nedsatt innadrotasjon
- Nedsatt ekstensjon
- Halting
- Smerter ved gange
- Lyskesmerter
- Knesmerter
- Asymmetriske hudfolder
- Ortolani pos
- Barlow pos
- Forsinket gangutvikling
- Anisomeli
- Hæl-seteprøve pos (froskeprøve)
- Bevegelsesinnskrenkning
- Annet (*spesifiser*)
-
-
-
-

ANNET

- Ingen behandling før proteseinnsetting
- Fritekst, se bakside

BEHANDLING HOFTELEDDSDYSPLASI

- | | Startdato/
alder | Sluttdato/
varighet |
|---|---------------------|------------------------|
| <input type="checkbox"/> Freijka pute | | |
| <input type="checkbox"/> Gips | | |
| <input type="checkbox"/> Ortose | | |
| <input type="checkbox"/> Strekkbeh | | |
| <input type="checkbox"/> Operasjon (<i>spesifiser type operasjon og dato</i>) | | |
| | | |
| | | |
| <input type="checkbox"/> Annen behandling (<i>spesifiser</i>) | | |
| | | |

BEHANDLING CALVÉ-LEGG-PERTHES

- | | Startdato/
alder | Sluttdato/
varighet |
|---|---------------------|------------------------|
| <input type="checkbox"/> Abduksjons-
ortose | | |
| <input type="checkbox"/> Strekk | | |
| <input type="checkbox"/> Fysioterapi | | |
| <input type="checkbox"/> Operasjon (<i>spesifiser type operasjon og dato</i>) | | |
| | | |
| <input type="checkbox"/> Annen behandling (<i>spesifiser</i>) | | |
| | | |

BEHANDLING EPIFYSIOLYSE

- | | | |
|---|-------|-------|
| <input type="checkbox"/> Operasjon (<i>spesifiser type operasjon og dato</i>) | | |
| | | |
| <input type="checkbox"/> Annen behandling (<i>spesifiser</i>) | | |
| | | |

KOMPLIKASJONER

- Ingen kjente
- Infeksjon
- Fraktur
- Avaskulær nekrose
- Pinn perforasjon
- Chondrolyse
- Annen

 Dato, sign.



Nasjonalt Register for Leddproteser
Ortopedisk klinikk, Helse Bergen HF
Haukeland Universitetssykehus
Møllendalsbakken 11
5021 BERGEN
tlf 55973742/55973743

F.n.r. (11 sifre).....

Navn:.....

(Skriv tydelig ev. pasient klistrelapp – spesifiser sykehus.)

Sykehus:.....

HOFTEPROTESER

ALLE TOTALPROTESER I HOFTELEDD REGISTRERES (ved hemiproteser etter hoftebrudd sendes hoftebruddskjema til Hoftebruddregisteret). Innsetting, skifting eller fjerning av protese eller protesedeler.

TIDLIGERE OPERASJON I AKTUELLE HOFTE (ev. flere kryss)

- ⁰ Nei
¹ Osteosyntese for fraktur i prox. femurende
² Hemiprotese pga. fraktur
³ Osteotomi
⁴ Artridese
⁵ Totalprotese(r)
⁶ Annen operasjon
- +

OPERASJONS DATO (dd.mm.åå) |_|_|_|_|_|_|_|_|

AKTUELLE OPERASJON (ett kryss)

- ¹ Primæroperasjon (også hvis hemiprotese tidligere)
² Reoperasjon (totalprotese tidligere)

AKTUELLE SIDE (ett kryss) (Bilateral opr. = 2 skjema)

- ¹ Høyre ² Venstre

AKTUELLE OPERASJON (KRYSS AV ENTEN I A ELLER B)

A. Primæroperasjon pga. (ev. flere kryss)

- ¹ Idiopatisk coxartrose
² Rheumatoid artritt
³ Sekvele etter frakt. colli. fem.
⁴ Sekv. dysplasi
⁵ Sekv. dysplasi med total luksasjon
⁶ Sekv. Perthes/Epifysiolyse
⁷ Mb. Bechterew
⁸ Akutt fraktura colli femoris
 Annet
- (f.eks caputnekrose, tidl. artridese o.l)
- +

B. Reoperasjon pga. (ev. flere kryss)

- ¹ Løs acetabularkomponent
² Løs femurkomponent
³ Luksasjon
⁴ Dyp infeksjon
⁵ Fraktur (ved protesen)
⁶ Smerter
⁷ Osteolyse i acetab. uten løsning
⁸ Osteolyse i femur uten løsning
 Annet
- (f.eks Girdlestone etter tidl. infisert protese)

REOPERASJONSTYPE (ev. flere kryss)

- ¹ Bytte av femurkomponent
² Bytte av acetabularkomponent
³ Bytte av hele protesen
⁴ Fjernet protese (f.eks Girdlestone)
Angi hvilke deler som ble fjernet
- ⁵ Bytte av plastforing
⁶ Bytte av caput
 Andre operasjoner
- +

TILGANG (ett kryss)

- ¹ Fremre (Smith-Petersen) ³ Lateral
² Anterolateral ⁴ Posterolateral
⁵ Annen

LEIE ⁰ Sideleie ¹ Rygg

TROCHANTEROSTEOTOMI ⁰ Nei ¹ Ja

BENTRANSPANTASJON (ev. flere kryss)

- Acetabulum ⁰ Nei ¹ Ja ² Benpakking
Femur ⁰ Nei ¹ Ja ² Benpakking a.m. Ling/Gie

BENTAP VED REVISJON (Paprosky's klassifisering se baksiden)

- | | | |
|---|--|--|
| Acetabulum | | Femur |
| <input type="checkbox"/> ¹ Type I | <input type="checkbox"/> ² Type II C | <input type="checkbox"/> ¹ Type I |
| <input type="checkbox"/> ² Type II A | <input type="checkbox"/> ³ Type III A | <input type="checkbox"/> ² Type II |
| <input type="checkbox"/> ³ Type II B | <input type="checkbox"/> ⁴ Type III B | <input type="checkbox"/> ³ Type III A |

PROTESE NAVN / DESIGN / "COATING"

(spesifiser nøyaktig eller bruk klistrelapp på baksiden)

Acetabulum

- Navn/Type
- ev. katalognummer
- Med hydroksylapatitt Uten hydroksylapatitt
¹ Sement med antibiotika – Navn
- ² Sement uten antibiotika – Navn
- ³ Usementert
- +

Femur

- Navn/Type
- ev. katalognummer
- Med hydroksylapatitt Uten hydroksylapatitt
¹ Sement med antibiotika – Navn
- ² Sement uten antibiotika – Navn
- ³ Usementert

Caput

- ¹ Faststittende caput
² Separat caput - Navn/Type
- ev. katalognummer
- Diameter

MINI INVASIV KIRURGI (MIS) ⁰ Nei ¹ Ja

COMPUTERNAVIGERING (CAOS) ⁰ Nei ¹ Ja

TROMBOSEPROFYLAKSE

⁰ Nei ¹ Ja, hvilken type

Dosering opr.dag..... Første dose gitt preopr ⁰ Nei ¹ Ja

Senere dosering..... Antatt varighet..... døgn

Ev. i kombinasjon med

Dosering..... Antatt varighet..... døgn

Strømpe ⁰ Nei ¹ Legg ² Legg + Lår Antatt varighet..... døgn

Mekanisk pumpe ⁰ Nei ¹ Fot ² Legg Antatt varighet..... døgn

SYSTEMISK ANTIBIOTIKAPROFYLAKSE

⁰ Nei ¹ Ja, hvilken (A).....

Dose (A)..... Totalt antall doser..... Varighet..... timer

Ev. i kombinasjon med (B).....

Dose (B)..... Totalt antall doser..... Varighet..... timer

OPERASJONSTUE

- ¹ "Green house"
² Operasjonsstue med laminaer luftstrøm
³ Vanlig operasjonsstue

OPERASJONSTID (hud til hud)min

PEROPERATIV KOMPLIKASJON

- ⁰ Nei
¹ Ja, hvilke(n)

ASA KLASSE (se baksiden for definisjon)

- ¹ Frisk
² Asymptomatisk tilstand som gir økt risiko
³ Symptomatisk sykdom
⁴ Livstruende sykdom
⁵ Moribund
- +

Lege

Legen som har fylt ut skjemaet (navnet registreres ikke i databasen).

Navn:

Navn/personnummer.....

Samtykke til deltagelse i Hoftestudien, Haukeland Universitetssykehus

Jeg har mottatt muntlig og skriftlig informasjon om prosjektet, og sier meg villig til å delta. Jeg er klar over at dataene som fremkommer vil bli lagret på Haukeland Universitetssykehus. Jeg kan når som helst trekke meg fra deltagelse, uten å oppgi grunn og uten at det får konsekvenser for meg. Jenter som mistenker at de er gravide, må selv utelukke dette før oppmøte til røntgen.

Bergen,.....2009

Signatur:

Dersom du er under 18 år må en av dine foreldre/foresatte godkjenne at du deltar i studien.

Bergen,.....2009

Forelder/foresattes signatur:.....

TA MED DENNE SAMTYKKE ERKLÆRINGEN NÅR DU MØTER TIL UNDERSØKELSE.

NAVN

Tidligere hofteplager eller andre leddplager

Før du møter til undersøkelse er det fint om du spør foreldrene dine om du noen gang har hatt noe galt med hoftene dine eller en annen leddlidelse. Kryss av i rubrikkene under på det som er aktuelt. Leveres med samtykkeerklæringen.

- Ingen problemer
- Medfødt hofteleddsdisplasi
- Serøs coxitt (ikke-bakteriell betennelse i hofteleddet)
- Septisk artritt i hofteledd (bakteriell betennelse i hofteleddet)
- Calvé Legg Perthes` sykdom
- Epifysiolyse
- Brudd
- Leddgikt (Reumatoid artritt)
- Annet (Spesifiser:.....)
- Vet ikke
- Har oppsøkt lege / Legevakt pga. problemer med hofte. Spesifiser:.....
- Har du noen sykdom som har vart over 3 måneder? Hvilken:.....

Hofteplager i nærmeste familie

Har du søsken som har medfødt hofteplager og har vært behandlet med pute?

- Ja Nei Vet ikke Hvis ”ja”, antall: (eks. 1 bror 2 søstre)

.....bror/brødre søster/søstre halvbror/halvbrødre halvsøster/halvsøstre

Har du foreldre som har hatt medfødt hofteplager? Ja Nei Vet ikke

Hvis ”ja”, hvem: mor far

Har foreldrene dine plager med hoftene i dag? Ja Nei Vet ikke

Hvis ”ja”, hvem: mor far

Mors høyde.....cm

Fars høyde.....cm

HOFTE 89

Haukeland Universitetssykehus

Mange takk for at du tar deg tid til å være med på Hoftestudien. Skjema brukes også for undersøkelse av helsetilstanden til eldre og alvorlig syke personer. Noen av spørsmålene kan derfor virke lite relevante for deg om du er helt frisk. Likevel ber vi deg lese gjennom hele skjema, og svare på alle spørsmålene. Der er totalt 43 spørsmål.

1. Deltakernummer:.....
2. Navn:
3. Fødselsnummer: |_|_|_|_|_|_| |_|_|_|_|_|_|
4. Yrke skoleelev annet (Spesifiser:.....)
5. Har du noen gang hatt plager fra høyre hofte (varighet over 1 måner)? Ja Nei
Hvis "JA", spesifiser.....
6. Har du hatt plager fra høyre hofte siste 3 måneder? Ja Nei
Hvis "JA", spesifiser.....
7. Har du noen gang hatt plager fra venstre hofte (varighet over 1 måner)? Ja Nei
Hvis "JA", spesifiser.....
8. Har du hatt plager fra venstre hofte siste 3 måneder? Ja Nei
Hvis "JA", spesifiser.....
9. Hvor ofte har du vondt i nakken?
 - omtrent hver dag
 - mer enn 1 gang pr uke
 - omtrent hver uke
 - omtrent hver måned
 - sjelden eller aldri

10. Hvor ofte har du vondt i ryggen?
- omtrent hver dag
 - mer enn 1 gang pr uke
 - omtrent hver uke
 - omtrent hver måned
 - sjelden eller aldri
11. Har du problemer som du relaterer til hoften, som gjør at du har vansker med å gå?
- Ja Nei Hvis "JA", spesifiser.....
12. Er det andre årsaker enn hofteplager som gjør at du har vansker med å gå?
(For eksempel smerter fra andre ledd, ryggsmarter, hjerte-karsykdom eller andre sykdommer som påvirker gangevnen din)
- Ja Nei Hvis "JA", spesifiser.....
13. Utenom skoletid: Hvor mange GANGER i uken driver du med idrett/mosjon slik at du blir andpusten og/eller svett?
- hver dag
 - 4-6 ganger i uken
 - 2-3 ganger i uken
 - 1 gang i uken
 - 1 gang i måneden
 - mindre enn 1 gang i måneden
 - aldri
14. Utenom skoletid: Hvor mange TIMER i uken driver du med idrett/mosjon slik at du blir andpusten og/eller svett?
- ingen
 - ½ time
 - 1 time
 - 2-3 timer
 - 4-6 timer
 - 7 timer eller mer

SMERTE- Tenk på smerten du opplevde I HOFTEN i løpet av de siste 48 timer.

15. Hvor mye smerter har du når du går på flatt underlag?
 ingen litt moderat stor svært stor
16. Hvor mye smerte har du når du går opp og ned trapper?
 ingen litt moderat stor svært stor
17. Hvor mye smerte har du om natten når du ligger i sengen?
 ingen litt moderat stor svært stor
18. Hvor mye smerter har du når du sitter eller ligger?
 ingen litt moderat stor svært stor
19. Hvor mye smerter har du når du står oppreist
 ingen litt moderat stor svært stor

STIVHET- Tenk på stivheten du har opplevd i HOFTEN i løpet av de siste 48 timer

20. Hvor alvorlig er stivheten i hoften din med en gang du våkner om morgenen?
 ingen litt moderat kraftig svært kraftig
21. Hvor alvorlig er stivheten i hoften din etter at du sitter ligger eller hviler senere på dagen?
 ingen litt moderat kraftig svært kraftig

**FUNKSJON- Tenk på hvor vanskelig det har vært å utføre følgende daglige fysiske aktiviteter i løpet av de siste 48 timene, som følge av SMERTE I HOFTEN. Med dette mener vi din bevegelsesevne og evne til å klare deg selv.
SPØRSMÅL: Hvor vanskelig har det vært å.....**

22. gå ned trapper?
 ingen litt moderat svært ekstremt
23. gå opp trapper?
 ingen litt moderat svært ekstremt
24. reise deg fra sittende?
 ingen litt moderat svært ekstremt
25. stå oppreist?
 ingen litt moderat svært ekstremt
26. bøye deg ned mot gulvet?
 ingen litt moderat svært ekstremt

27. gå på flatt underlag?

ingen litt moderat svært ekstremt

28. komme deg inn/ut av en bil?

ingen litt moderat svært ekstremt

29. gå på handletur?

ingen litt moderat svært ekstremt

30. ta på strømper?

ingen litt moderat svært ekstremt

31. stå opp fra sengen?

ingen litt moderat svært ekstremt

32. ta av strømper?

ingen litt moderat svært ekstremt

33. ligge i sengen?

ingen litt moderat svært ekstremt

34. komme deg inn/ut av dusj/badekar?

ingen litt moderat svært ekstremt

35. sitte?

ingen litt moderat svært ekstremt

36. komme deg til toalettet?

ingen litt moderat svært ekstremt

37. tungt husarbeid?

ingen litt moderat svært ekstremt

38. lett husarbeid?

ingen litt moderat svært ekstremt

I de neste 5 spørsmålene (EQ-5D-spørsmålene (<http://www.euroqol.org>) ønsker vi å vite hvordan livssituasjonen din er:

39. Hvordan opplever du gangevnen din?

- ¹ Jeg har ingen problemer med å gå omkring
- ² Jeg har litt problemer med å gå omkring
- ³ Jeg er sengeliggende

40. Hvordan klarer du personlig stell?

- ¹ Jeg har ingen problemer med personlig stell
- ² Jeg har litt problemer med å vaske meg eller kle meg
- ³ Jeg klarer ikke å vaske meg eller kle meg

41. Hvordan klarer du dine vanlige gjøremål (f.eks. arbeid, studier, husarbeid, familie- og fritidsaktiviteter)?

- ¹ Jeg har ingen problemer med å utføre mine vanlige gjøremål
- ² Jeg har litt problemer med å utføre mine vanlige gjøremål
- ³ Jeg er ute av stand til å utføre mine vanlige gjøremål

42. Smerter eller ubehag?

- ¹ Jeg har verken smerte eller ubehag
- ² Jeg har moderat smerte eller ubehag
- ³ Jeg har sterk smerte eller ubehag

43. Angst eller depresjon?

- ¹ Jeg er verken engstelig eller deprimert
- ² Jeg er noe engstelig eller deprimert
- ³ Jeg er svært engstelig eller deprimert

Mange takk for at du tok deg tid til å svare på spørreskjema!

Trude G. Lehmann
Cand.med

Lene B. Laborie
Cand.med

Ingvild Øvstebø Engesæter
Stud.med

Karen Rosendahl
Seksjonsoverlege, Professor dr. med
Radiologisk avdeling

Lars Birger Engesæter
Seksjonsoverlege, Professor dr. med
Barneortopedisk avdeling

Navnelapp

deltakernr:.....

Klinisk undersøkelse

Us dato.....

Høyde:.....cm

Vekt:.....kg

Status:

	Høyre	Venstre
Fleksjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Ekstensjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Abduksjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Adduksjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Innadrotasjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Utadrotasjon:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Forkortning	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> mm	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> mm
Impingement	<input type="checkbox"/>	<input type="checkbox"/>

Mobilitet

	Høyre	Venstre
Hyberekstensjon i albu > 10°?	<input type="checkbox"/>	<input type="checkbox"/>
Hyperekstensjon i kne > 10°?	<input type="checkbox"/>	<input type="checkbox"/>
Legger tommel ned på underarm?	<input type="checkbox"/>	<input type="checkbox"/>
>90° dorsalfleksjon i 5. fingers grunnledd?	<input type="checkbox"/>	<input type="checkbox"/>
Ta i gulvet med håndflate med strake knær		<input type="checkbox"/>

14. Papers I-IV

In situ fixation of slipped capital femoral epiphysis with Steinmann pins

67 patients followed for 2–16 years

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Background and purpose Slipped capital femoral epiphysis (SCFE) is often treated by surgical fixation; however, no agreement exists regarding technique. We analyzed the outcome of in situ fixation with Steinmann pins.

Patients and methods All 67 subjects operated for slipped capital femoral epiphysis at Haukeland University Hospital during the period 1990–2007 were included. All were treated by in situ fixation with 2 or 3 parallel Steinmann pins (8 mm threads at the medial end). The follow-up evaluation consisted of clinical examination and hip radiographs. Radiographic outcome was based on measurements of slip progression, growth of the femoral neck, leg length discrepancy, and signs of avascular necrosis and chondrolysis.

Results 67 subjects (41 males) were operated due to unilateral slips (n = 47) or bilateral slips (n = 20). Mean age at time of diagnosis was 13 (7.2–16) years. Mean age at follow-up was 19 (14–30) years, with a mean postoperative interval of 6.0 (2–16) years. The operated femoral neck was 9% longer at skeletal maturity than at surgery, indicating continued growth of the femoral neck. At skeletal maturity, 12 subjects had radiographic features suggestive of a previous asymptomatic slip of the contralateral hip. The total number of bilateral cases of SCFE was 32, i.e. half of the children had bilateral SCFE. 3 subjects required additional surgery and mild avascular necrosis of the femoral head was seen in 1 patient. None had slip progression or chondrolysis.

Interpretation In situ pinning of SCFE with partly threaded Steinmann pins appears to be a feasible and safe method, with few complications. The technique allows further growth of the femoral neck.

Slipped capital femoral epiphysis (SCFE) is a disease of unknown etiology, but mechanical, biological and hereditary factors are likely to play a role (Barrios et al. 2005, Murray and Wilson 2008). The rationale for treatment of SCFE is to restore hip function, prevent further slip, and to reduce the risk of subsequent degenerative changes. Several surgical techniques have been recommended such as cannulated screws (Chen et al. 2009), hook-pins (Hansson 1982), specially constructed screws (Wensaas and Svenningsen 2005), and most recently surgical hip dislocation with subcapital correction osteotomy (Leunig et al. 2007). However, currently there is no evidence to support the superiority of one particular technique over another.

In situ fixation is advocated by most authors (Boyer et al. 1981, Carey et al. 1987, Givon and Bowen 1999) since peroperative reduction may increase the risk of avascular necrosis (Ordeberg et al. 1983, Carney et al. 1991, Lim et al. 2007). Physiodesis to prevent further growth—thus stabilizing the physis—is recommended by some authors (Carey et al. 1987, Aronsson and Karol 1996). Slip of the contralateral hip is reported in more than half of the cases (Hägglund et al. 1988, Castro et al. 2000) and controversies exist regarding prophylactic fixation of the contralateral hip. According to Jerre et al. (1994), more than two-thirds of the contralateral slips are asymptomatic and are therefore only detected at close follow-ups including hip radiographs at short intervals. Immediate prophylactic fixation of the contralateral hip has been advocated by several authors (Hägglund et al. 1988, Schultz et al. 2002, Krauspe et al. 2004).

- In this paper, we present clinical and radiographic results of a novel, simple technique for in situ fixation of the femoral head with partially threaded Steinmann pins to enable further growth of the femoral neck.

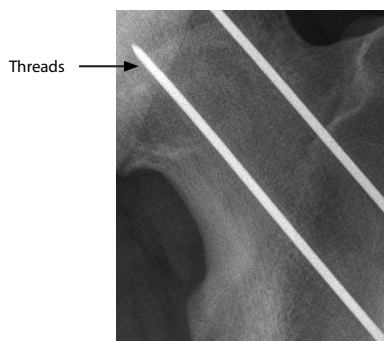


Figure 1. Steinmann pin with threads in the medial 8-mm tip.

Patients and methods

All 67 subjects operated for SCFE at Haukeland University Hospital (Norway) during the period 1990–2007 were approached by mail in 2008 and were invited to participate in a follow-up including a clinical and radiographic assessment. Data on age at diagnosis and sex, and clinical data (duration and type of preoperative symptoms, technique, and duration of surgery) were collected from the medical records. The slips were classified according to Herring (2008): acute slip (onset of symptoms within 3 weeks of the diagnosis), acute-on-chronic slip (symptoms for more than 3 weeks with an acute deterioration over the most recent 3 weeks), chronic slip (symptoms for more than 3 weeks), and pre-slip (pain and clinical findings in the contralateral hip without any radiographic evidence of SCFE). A pelvic radiograph (frog-leg view) at the time of diagnosis was used to classify the degree of slip into mild, moderate, or severe based on measurements of the lateral epiphyseal shaft angle (Southwick 1967). The slip was considered mild if the angle was less than 30°, moderate if the angle was 30–50°, and severe when the angle was more than 50° (Boyer et al. 1981, Carney et al. 1991). In cases where there were missing radiographs (n = 21), data from the medical records or from the radiographic report were used to classify the degree of slip. We did not have information on the stability of the slip in all subjects.

The surgical procedure was performed with the child supine on a traction table. A uniplane or biplane image intensifier was used. The surgeon was responsible for placing the affected leg in traction on the operating table, to avoid forceful reduction. In children with acute or acute-on-chronic SCFE, very gentle repositioning was allowed (careful internal rotation on a flexed hip). The surgeon on call performed the operation, i.e. 42 surgeons performed between 1 and 13 operations each during the study period. A percutaneous fixation technique was used, with a 2–3-cm skin incision. 2 or 3 parallel Steinmann pins (diameter 2.3 mm) with threads in the 8-mm medial end (Figure 1) (Smith and Nephew, Memphis, TN) were drilled

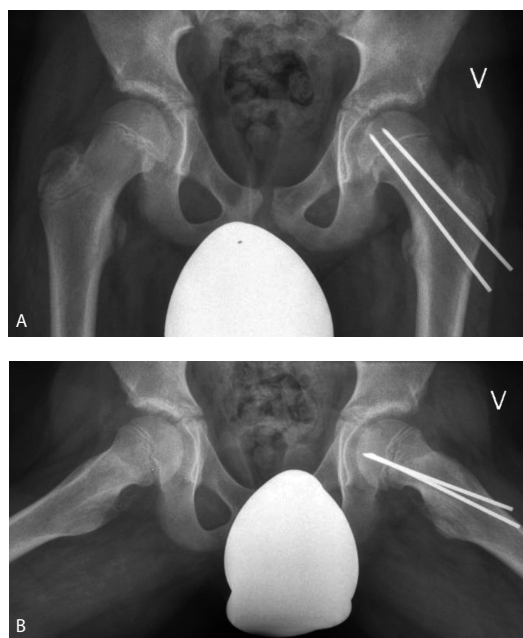


Figure 2. Postoperative radiographs of a 14-year-old boy after percutaneous pinning of SCFE. A. supine AP view. B. Frog-leg view.

under fluoroscopic guidance. To ease the placement and to protect the soft tissue, a drill guide was used. During the first 10-year period, we used 3 pins (n = 39), while 2 were used for the rest of the period (n = 45). 3 children had 4 pins inserted at the start of the study. Pins were cut 1–2 cm from the lateral femoral cortex (Figure 2). Postoperatively, the child was mobilized with crutches and partially weight-bearing for 4–6 weeks; thereafter, there were no restrictions. None of the children had prophylactic pinning of the contralateral hip. Subjects were followed annually at the outpatient clinic, until closure of the proximal femoral physis. The pins were then removed under general anesthesia.

Outcome

Clinical and radiographic findings after physal closure were used to assess long-term outcome (n = 60 subjects). 4 subjects (5 hips) did not attend the final follow-up (after 1 reminder) and 3 subjects (5 hips) had not yet reached skeletal maturity with closure of the proximal femoral growth plate. These 7 subjects were excluded from the analysis of long-term outcome.

The radiographic examination at the final follow-up included 2 supine views (1 anteroposterior (AP) and 1 frog-leg view). Radiographic outcomes were slip progression of more than 10° as assessed by Southwick's lateral epiphyseal-shaft

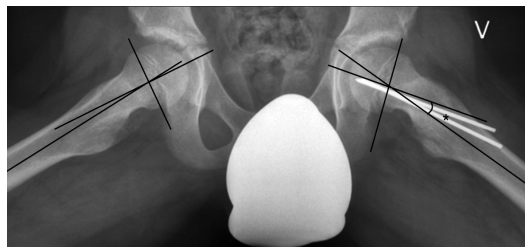


Figure 3. Measurement of the lateral epiphyseal shaft angles on a frog-leg view in a 14-year-old boy (the left angle is marked with an asterisk). The angle is measured in the following way: 90° minus the measured angle between a mid-diaphyseal line and a line through the anterior and posterior aspects of the physis. Normal angle on the right side (4°) and an angle of 23° on the left side.

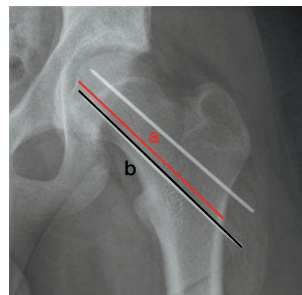


Figure 4. Method of calculating the ratio between lengths of the femoral neck and pin. a: length of femoral neck; b: length of Steinmann pin. Ratio: a/b.

angle (Southwick 1967) (Figure 3), signs of avascular necrosis (Kalamchi and MacEwen 1980), leg length discrepancy as assessed by differences in articulo-trochanteric distance (ATD) (measured from the superior margins of the greater trochanter to the superior margins of the femoral head), longitudinal growth of the femoral neck, and whether there was evidence of a chondrolysis. Longitudinal growth of the femoral neck was estimated by constructing a ratio between the length of the femoral neck to the length of the Steinmann pin, as measured on the AP pelvic radiograph (Figure 4). The ratio was calculated on the first postoperative radiograph and the latest radiograph before pin removal. The mean difference in ratio was calculated. Chondrolysis was defined as more than 50% reduction of minimal joint space compared to the contralateral side (Loder et al. 2000). Slip progression was defined as an increased lateral epiphyseal shaft angle by more than 10° from surgery to final follow-up at skeletal maturity (Carney et al. 2003). In accordance with Jerre, we considered a lateral epiphyseal-shaft angle above 13° in the asymptomatic, contralateral hip to be diagnostic of a silent slip (Loder et al. 1993, Jerre et al. 1994).

Clinical long-term outcomes were based on clinical assessment of bilateral hip motions for subjects operated unilaterally and without signs of an asymptomatic slip at follow-up ($n = 31$). To increase the accuracy of the radiographic assessment, all radiographs were re-measured by one of the authors (TL). Repeatability of the measurements was evaluated by re-reading all images (masked regarding other data) after 6 months.

Ethics

The procedures followed were in accordance with the ethical standards of the Regional Ethical Committee for Medical and Health Research. Written informed consent was obtained from all participants.

Statistics

Femoral neck-pin ratio postoperatively and at skeletal maturity

was compared using paired sample t-test. Association between severity of slip and duration of symptoms was analyzed by one-way ANOVA. Intra-observer variation for continuous variables was assessed by estimating the mean differences and their standard deviations (SDs). We then calculated the mean differences $\times 1.96$ SD, expecting 95% of the differences between measurements to lie between these limits (repeatability coefficient as suggested by Bland and Altman (2003)). All p -values < 0.05 were considered statistically significant. The analyses were performed using SPSS for Windows version 17.0. Clustered observations were controlled for using the statistical program gllamm in Stata software version 11.

Results

67 subjects (41 males) with 87 slips were operated during the study period of 18 years (1990–2007) (Table). Mean age at diagnosis was 13 (7.2–16) years: 13 years for boys and 12 years for girls. 47 subjects had unilateral involvement (33 left hips) and 20 had bilateral slips.

Of the 20 individuals with bilateral slips, only 5 (2 males) presented with bilateral symptoms and had immediate bilateral surgery. For the 15 children who suffered sequential slips, mean age at diagnosis of the initial slip (8 mild, 7 moderate, 3 severe, and 2 unclassified) was 13 (11–16) years, 11 (11–12) years for girls and 13 (12–16) years for boys. The contralateral slip was operated on average 9 (1–36) months after the initial operation.

Children with moderate or severe slips had longer duration of symptoms than children with mild slips ($p = 0.004$). Symptom duration was similar in children with moderate slips and in those with severe slips. 4 children had additional disease associated with SCFE: 1 had trisomy for chromosome 21 (10 years of age), 2 had hypopituitarism (11 and 16 years old), and 1 received growth hormone medication due to hormonal deficiency (12 years old).

Severity and type of slip (given for each hip) and symptoms at the time of diagnosis (given for each patient) in 67 subjects with 87 slips

	Males	Females	Total
Severity of slip (87 hips)			
mild	32 (37%)	11 (13%)	43 (49%)
moderate	16 (18%)	12 (14%)	28 (32%)
severe	7 (8%)	7 (8%)	14 (16%)
not classified	0	2 (2%)	2 (2%)
Type of slip (87 hips)			
acute slip	6 (7%)	6 (7%)	12 (14%)
chronic slip	36 (41%)	17 (20%)	53 (61%)
acute-on-chronic slip	8 (9%)	6 (7%)	14 (16%)
pre-slip	5 (6%)	3 (3%)	8 (9%)
Duration of symptoms (months)			
mean (SD) (67 subjects)	5.2 (6.3)	5.6 (6.6)	5.3 (6.4)
mild slip	3.5 (5.2)	2.3 (2.3)	3.2 (4.7)
moderate slip	8.3 (8.3)	6.4 (5.5)	7.4 (7.2)
severe slip	5.8 (1.5)	10.6 (9.7)	8.4 (7.4)
Symptoms (87 hips)			
limp	40 (73%)	27 (84%)	67 (77%)
pain	55 (100%)	31 (97%)	86 (99%)
–hip/thigh	40 (73%)	25 (78%)	65 (75%)
–thigh/knee	7 (13%)	3 (9%)	10 (11%)
–knee	3 (5%)	2 (6%)	5 (6%)
–hip/thigh/knee	5 (9%)	1 (3%)	6 (7%)

Surgery

45 of the hips were treated with 2 Steinmann pins, 39 hips had 3 pins inserted, and in 3 hips 4 pins were used. The mean duration of the operation was 40 (10–105) min, 36 min in those having 2 pins inserted including 5 children with bilateral procedures (with total operation time divided by 2 for each side). There were acute surgical complications in 10 hips; in 3, the postoperative radiographs showed that the pins were penetrating the joint (all of these were replaced after 1–2 days) and in 5 the pins protruded too far into the soft tissues laterally (these were shortened within 24 h). 2 patients received antibiotics for a superficial wound infection. None of these 10 patients suffered long-term sequelae. Later, additional surgery was required in 3 children, of whom 1 had a femur lengthening osteotomy due to a leg length discrepancy of 2.5 cm, 1 needed a re-fixation of the femoral head due to displaced pins, and 1 had a fracture to the femur 2 weeks after pin removal.

The mean time from operation until removal of the pins was 3.3 (1.0–7.1) years. Mean duration of pin removal was 47 (10–146) min (the one subject with operation time of 146 min had removal of pins done in same session as lengthening osteotomy with intramedullary nailing). All subjects who were operated on for bilateral SCFE had their pins removed in 1 session. For these, operation time was calculated as the total time divided by 2. There were no pin fractures during removal. At follow-up, the pins had been removed in 74 of the 87 hips. In 4 of the remaining hips, the pins were entirely embedded in bone and were thus not removed, while 4 subjects declined. 3 subjects (5 hips) had not reached skeletal maturity at the last follow-up.

Long-term outcome

The 60 subjects with long-term follow-up (see above) had a mean age at follow-up of 19 (14–30) years, with a mean follow-up time of 6.0 (2–16) years after surgery. 1 person had radiographic evidence of mild avascular necrosis. No cases of chondrolysis or slip progression were seen.

Mean femoral neck-pin ratio postoperatively was 0.92 (0.73–1.0) and at skeletal maturity it was 1.0 (0.80–1.2). Mean difference in femoral neck-pin ratio at skeletal maturity was 0.08 (–0.08 to 0.31) compared to first postoperative measurement, and the ratio increased in all but 1 hip. The femoral neck had a 9% increase in length at skeletal maturity compared to the length postoperatively ($p < 0.001$).

For 31 subjects who had unilateral surgery without any signs or suggestions of contralateral involvement, movement in the operated hip was compared to that in the normal hip. A mean reduction of 5° (SD = 11) in internal rotation and a mean increase of 9° (SD = 9) in external rotation was found for the operated hip. These were not statistically significant, however. The mean difference in ATD between the operated hip and the contralateral hip for subjects operated unilaterally was 7.3 (0–17) mm.

At follow-up, 12 subjects (6 males) had radiographic findings suggestive of a contralateral slip (11 mild, 1 moderate) which had not been diagnosed previously. The mean age at diagnosis of the initial slip for these subjects was 12 (7.2–15) years. The mean Southwick's angle for the asymptomatic slip was 19° (13–33). Thus, 32 of the 67 subjects (20 males) had bilateral slips at follow-up.

Intraobserver variation for Southwick's angle and ATD was acceptable, with the following mean differences (SD) and their repeatability coefficients ($n = 64$). Southwick's angle, right hip: -0.5° (SD 2.5), -5.4° to 4.4° ; and left hip: -0.03° (SD 3.3), -6.5° to 6.5° . ATD, right hip: 0.2 mm (SD 1.1), -2.0 mm to 2.4 mm; and left hip: 0.2 mm (SD 1.5), -2.7 mm to 3.1 mm. Analyses taking the few clustered observations into account did not alter any of the findings in this study.

Discussion

This study indicates that in situ pinning of slipped capital femoral epiphysis with partly threaded Steinmann pins is a feasible and safe technique with few perioperative and postoperative complications, and with good clinical and radiographic long-term outcome. The technique enables further growth of the femoral neck, with an acceptable leg length discrepancy at skeletal maturity. None of the operated hips had a slip progression of more than 10°.

Before introducing this new surgical technique for stabilization of the epiphysis in SCFE, we showed in a laboratory setting that the mechanical strength of Steinmann pins was sufficient for fixation of human femoral neck osteotomies and accordingly also for SCFE (Ryning et al. 1990). We

initially used 3 Steinmann pins, but later reduced the number to 2.

Slip progression after stabilization with a single screw has been reported by several authors (Carney et al. 1991, Aronson and Carlson 1992, Denton 1993). Carney et al. (2003) found that 20% suffered a slip progression of 10° or more when operated with a single cannulated screw. The idea that double screw fixation is more likely to provide torsional stability in non-reduced slips than a single screw has been verified in artificially created slips in bovine femurs (Segal et al. 2006).

Others have used multiple Kirchner wires to fixate the femoral head. In a study of 29 patients, a repeat transfixation was judged to be necessary in 7 of the cases as the wires lost contact with the femoral head during growth (Seller et al. 2006). We believe that our favorable results may be due in part to the threads at the end of the pins, securing sufficient anchorage within the femoral head during the residual growth.

Avascular necrosis (AVN) of the femoral head is a severe surgical complication. Carey et al. (1987) reviewed 60 patients operated with threaded pin fixation. At follow-up of between 4 and 13 years, 8 patients had findings consistent with AVN. Carney et al. (1991) reported on 155 operated hips with a mean follow-up of 41 years. AVN was diagnosed in 12% of the subjects, and was more frequent in those with severe slips. They also found a positive association between AVN and penetration of a pin into the joint. We found 1 mild AVN, with partial involvement of the femoral head, in a boy with a severe slip after having had symptoms for 3.5 months. He had 3 pins inserted, and later suffered a leg length discrepancy of 2.5 cm, which was subsequently treated with a leg lengthening procedure. AVN was not seen in any of the 3 subjects who had pin penetration to the joint.

The most serious complication seen was a subtrochanteric femoral fracture 2 weeks after pin removal, most likely caused by extensive bone chiselling. We no longer remove pins that are embedded in bone. Accordingly, in 4 subjects the pins were not removed.

The rationale for treatment in SCFE is to prevent further epiphyseal slip. Some authors advocate that this is best achieved through artificial fusion of the proximal growth plate. However, this may lead to leg length discrepancy, more so in younger subjects, and also to overgrowth of the greater trochanter (Howorth 1966). Such overgrowth may again lead to impingement and reduced abduction forces, with limping. It has been argued that prophylactic pinning of the contralateral hip may reduce the risk of leg length discrepancy (Castro et al. 2000, Riad et al. 2007). To our knowledge, none of the studies favoring surgical closure of the growth plate have examined leg length discrepancy at skeletal maturity.

Remodeling after SCFE results from bone deposition anteromedially and absorption posterolaterally. Several authors claim that remodeling also results from reduced Southwick's angle (Bellemans et al. 1996). In theory, this reduced angle may result from further asymmetric growth of the femoral

neck. Our results indicate that stabilization of the epiphysis from further slip is possible without stopping the longitudinal growth of the femoral neck. This may lead to better biomechanics, improved remodeling, and reduced leg length discrepancy. When using ATD as a measure of leg length discrepancy, it should be kept in mind that the ATD is dependent on the degree of initial slip, the remodeling, and the growth of the femoral neck.

Bilateral involvement was seen in half of the subjects, one third of which were undiagnosed until the subjects were adults. In a long-term follow-up of 260 patients from 1988, Häggglund et al. found that 61% had bilateral slips at skeletal maturity, 40% of which remained undiagnosed until the long-term follow-up. In another study involving 224 children, Loder et al. (1993) reported that 37% had bilateral slips. In a retrospective study of 100 patients, Jerre et al. (1996) found bilateral slip in 59% after 32 years observation. Around two-thirds of these were asymptomatic, and 18% were first diagnosed after skeletal maturity. As demonstrated by Bellemans et al. (1996), remodeling after SCFE also results from reduced Southwicks angle. This remodeling may result in an underestimation of bilateral slips. Small slips may have remodeled, resulting in a head-shaft angle that is found to be normal at follow-up (Clarke and Harrison 1986).

In a report published by Häggglund in 1996, 25% of patients with an undiagnosed slip had coxarthrosis before the age of 50, and during recent years it has been discussed that even silent slips could be the cause of femoroacetabular impingement. This shows that even the minor slips may give problems later in life, and that preventing a silent slip may be important. Based on the information in the literature and on our results, we have now changed the clinical routine in our department to prophylactic pinning of the contralateral hip in children presenting with a unilateral slip.

TGL was responsible for the study design, for performing the analyses together with SAL, and for drafting the first draft. LBE established the operation technique. All authors participated in interpretation of the results and in preparation of the manuscript.

No competing interests declared.

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Total hip arthroplasty in young adults, with focus on Perthes' disease and slipped capital femoral epiphysis

Follow-up of 540 subjects reported to the Norwegian Arthroplasty Register during 1987–2007

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Background and purpose Pediatric hip diseases account for 9% of all primary hip arthroplasties in the Norwegian Arthroplasty Register. We wanted to validate the diagnosis as reported to the register and to assess the quality of life of these patients after hip replacement.

Patients and methods 540 patients accepted to participate in this follow-up study (634 hips). All were less than 40 years of age and had been reported to the Norwegian Arthroplasty Register as having undergone a primary total hip arthroplasty (THA) between 1987 and 2007. The underlying diagnosis, age at diagnosis, and type of treatment given prior to the hip replacement were recorded from the original hospital notes.

Results The diagnoses reported to the Norwegian Arthroplasty Register were confirmed to be correct in 91% of all cases (538/592). For the 94 hips that had been treated due to Perthes' disease or slipped capital femoral epiphysis (SCFE), the diagnosis was verified in 95% of cases (89/94). The corresponding proportion for inflammatory hip disease was 98% (137/140) and it was only 61% for primary osteoarthritis (19/31). The self reported quality of life (EQ-5D) was poorer for these young patients with THA than for persons in age-matched cohorts from Great Britain and Sweden, except for those with an underlying SCFE.

Interpretation The diagnoses reported to the Norwegian Arthroplasty Register as the underlying cause of THA were correct in 91% of cases. Individuals who undergo THA before the age of 40 have a reduced quality of life, except for those requiring a hip replacement because of SCFE.

total hip arthroplasty (THA). According to data from the Norwegian Arthroplasty Register (NAR), pediatric hip disorders account for 9% of all primary hip arthroplasties (Norwegian Arthroplasty Register Annual Report 2010). Studies on the long-term outcome of Perthes' disease have indicated that the risk of later degenerative change varies according to age and the degree of involvement of the femoral head at presentation (Wiig et al. 2008). For SCFE, delayed diagnosis and treatment and the degree of residual deformity are associated with poorer functional outcome (Carney and Weinstein 1996, Gent and Clarke 2004). Only a few studies have addressed the quality of life of these 2 patient groups after hip replacement (Tellini et al. 2008, Wangen et al. 2008).

During the last 20–30 years, registries for THA have been established in all the Scandinavian countries. In Norway, an arthroplasty register has been running since 1987 (Havelin et al. 2000). Although reporting is not compulsory, the register has data on 98% of all hip replacements (Espehaug et al. 2006). However, little has been published on the validity of such registry data (Pedersen et al. 2004, Arthursson et al. 2005, Engesæter et al. 2011).

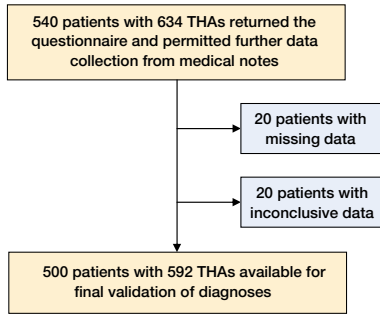
We therefore evaluated the accuracy of the diagnoses reported to the NAR for young adults. For patients with SCFE and Perthes' disease, we also determined the age at diagnosis and types of treatment given prior to THA, and also the quality of life following hip replacement.

Patients and methods

Patients

In this study we included patients born after January 1, 1967 (when the Medical Birth Registry of Norway was established)

Pediatric hip disorders such as developmental dysplasia of the hip (DDH), Perthes' disease, and slipped capital femoral epiphysis (SCFE) may lead to degenerative joint disease requiring a



Flow of patients and THAs through the study.

who had undergone THA and had been reported to the Norwegian Arthroplasty Register (NAR) during the period 1987–2007. 732 patients with 866 primary THAs were registered. 19 patients were excluded due to death or emigration. The remaining 713 patients were approached by letter and invited to complete 2 questionnaires on hip diagnosis and quality of life. After one reminder 578 (81%) responded, and of these, 540 patients (74% of the original cohort; corresponding to 634 hips) gave permission for further information on their hip disease to be collected from their medical records in the relevant hospital(s) (Figure) (Engesaeter et al. 2011).

Questionnaires

The first questionnaire was custom-made, and included questions on age at diagnosis and whether or not they agreed to the diagnosis that had been reported to the NAR. If they disagreed on the diagnosis, they were asked to give the correct diagnosis.

The second questionnaire was EQ-5D, which is a standard health-related quality of life questionnaire that gives an EQ-5D index, where 0 is being dead and 100 is having the best possible health (Dolan 1997). An index of below 0 is ranked as a situation worse than death. We compared our findings with age-matched populations from Sweden and Great Britain (18–39 years) (Szende and Williams 2004).

Collection of data from the medical records

For patients who agreed to the diagnosis recorded in the NAR, and who had been registered with a diagnosis of rheumatoid arthritis, ankylosing spondylitis (morbus Bechterew) or sequelae of a femoral neck fracture, we accepted the diagnosis as being correct (155 hips) without collecting further information from their medical records. For patients who had been registered as having primary osteoarthritis, hip dysplasia (DDH), Perthes' disease/slipped capital femoral epiphysis (SCFE), or "others"—and for patients who disagreed about the diagnosis recorded—further information was obtained from the hospital notes (479 hips). The medical notes were searched for information on age at the time of diagnosis and all the treatment

given. Original radiographs were unavailable for many of the patients, due to Norwegian legislation which states that radiographs do not need to be stored for more than 10 years after the last contact with the patient. The 634 hip replacements were performed in 48 hospitals. Data from the medical records were either collected directly from the 14 hospitals that performed 5 or more THAs or were received by post from the remaining 34 hospitals. Data on 22 hips (in 20 patients) were missing, and data on 20 hips (in 20 patients) were inconclusive, leaving 500 patients (68% of the original cohort) with 592 THAs for further analysis (Figure 1). Patients reported to have the diagnoses sequelae of dysplasia or sequelae of dysplasia with luxation (dislocated at the time of THA) were pooled into one group (sequelae of DDH) for further analysis.

For diagnoses that were found to be incorrect after validation, we collected the original form submitted to the NAR and decided whether an incorrect diagnosis had been reported by the surgeon or whether there had been an error during the registration process.

Incidence of SCFE in Norway

The incidence of Perthes' disease in Norway has been reported to be 9.2 per 10⁵ (Wiig et al. 2008). There has been no similar study for SCFE, and an incidence was therefore calculated based on data from the Norwegian Patient Register (NPR). This is a mandatory, national registry to which all hospitals report regarding diagnoses and operation codes when patients are discharged. The incidence of SCFE for subjects less than 16 years of age during the period 2000–2009 was calculated based on original data that had been reported concerning the annual number of hips diagnosed with SCFE (ICD-10 code M930), with a corresponding primary operation code. This was divided by the total number of individuals under 16 years of age in Norway during the same period. These data were received from Statistics Norway (www.ssb.no). To obtain the annual incidence of patients operated for SCFE, the mean annual number of operated hips was adjusted down based on the assumption that about 20–30% of patients with SCFE have bilateral operations (Hägglund et al. 1984, Loder 1996, Lehmann et al. 2011).

The Norwegian Arthroplasty Register

The registration form is filled in by the surgeon immediately after the operation and includes information on date of surgery, underlying hip disorder classified into 1 of 9 categories (Table 1), the type of surgery, and whether it was primary surgery or a re-operation (Havelin et al. 2000). The diagnoses of Perthes' disease and SCFE are, however, pooled in the registration form as 1 common option.

Ethics

The study was approved by the Regional Ethics Committee for Medical and Health Research, reg. number 238.03, and written informed consent was obtained from all the participants.

Table 1. Baseline characteristics of attendees and non-attendees for the cohort and for subjects with THA secondary to Perthes'/SCFE reported to the NAR

	Attendees	95% CI	Non-attendees	95% CI	p-value
Number of patients	500		232		
Male, n (%)	218 (44%)	39–48	127 (55%)	48–61	0.008
Age at THA, mean	28.7	28–29	28.3	27–29	0.5
Type of underlying diagnosis, n (%)					
Primary osteoarthritis	28 (5.6%)	3.5–7.7	19 (8.3%)	4.6–12	0.2
JIA / RA	81 (16.1%)	13–20	25 (11%)	6.7–15	0.06
Sequelae of femoral neck fracture	26 (5.2%)	3.2–7.2	19 (8.3%)	4.6–12	0.1
Sequelae of DDH	129 (25.7%)	22–30	44 (19%)	14–24	0.052
Sequelae of Perthes'/ SCFE	91 (18.1%)	15–22	42 (18%)	13–23	1.0
Ankylosing spondylitis	20 (4.0%)	2.2–5.8	8 (3.5%)	1.1–5.8	0.7
Acute femoral neck fracture	2 (0.4%)	–1.6 to 2.4	0		0.3
Others	126 (25.1%)	21–29	73 (32%)	25–38	0.06
Perthes' disease/SCFE	91		42		
Male, n (%)	61 (67%)	57–77	32 (76%)	9.3–18	0.3
Age at THA, mean	27.5	26–29	25.8	24–28	0.2

JIA: juvenile idiopathic arthritis; RA: rheumatoid arthritis; DDH: developmental dysplasia of the hip; SCFE: slipped capital femoral epiphysis.

Table 2. Validation of diagnoses reported to the Norwegian Arthroplasty Register based on the original medical records and patient self-reporting

Diagnosis as reported to the NAR	No. of THAs	Correct diagnosis	95% CI
Primary osteoarthritis	31	19 (61%)	44–79
JIA / RA	112	109 (97%)	94–100
Sequelae of femoral neck fracture	26	25 (96%)	87–104
Sequelae of DDH	150	132 (88%)	83–93
Sequelae of Perthes'/SCFE	94	89 (95%)	90–99
Ankylosing spondylitis (morbus Bechterew)	28	28 (100%)	100–100
Acute fracture of the femoral neck	2	2 (100%)	100–100
Others, specified	145	134 (92%)	84–101
Missing diagnosis	4	0	0–0
Total	592	538	

Abbreviations: See Table 1.

Statistics

The data are summarized using mean (range). Means were compared using independent-samples t-test. The approach of Welch was used when equal variance was assumed, based on Levene's test for equality. Chi-square tests were used to compare attendees with non-attendees. Both hips were used when validating the correctness of reported diagnoses. There were no differences in the results when only 1 hip from each patient was used. Analyses of baseline characteristics, prior treatment, and quality of life were done on the patients. All analyses were performed with the SPSS software version 17.0.

Results

500 patients (344 females, 592 THAs) were included. Except

for more females attending ($p = 0.008$), there were no statistically significant differences in baseline characteristics between the 500 attendees and the 213 non-attendees (Table 1). Mean age at the time of hip replacement was 29 (12–41) years, with no significant differences between the sexes. Mean age at follow-up was 35 (17–41) years.

538 of the 592 registry-based diagnoses were compared to questionnaires/medical records and judged to be correct in 91% of cases (95% CI: 83–99) (Table 2).

41% (240/592) of the THAs had been performed due to hip dysplasia (DDH) (142 hips), Perthes' disease (72 hips), or SCFE (29 hips). For 3 patients, the diagnoses of both DDH and Perthes' disease had been reported and had also been suggested in the medical notes. For the purposes of this study, these patients were included in the Perthes' disease group.

Of the 240 THAs performed due to pediatric hip disorders, 221 (92%) were correctly registered in the NAR (Table 2).

Table 3. Frequency of different hip disorders after validation. In 5 hips, 2 diagnosis were likely; 2 hips showed RA and DDH (same patient) and 3 hips showed DDH and Perthes' disease

Diagnosis	Correct numbers after validation (hips)
Primary arthrosis	18
JIA / RA	110
Sequelae of femoral neck fracture	31
Sequelae of DDH	142
Sequelae of Perthes' disease	72
Sequelae of SCFE	29
Ankylosing spondylitis	30
Acute fracture of the femoral neck	2
Others, specified	162
Missing diagnosis	0

Abbreviations: See Table 1.

18 hips that had been incorrectly reported as hip dysplasia were validated to be Perthes' disease (5 hips), SCFE (1 hip), or other specified diagnoses (12 hips). 13 hips that had been incorrectly reported as primary osteoarthritis were re-diagnosed as hip dysplasia or other specified pathologies. 98% of hips (137/140) that were operated due to rheumatoid arthritis or ankylosing spondylitis had been correctly diagnosed initially (Table 2).

43 of the 54 incorrect diagnoses registered in the NAR were due to mistakes made by the surgeons in filling in the forms. However, for 8 hips reported as "other specified diagnosis", the surgeon had also noted the correct diagnosis but this had not been registered correctly in the NAR (4 sequelae of femoral neck fracture, 3 SCFE, and 1 juvenile idiopathic arthritis/RA). 3 hips had been reported correctly on the form by the surgeon but had been wrongly registered by the secretary at the NAR.

101 of 500 subjects (20%) underwent THA due to Perthes' disease (72 patients, 52 males) or SCFE (29 patients, 16 females) (Table 3). None of these had had bilateral THA. For the 72 patients with Perthes' disease, information on treatment prior to the THA was available for 44. 24 patients had undergone surgery, while 20 had only received nonoperative treatment. For patients with SCFE, age at diagnosis and operation was 13 (10–15) years. 1 patient presented with symptoms at the age of 24 years and underwent THA 7 years later.

Quality of life, EQ-5D

The mean EQ-5D index score for all subjects (500 patients) was 71 (8–100), 73 for males and 70 for females ($p = 0.2$), which was lower than that reported for an age-matched cohort in Sweden (89) and the UK (86) ($p < 0.001$). The mean score for those who underwent THA due to SCFE was significantly higher than that reported for those with Perthes' (81 vs. 74; $p = 0.04$) or hip dysplasia (81 vs. 69; $p = 0.008$) (Table 4). The score for those operated because of SCFE was similar to that reported for an age-matched cohort in the UK ($p = 0.13$), but

Table 4. EQ-5D index for patients with different diagnoses

Diagnosis	EQ-5D scores ^a	(95% CI)
Primary osteoarthritis	73	61–85
JIA / RA	66	61–71
Sequelae of femoral neck fracture	68	59–77
Sequelae of DDH	69	65–73
Sequelae of Perthes	74	70–79
Sequelae of SCFE	81	75–87
Ankylosing spondylitis	73	64–82
Acute fracture of the femoral neck ^b	44	36–52
Others, specified	74	70–78
All diagnoses	71	69–73

^a 0 = worse imaginable health; 100 = best possible health.

^b Only 2 patients were operated due to acute fracture of the femoral neck.

it was lower than that reported for an age-matched population in Sweden ($p = 0.03$).

Incidence of SCFE

The annual number of hips operated for SCFE that were reported to the NPR during the period 2000–2009 varied from 29 to 46, with a mean of 38, giving an annual incidence of diagnosed hips with SCFE of 4 per 10⁵ for children below the age of 16 years. When adjusting for bilaterality, this gave an annual incidence of patients with SCFE of about 3 per 10⁵.

Discussion

We found that the underlying cause of total hip replacement was correctly reported to the NAR in 91% of all subjects less than 40 years of age and in 95% of patients operated due to Perthes' disease or SCFE. Except for those operated due to an underlying SCFE, quality of life as assessed by the EQ-5D index was poorer than in age-matched cohorts.

The strengths of our study include the high number of participants and the collection of additional data from the medical records. Except for gender, there were no statistically significant differences between the baseline data of the 213 non-attendees and those of the attendees. This was not unexpected, since females are more liable to respond to surveys (Hill et al. 1997). Thus, there is little reason to believe that our cohort was flawed by selection bias. Our findings regarding validation of diagnoses compare favorably with a study from the Danish Hip Arthroplasty Register involving 459 patients (Pedersen et al. 2004). After having reviewed the medical records and preoperative radiographs, these authors found that a reported diagnosis had a positive predictive value of 84%. The outcome most probably reflects difficulties in assessing an underlying diagnosis in older age groups, as secondary degenerative changes tend to obscure underlying pathologies.

The observation that primary osteoarthritis was the diagnosis that was most commonly incorrectly reported was not unexpected, since severe arthritis warranting a THA at this young age would tend to obscure an underlying diagnosis such as DDH, Perthes' disease, or SCFE (Murray 1965).

Children with Perthes' disease had their diagnosis at 7 years of age; one third of them had undergone surgical treatment and slightly less than one third had had nonoperative treatment alone. According to the medical notes, the remainder had received no treatment at all—although 17 of these patients reported otherwise in the questionnaire. This controversy may be due in part to inaccurate medical notes, recall bias, or both. For those with SCFE, age at diagnosis was slightly higher—around 12 years—and all but 1 had had prompt surgery at the time of diagnosis.

The initial treatment of Perthes' disease depends on age and the severity of femoral head necrosis (Wiig et al. 2008). For SCFE, the standard treatment is operative stabilization of the femoral epiphysis (Loder et al. 2008), aiming at prevention or delay of degenerative change (Carney et al. 1991). In the present study, all but 1 of the patients with SCFE and one third of those with Perthes' disease had hip-preserving surgery as adolescents. Since most of the initial radiographs were unavailable, we could not determine whether those receiving surgery for Perthes' disease were more severely affected than those who were treated nonoperatively. Likewise, we were unable to determine the degree of slip prior to initial surgery.

Calculation of the annual incidence of SCFE in children less than 16 years was based on the NPR. Diagnoses of SCFE in the NPR are not validated, but a study from Arthurson et al. (2005) reported a difference of only 3.4% in data reported to this mandatory, national register compared to data reported to the NAR from a single hospital. All hospitals are obliged to report their patients to this administrative register, and there is little reason to believe that patients with SCFE were under- or over-represented. The NPR contains information on the number of operated hips only, not to the number of operated children. However, in a recent study, we showed that 30% of children with SCFE suffer bilateral involvement (Lehmann et al. 2011), providing a ratio on which to base the estimated incidence. This number is in accordance with that reported by other authors (Hägglund et al. 1984, Loder 1996). Moreover, none of the hospitals performed prophylactic fixation of the contralateral hip during the study period. The annual incidence of 3 per 10^5 also compares well with other studies (Loder et al. 2000, Krauspe et al. 2004). In comparison, the incidence of Perthes' disease was found to be 9 per 10^5 in a large, randomized national trial (Wiig et al. 2008).

When comparing the number of operated prosthesis in SCFE or Perthes' disease with the incidences of the diseases (3 per 10^5 for SCFE and 9 per 10^5 for Perthes' disease), we can see that the risk of undergoing THA was about the same for the 2 diseases.

Of those patients who underwent THA as a result of SCFE, more than half of them (16 of 29) were females. This was rather surprising since SCFE is seen more frequently in males (2:1) (Loder et al. 2000, Gholve et al. 2009). One explanation may be that girls suffer a more severe slip than boys. Again, due to the unavailability of the initial radiographs, we could not investigate this in detail. One could speculate that there is a diagnostic delay leading to a more severe slip in girls, since doctors are more prone to consider SCFE as a possible diagnosis in males. A previous study of 67 patients with SCFE from our institution supports this, in that the female patients had almost 2 months longer duration of symptoms and nearly two-thirds had a moderate or severe slip compared to one third of the boys (Lehmann et al. 2011). Longer duration of symptoms is known to increase the severity of the slip (Loder et al. 2006).

In this study, we found that the quality of life after THA is reduced for patients below 40 years of age as compared to healthy age-matched controls. This has also been demonstrated by Wangen et al. (2008) in a study of 49 patients aged 30 or less. They found a mean EQ-5D index of 68 as compared to 71 in our study. In comparison, indices from age-matched Swedish or British cohorts have been reported as being 85–90 (Szende and Williams 2004). When subdivided into different diagnoses, we found that patients who had been operated due to SCFE had a better quality of life than the other groups. The reasons for this are unclear, but one explanation may be that the femoral head alone, and not the acetabulum, is involved in the underlying disease. In another study from the NAR (Engesæter et al. 2003), it was found that revision rates for patients requiring THA due to Perthes' disease/SCFE were lower than for other diagnoses, but since both Perthes' disease and SCFE are reported under the same tick box in the registration form, it was not possible to ascertain whether SCFEs or the Perthes' disease caused the favorable results in that study. In the next revision of the NAR form, the diagnosis of Perthes' disease and SCFE will be registered separately.

In conclusion, data held in the NAR on the underlying diagnosis for THA in young adults was of high quality, with 91% of the diagnoses being correctly reported. THA patients had a poorer quality of life than those in age-matched cohorts in Sweden and the UK, except for those who underwent THA as a result of SCFE.

TGL, IØE, SAL, and LBE were responsible for the study design. TGL performed the analyses and drafted the manuscript. IØE and TGL collected all the medical notes from the hospitals. All authors participated in interpretation of the results and in preparation of the manuscript.

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No competing interests declared.

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Radiographic findings which may indicate an undergone, silent slipped capital femoral epiphysis in a cohort of 2072 young adults.

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Abstract

In patients operated for unilateral slipped capital femoral epiphysis (SCFE) the reported prevalence of an asymptomatic slip of the contralateral hip is up to 40%. Based on a population based cohort of 2072 healthy adolescents (58% females) we here report on radiographic and clinical findings suggestive of a possible previous SCFE. Commonly used cut-off values for Southwick's lateral head-shaft angle ($\geq 13^\circ$) and Murray's tilt-index (≥ 1.35) were used. New reference intervals for these measurements at skeletal maturity are also presented.

At follow-up mean age was 18.6 (17.2-20.1) years, 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. 6.6% of the cohort had Southwick's lateral head-shaft angle $\geq 13^\circ$, suggestive of a possible slip. Murray's tilt-index ≥ 1.35 was demonstrated in 13.1% of the cohort, predominantly in males in whom this finding was associated with additional radiographic findings, but no clinical findings suggestive of SCFE.

This study may indicate that 6.6% of young adults have radiological findings of a possible undergone SCFE which seems to be more common than previously reported.

Introduction

Slipped capital femoral epiphysis (SCFE) is one of the most common hip disorders in adolescents¹, typically diagnosed between 11 and 15 years of age². Known risk factors are male sex, 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 4 to 80 per 100.000^{2,5,6} according to ethnicity and method of ascertainment.

The association between SCFE and development of degenerative changes has been shown in several previous reports⁷⁻¹⁰. Murray stated that even a minor silent slip may lead to tilt deformities presenting as an idiopathic osteoarthritis (OA) later in life⁹. However, his view has been opposed by Resnick¹¹, claiming that the tilt deformity occasionally seen in some patients with OA is more likely to be secondary to degenerative change, and not the other way around. In a recent study on 67 patients with SCFE¹², we showed that around half had radiographic findings suggestive of a bilateral slip, of which more than one third was asymptomatic. The diagnosis was based on radiographic findings; including a Southwick lateral head-shaft angle $\geq 13^\circ$ ^{13,14}. Jerre and colleagues found, in a series of 100 patients that up to two thirds of patients with bilateral SCFE had an asymptomatic slip on the contralateral side at later follow-ups, based on a slip angle of > 13 degrees¹⁴.

In the present study we report on the prevalence of radiographic findings suggestive of an undergone SCFE, based on the commonly used cut-off values for the Southwick's lateral head-shaft angle and Murray's tilt-index and also present new reference intervals for measurements commonly used for the diagnosis of SCFE.

Material and Method

Patients

During 2007 to 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 trial¹⁵. The initial cohort comprised all 5068 newborns delivered at Haukeland University Hospital in Bergen, Norway during 1989. 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 as defined for the present study (n=745). 2081 (52%) agreed to participate, of whom 1207 (58%) were females. 7 females were excluded due to uncertain pregnancy status, 1 female due to a subluxated hip related to severe cerebral palsy and 1 male due to recently taken pelvic radiographs (Figure 1). The follow-up at 18-19 years of age included 2 questionnaires, two hip radiographs and a clinical examination.

Questionnaires

The first questionnaire addressed hip problems in parents and siblings, while the second included data on hip pain, walking disabilities, training habits, quality of life (EQ-5D (www.euroqol.org)) and WOMAC Osteoarthritis Index (www.womac.org). Quality of life was assessed using a standardized health related quality of life questionnaire (EQ-5D) scoring 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 Osteoarthritis Index is a three dimensional patient-centred health status questionnaire designed to capture elements of pain, stiffness and physical disability

in patients with osteoarthritis of the hip. The index is calculated from 24 5-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, ½ hour, 1 hour, 2-3 hours, 4-6 hours or ≥ hours).

Radiographs

All examinations were performed at the Radiological Department, Haukeland University Hospital, using a low-dose technique (direct digital radiography, Digital Diagnost System, version 1.5, Philips Medical Systems, the Netherlands). 2 views were obtained, an erect anteroposterior (AP) view (feet pointing forward, neutral ab-adduction position of the hips)¹⁶ and a frog leg view, using a film/focus distance of 1.2m and centred at 2cm proximal to the pubic bone (Figure 2a and b).

All examinations were performed by the same, specially trained radiographer according to a standardized protocol. The images were analysed by one observer (LBL) measuring the lateral head-shaft angle (frog leg view)¹⁷ (Figure 3) and Murray's tilt-index (AP view)⁹ (Figure 4), and new reference intervals were established based on the upper 95% reference interval (mean + 1.96 SD) of our cohort. To examine prevalences of radiographic findings suggestive of an undergone slip, we used cut-off values of 13° for the head-shaft angle^{13, 14} and 1.35 for the tilt-index⁹ according to the literature. In a separate session, the radiographs were analysed subjectively by one radiologist with 25 years of experience in muscle-skeletal reading (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 3 measurements of the joint space width (JSW); medially, in the middle and laterally^{18, 19}. A JSW-width of ≤ 2.0 mm²⁰ was suggestive of degenerative changes.

Clinical examination

The clinical examinations were performed by 1 of 5 specially trained physicians, and included height, weight, leg length differences, hip mobility, Brighton's hypermobility score, range of motion of the hip (flexion, extension, ab- and adduction, internal and external rotation) and an impingement test (flexion+adduction+internal rotation). All physicians standardized 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. 9 participants were scheduled for immediate follow-up by a senior radiologist (KR) and a senior orthopaedic surgeon (LBE) due to clinical or radiographic findings related to hip, pelvis or lower spine.

Statistics

Data have been summarised using mean and range. Continuous variables have been compared using independent sample t-tests and Chi-square and Fishers exact tests for categorical variables. A significance level of 0.05 was decided a priori, and all the reported p-values are two-tailed. Associations among different radiographic findings were analysed by calculating the odds ratio (OR) between each of the features separately, and an OR greater than 2.0 was considered to indicate a clinical relevant association. To examine for significant differences in BMI by head-shaft angle, BMI was dichotomised as overweight (BMI ≥ 25 kg/m²) or not.

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, foetal position, and multiple births as covariates ²¹ based on data from the Medical Birth Registry. Different sets of probability weights were made for each of the prevalence calculations, due to slight differences in missing values between the measures. The statistical package PASW Statistics 18 ® (SPSS Inc., Chicago, Ill) was used for the statistical analyses, while the survey tools in Stata Statistical Software: Release 11 (StataCorp. 2009. College Station, TX: StataCorp LP) was used for the calculation of the prevalence estimates.

Results

A total of 2072 subjects were included in the study (Figure 1). There were more females (58%) than males amongst the attendees, and prevalences were adjusted for non-responders. The mean age at follow-up was 18.6 years (17.2-20.1). The head-shaft angle was possible to measure in at least one hip in 1925 (93%) of the subjects, and bilaterally in 1588 (77%), while the corresponding figures for the tilt-index were 2056 (99%) and 2024 (98%), respectively.

The mean head-shaft angle was 0.9° (-22° - 23°) for right hips, -0.6° (-27° - 22°) for left and 0.2° (-27° - 23°) for all hips with upper 95% reference intervals of 13.9° , 13.3° and 13.8° respectively. Statistical significant differences were found between males and females (Table 1). The mean tilt-index was 1.1 (0.6 - 1.9) for right hips, 1.0 (0.5 - 2.1) for left hips and 1.0 (0.5 - 2.1) for both hips (Table 1) with upper 95% reference interval of 1.43, 1.42 and 1.43 respectively.

Adjusted for non-responders, head-shaft angles $\geq 13^{\circ}$ was measured in 7.6% of the males, in 5.5% of the females and in 6.6% of the entire cohort, while a tilt-index ≥ 1.35 was found in 19.9% of the males, in 6.0% of the females and 13.1 % of all (Table 2). Only 6 subjects (4 males) tested positive for both markers.

Age, BMI and self-reported information on health status, hip problems and exercise at follow-up as well as range of hip motion are listed in Tables 3 and 4. The BMI was significantly higher (23.8 kg/m^2) for those with a head-shaft angle $\geq 13^{\circ}$ as compared to those with lower angles (22.8 kg/m^2) ($p=0.019$). The difference in the BMI remained statistical significant only in males ($p=0.035$), but not in females ($p=0.13$). A BMI ≥ 25 was seen in 32% of those with a head-shaft angle $\geq 13^{\circ}$ vs 21% of those with an angle below 13° ($p=0.007$). However, both groups had a mean value below the threshold for overweight and the clinical importance can be questioned. The

mean internal hip-rotation was decreased 10° for persons with high head-shaft angle compared to those with a low angle ($p<0.001$), while the external rotation was increased 7° ($p<0.001$). The differences in internal and external rotation remained statistical significant for both sexes, except for left hip in boys where the reduction in internal rotation was not statistically significant. No differences between groups were found for the remaining hip mobilities (Table 4), or for the degree of physical exercise. When based on our new 95% reference intervals for 19 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 ($p<0.001$).

No differences in BMI ($p=0.71$), hip mobility or physical exercise were seen between those with a tilt-index below or above 1.35 or 1.43 for either sex.

There were no associations between the head-shaft angle and subjectively assessed radiological findings, such as pistol grip deformity or a focal femoral neck prominence (OR 0.6 – 1.7) (Table 5). Opposite, tilt-index was associated with a pistol grip deformity, focal prominence of the femoral neck and lateral flattening (Table 5). When analysing subgroups these associations were still significant for males, but not for females. No differences were seen in joint space width (JSW) according to head-shaft angle, using two different cut-off values (13 ° and 14 °) or the tilt-index (using cut-offs of 1.35 and 1.43).

EQ-5D, WOMAC and self-reported hip problems

Mean score for quality of life as assessed by the EQ-5D was 92 (21 - 100), 94 (21 - 100) for males and 91 (26 - 100) for females ($p<0.001$) (Table 3), with no differences according to head-shaft angle ($p=0.21$) or tilt-index ($p=0.63$). Median WOMAC score was 0, mean 1.6 (range 0-68). Females scored significantly higher as compared to

males ($p=0.002$), but no difference was found with respect to the radiological measurements.. 99 (4.9%) of the participants reported some problems with walking, however, no differences were seen according to high or low head-shaft angle ($p=0.81$) or tilt-index ($p=0.73$).

109 (5.4%) had experienced “clicking”, stiffness or pain in the hip during the last 3 months, but with no correlation to the radiological findings.

Discussion

In this cohort of healthy 18-19-year old Norwegians we found an association between Southwick's head-shaft angle $\geq 13^\circ$ and clinical findings common in patients with SCFE such as reduced internal rotation, increased external rotation and a high BMI. Based on cut-off value for head-shaft angle of $\geq 13^\circ$, 6.6% of the cohort, 7.6% of males and 5.5% of females, had radiological findings indicating a previous slip. A high tilt-index (≥ 1.35) demonstrated in 13.1% of the cohort was associated with additional radiographic but no clinical findings suggestive of SCFE. Regarding the 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 (mean+2SD) for the head-shaft angle and the tilt-index in 18-19 year-olds, support the commonly used cut-offs of 13° and 1.35^{13, 14}. The cut-off of 13° is based on studies addressing radiographical findings of SCFE and not on population based cohorts. For the purpose 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 analysis did not differ substantially.

Several authors have used the difference in head-shaft angle between pathological and healthy hips in the diagnosis of SCFE²²⁻²⁵. This approach may be flawed, as up to 60% of those suffering SCFE have bilateral involvement^{12, 26, 27}. Of the different radiological measurements used to diagnose SCFE,^{3, 9, 17, 28} none has proven superior regarding intra- and inter- repeatability²⁹⁻³¹. Carney in 2005 found the intra-observer variability of the head-shaft angle to be $\pm 6^\circ$ in a study including 108 hips, while Loder in 1999 found it to be $\pm 12^\circ$ in a study of 48 hips. He also tested the

variability for several other measurements and concluded that the head-shaft angle classified into discrete categories as mild, moderate and severe slip might increase the accuracy^{3, 28, 30}.

The tilt-index, including the commonly used cut-off of 1.35, was initially proposed by Murray⁹. 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 sex, overweight, and a reduced range of hip-motion, especially internal rotation, flexion and abduction³². Our findings support these associations, as males with high head-shaft angles had a higher mean BMI, lower internal rotation and higher external rotation as compared to the rest of the male cohort. Except for the higher BMI, similar associations were seen for females.

Corresponding associations were, however, not found for the tilt-index. In a previous study¹² including 67 children and adolescents with an established SCFE, only around 25% had a tilt-index above 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 the 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. Murray⁹ suggested that the pistol grip deformity may be caused by a previous slip; however, our results lend no support to this theory.

Further, Resneck¹¹ proposed that the pistol grip or tilt-index was due to degenerative changes in elderly patients with osteoarthritis (OA). However, our study indicates that

the tilt-deformity is present long before any signs of OA. In our cohort the number of participants with a high tilt-index corresponds well with papers addressing impingement^{20, 33, 34}. About 20 % of young males and 3-4 % of females are thought to have a pistol grip deformity which in time may give rise to a cam impingement. We acknowledge some limitations to our study; first, the high number of radiographs being difficult to measure, particularly with regard to the head-shaft angle. These radiographs were, however, 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 hypothesize that teenagers with on-going 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 as compared to those with lower values. Further, 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, generalisation of the results must be done with care. Third, there is the possibility that bony remodelling lasting until skeletal maturity may have masked a previous slip^{35, 36}.

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

A high number of radiographical findings associated with possible previous slips were found in our cohort, and much higher than found in clinical studies of patients treated due to SCFE^{6, 27}. However, a study from Goodman et al³⁷ reported on post-slip morphology in human skeletons. They 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 this post-slip morphology and 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 19-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.

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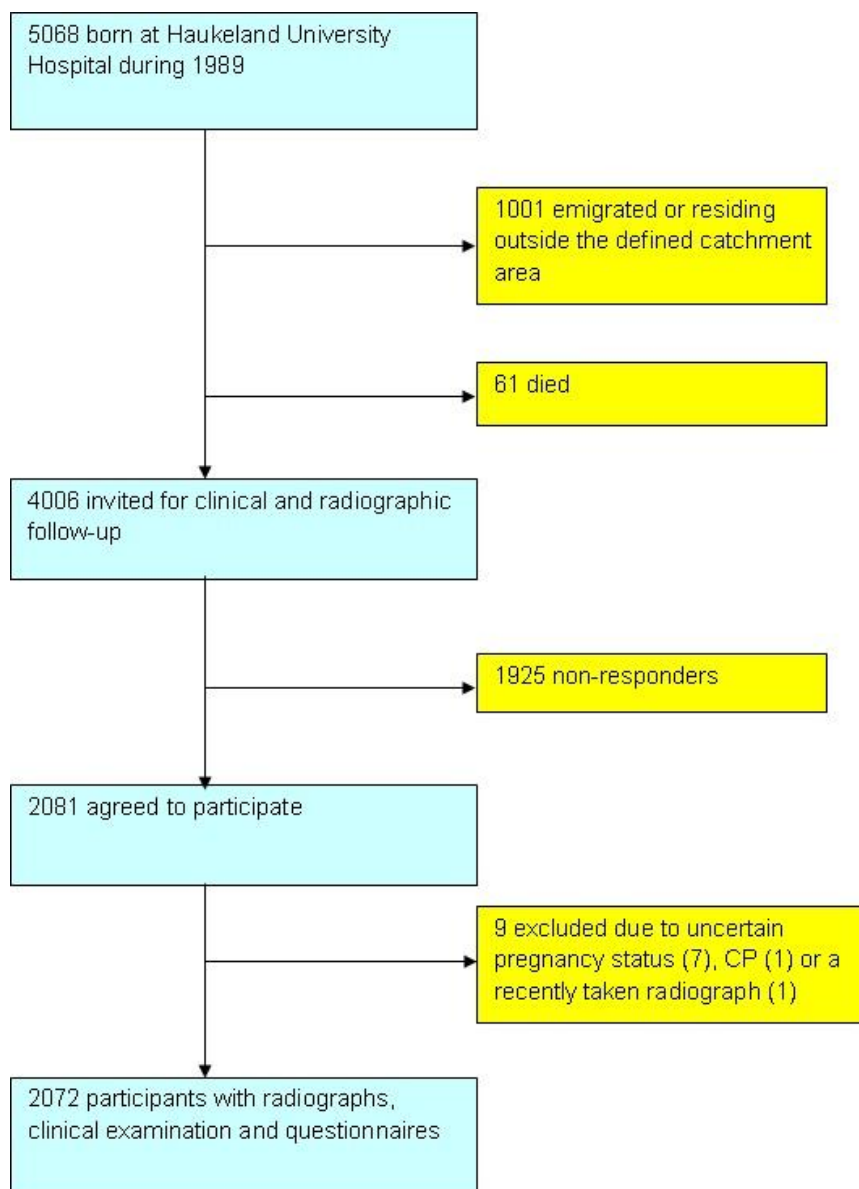


Figure 1. Flow of participants in the study.



Figure 2. Radiography A) erect AP view and B) supine frog-leg view.



Figure 3. Measurement of Southwick's lateral head-shaft angle on a frog-leg view.

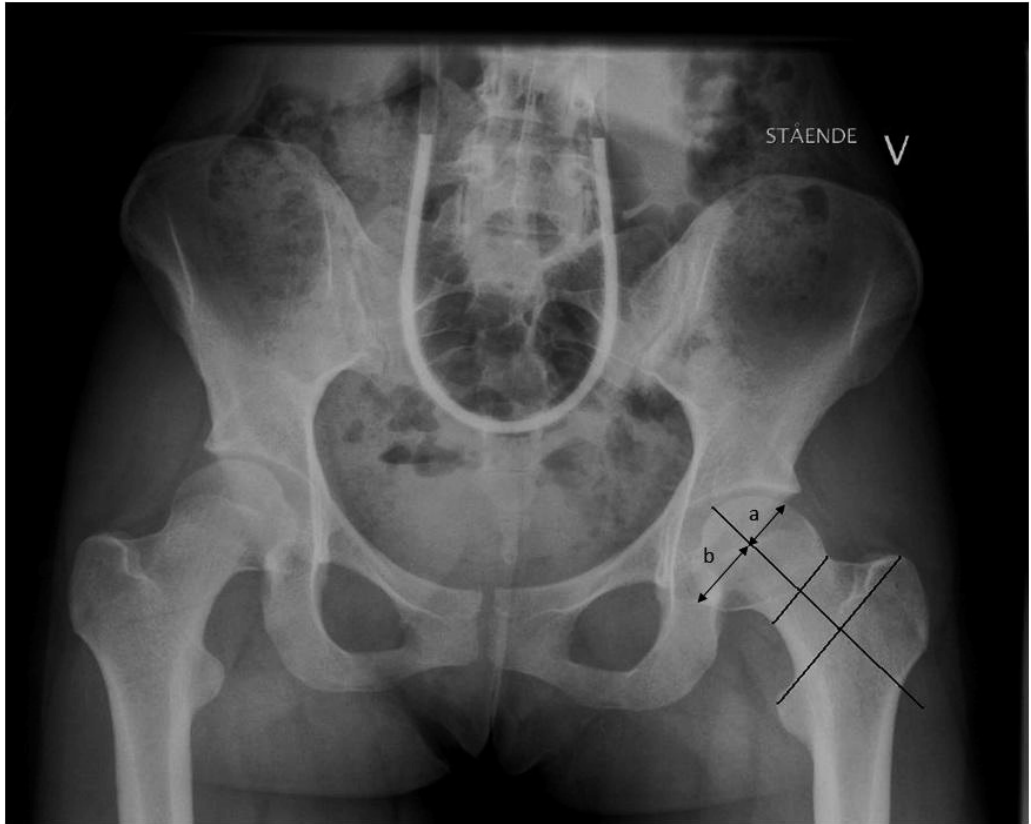


Figure 4. Measurement of Murray's tilt index as defined by the ratio b/a .

Table 1. Radiological hip measurements in a population based cohort of 2072 18/19 year olds, by sex.

Hip measurements	Males (n=873)	Females (n=1199)	P-value	Total (n=2072)
Head-shaft angle (°), mean (range)				
-right hip, n ¹ = 1798	1.4 (-21-23)	0.6 (-22-20)	0.010	0.9 (-22-23)
-left hip, n= 1712	0.5 (-23-22)	-1.2 (-27-21)	<0.001	-0.6 (-27-22)
Tilt-index, mean (range)				
-right hip, n= 2037	1.1 (0.7-1.9)	1.0 (0.6-1.8)	<0.001	1.1 (0.6-1.9)
-left hip, n= 2042	1.1 (0.6-2.1)	1.0 (0.5-1.7)	<0.001	1.0 (0.5-2.1)

¹n = the number of successful measurements

Table 2. Prevalence (with 95% CI) of 18/19-year-olds with radiographic findings (by side), believed to be associated with an undergone, asymptomatic SCFE, in a population based cohort of 2072 healthy adolescents. Numbers were adjusted for non-responders.

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

Table 3. Age, body mass index (BMI) and self-reported information on health status, hip problems and exercise in a population based cohort of 2072 18/19-year olds, by sex.

Variable	Males (n=873)	Females (n=1199)	Total (n=2072)	p-value
Age (years), mean (range)	18.6 (17.2-20.1)	18.6 (17.2-20.1)	18.6 (17.2-20.1)	0.53
BMI, (kg/m ²), mean (range)	23.3 (15.0-54)	23.0 (14.2-42.5)	23.2 (14.2-54.1)	0.05
Total WOMAC-score, mean (range)	1.3 (0-68)	2.0 (0-45)	1.6 (0-68)	0.002
EQ-5D-score, mean (range)	94 (21-100)	91 (26-100)	92 (21-100)	<0.001
Hip problem ever	5.6%	12.8%	9.7%	<0.001
Physical exercise 2 hours or more per week	71%	63%	67%	<0.001

Table 4. Mean values for range of hip motions in degrees for participants with head-shaft angle <13° and ≥ 13°, by sex, presented for right and left hip with corresponding p-values and value for all males and all females in the cohort.

	Right hip			Left hip		
	Head-shaft angle <13°	Head-shaft angle ≥13°	p-value	Head-shaft angle <13°	Head-shaft angle ≥13°	p-value
Males						
Flexion	118	118	0.82	118	121	0.19
Extension	26	27	0.78	26	27	0.33
Abduction	59	59	0.55	59	60	0.29
Adduction	39	39	0.79	39	38	0.70
Internal rotation	40	33	0.002	40	35	0.20
External rotation	56	61	0.029	35	64	0.003
Females						
Flexion	123	122	0.36	123	123	0.92
Extension	28	28	0.94	28	27	0.94
Abduction	62	61	0.24	62	62	0.24
Adduction	39	39	0.41	39	37	0.10
Internal rotation	53	43	<0.001	54	46	0.007
External rotation	46	54	<0.001	45	52	0.004
				All cohort	All cohort	
				118	118	
				26	26	
				59	59	
				39	39	
				39	39	
				57	57	
				123	123	
				28	28	
				62	62	
				39	39	
				53	53	
				46	46	

Table 5. Associations among subjectively assessed radiographic features with head-shaft angle and tilt-index calculated using odds ratios (95%CI).

Radiographic Feature	Head-shaft angle $\geq 13^\circ$		Tilt-index ≥ 1.35	
	Right (n=67)	Left (n=52)	Right (n=164)	Left (n=123)
Pistol-grip deformity (n=387)	0.6 (0.2-1.8)	0.6 (0.2-2.0)	4.3 (2.9-6.4)	3.0 (1.9-4.7)
Lateral flattening of femoral head (n=325)	1.7 (0.8-3.7)*	1.5 (0.7-3.8)*	2.6 (1.7-4.2)	1.5 (0.8-2.6)*
Focal prominence of femoral neck (n=186)	1.1 (0.3-3.6)*	0.5 (0.1-3.5)*	2.0 (1.1-3.8)	3.0 (1.6-5.4)*

* No females with both radiographic findings

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Contributions of authors

All authors participated in the planning and implementation of the study. TGL was mainly responsible for performing the statistical analysis and drafting the manuscript. LBL has measured all the radiographs. SAL has been responsible for the drop out analysis. All authors have contributed to its intellectual content.

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Intra- and inter-observer repeatability of radiographic measurements for previously slipped capital femoral epiphysis at skeletal maturity

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Abstract

Background: Recent studies suggest that even a mild slip of the femoral capital epiphysis may lead to later degenerative changes when undiagnosed. However, little is written on the accuracy of radiographic measurements used to diagnose a slip at skeletal maturity.

Purpose: To assess the accuracy of radiographic measurements commonly used for assessment of previously slipped capital femoral epiphysis (SCFE) at skeletal maturity.

Material and Methods: All children born at our hospital during 1989 (n=4006) were invited to participate in a follow-up hip trial at age 18-19 years. Erect pelvic anteroposterior and supine frog leg radiographs were obtained in a standardized fashion. For the purpose of this study, we selected a subset of 100 radiographs. To balance the dataset, we added another 28 radiographs from skeletal mature patients diagnosed and operated for a SCFE. Two observers independently measured Southwick's head-shaft angle, Murray's tilt-index and the femoral head-neck angle. Intra- and inter- observer variation was assessed using the mean difference, with its 95% limits of agreement.

Results: A high percentage of the images (40%), particularly for the measurement of the Southwick's head-shaft angle, were judged immeasurable by at least one observer. Mean head-shaft angle was 11.0° (SD=17.0), head-neck angle was 8.0° (SD=12.0) and Murray's tilt-index 1.18 (SD=0.4). For head-shaft angle, the mean difference between measurements (Observer 2) was 0.8° (SD=2.7°, 95% limits of agreement -4.5° to 6.1°), while the corresponding figures for the Murray's tilt-index was 0.02 (SD=0.08, 95% limits of agreement -0.18 to 0.14) and for the head-neck angle 0.9° (SD=4.0, 95% limits of agreement of -6.9° to 8.7°). Slightly higher variance was seen for Observer 1 and between the two observers.

Conclusion: Common radiographic measurements for the assessment of a previously slipped capital femoral epiphysis are relatively inaccurate in skeletal mature adolescents, in particular between observers (inter-observer), but also for the same observer (intra-observer). Our results underscore the importance of thorough standardization for both image- and measurement technique when used in a clinical setting.

Keywords: Slipped capital femoral epiphysis, measurement repeatability, intra- and inter- observer, Southwick's head-shaft angle, Murray's tilt-index, head-neck angle.

Slipped capital femoral epiphysis (SCFE) is one of the most common hip disorders in adolescents (1) with a reported annual incidence around 3-5 per 100.000 (2, 3), and up to 60% being bilateral (4). Pathoanatomically, there is a separation of the femoral head from the metaphysis; the femoral head remaining within the acetabulum and the metaphysis moving superio-anteriorly in relation to the head (5). The etiology is unknown, but both mechanical and endocrinological factors are thought to play a role (6, 7). Patients typically present with insidious onset of thigh or knee pain with a painful limp. The diagnosis is based on clinical and radiological findings; hip motion will be limited, particularly internal rotation. Commonly used radiological markers for SCFE are Southwick's head-shaft angle (8) as measured on the anteroposterior (AP) (9, 10) or frog-leg views (1, 11, 12), posterior sloping angle of Barrios (13), Klein's tangent (14), Murray's tilt-index (15, 16), displacement of the femoral epiphysis on the metaphysis measured in mm or % (17, 18) and the lateral slip angle (19, 20). An extensive literature research, however, revealed only a few studies addressing the repeatability of these measurements (21, 22). Variability in two of the most used methods, namely the lateral head-shaft angle and amount of displacement of the epiphysis on the metaphysis both measured on the frog-leg view, was tested with a conclusion that angular measurements converted into a discrete category (mild, moderate, severe) was the only measurement yielding an acceptable intra- and inter-observer variation (22).

As part of a large clinical and radiological follow-up of a previous randomized hip-trial (23), we aimed at examining intra- and inter-observer repeatability for radiographic measurements commonly used for measurements of a previous slipped capital femoral epiphysis, namely the Southwick's head-shaft angle, the femoral head-neck angle and Murray's tilt-index.

Material and Methods

The Regional Ethical Committee for Medical and Health Research approved this study (No 3.2006.144), and written informed consent was obtained from all the participants.

A sample of 100 pelvic radiographs from 19 year olds (67 females) participating in a longitudinal, population-based study on hip-disorders in childhood (23) were included. These radiographs were drawn from a total of 1200 examinations (the 1200 initial participants from a total of 2082, attendance rate of 52%), which had been scored a priori with respect to acetabular shape, “pistol grip deformity”, femoral neck irregularities, amongst others. Both subjectively normal hips and hips with subjective findings of pistol grip and different acetabular shape were included. None of the subjects had been treated for SCFE. To obtain a data set including both presumptive normal as well as SCFE hips, we added 28 hip examinations from skeletal mature patients previously operated for SCFE (24).

All examinations were performed at the Department of Radiology at our hospital, using a low-dose technique (Direct Digital Radiography, Digital Diagnost System, version 1.5, Philips Medical Systems, Best, The Netherlands). Two views were obtained, an erect anteroposterior (AP) view (feet pointing forward, neutral ab-adduction position of the hips) (25) and a supine frog leg view, using a film/focus distance of 1.2m and centered at 2cm proximal to the pubic bone.

Technical image criteria for inclusion were an obturator index between 0.7 and 1.8 according to Tönnis (1976) (26), and for measurement of the head-shaft angle, 2cm of the proximal femoral metaphysis had to be included in the frog-leg-view. Further, the observers were instructed to omit measurements if the measurement points could not be

accurately set. The radiographs were analyzed on an Agfa PACS system (Agfa IMPAX Web1000 v.5.0, Agfa Gevaert, Mortsel, Belgium). Two different observers, one consultant radiologist with more than 20 years of experience in musculoskeletal radiology (Observer 1) and one consultant radiologist with 5 years of experience in musculoskeletal readings (Observer 2), performed the following measurements, using the mean of two measurements (27): Southwick's head-shaft angle (frog-leg view), head-neck angle (frog-leg view) and Murray's tilt-index (AP view) (Fig. 1a-c). The readers were masked to the other findings, and were allowed to use the preferred screen settings. Standardization of the measurements was performed prior to the study by thorough discussions and measurements of 20 different pelvic radiographs. Both observers reread all radiographs after a period of three months, masked to the previous measurements. Intra- and inter-observer variation for each of the measurements was assessed using the mean difference, with its 95% limits of agreement (27, 28). For the purpose of graphic presentation we plotted the differences against the mean measurements (Bland-Altman plots). All results are given for left hip. The statistical package PASW Statistics 18 ® (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses.

Results

For measurements of Southwick's head-shaft angle, Murray's tilt-index and the head-neck angle, 75, 119 and 109 of the cases, respectively, were judged measurable by both observers (Table 1). Mean head-shaft angle was 11° (SD=17.0), mean tilt-index was 1.18 (SD=0.4), and mean head-neck angle was 8.0° (SD=12.0).

For observer two, the mean difference in head-shaft angle between two measurements was 0.8° (SD=2.7 $^{\circ}$, 95% limits of agreement -4.5° to 6.1°) (Table 1, Fig. 2). For the head-neck angle, there was a mean difference between measurements of 0.9° (SD=4.0) and 95% limit of agreement of -6.9° to 8.7° . The mean difference for the tilt-index was 0.02 (SD=0.08) and the 95% limits of agreement was -0.18 to 0.14. Slightly higher variation was seen for Observer 1 (Table 1, Fig. 2).

The mean difference in head-shaft angle between the two observers was 1.3° (SD=3.9) however the 95% limit of agreement ranged from -6.3 to 8.9° (Table 1, Fig. 2).

Discussion

We have shown that commonly used, radiographic measurements for the assessment of a previous SCFE are relatively inaccurate, in particular inter-observer, but also for intra-observer. Further, a high percentage of the images, particularly for the measurement of the Southwick's head-shaft angle, were judged immeasurable by both observers. Our results underscore the importance of thorough standardization of measurement techniques.

One limitation to our study is an unbalanced dataset with regard to slips, despite efforts being made to include hips with different shape of the femoral head and of the acetabulum. Secondly, the frog leg view posed problems in large subjects as even the largest field of view available did not cover enough of the proximal femur for the Southwick's angle to be measured. Further, the physeal line was partly fused in a proportion of the subjects, or too little of the femoral shaft was visible, hindering measurement of the head-shaft angle for at least one of the observers (53/128). Although the study was not designed to perform subgroup analysis, no differences in repeatability/reproducibility were seen between those treated for a previous SCFE and those not treated.

The strengths of this study include the standardized examinations, one particularly trained radiographer performing all the radiographs according to a well-defined protocol and the high numbers and relatively thorough standardization of the measurements performed.

Overall the degree of inter-observer variation was higher than the intra-observer variation for all three markers. In addition the Bland-Altman analysis demonstrated that although the mean difference between the two readers was small the standard deviation was large, with a relatively wide 95% limit of agreement. The increased variability in the measurements generated between the two observers when compared to that seen for each

of the two observers is intuitive. However this difference also indicates that the standardization between the two observers might have been even better.

Of the angular measurements under investigation, the Southwick's head-shaft angle appeared to be the more consistent, with relatively low variability both within and between observers as compared to the measurement of the femoral head-neck angle. Our results compare well with a previous study on slip angle in 38 children diagnosed with SCFE (22). Head-shaft angle of 12° was used as a limit where bilateral SCFE was diagnosed. They found that Southwick's angle based on a frog-leg view was the more accurate measurement, however, with 95% limits of agreement of ± 12 degrees for both intra- and inter- observer variability. They recommended converting into discrete categories to achieve better variability. Another study of 108 hips, showed a $\pm 5.9^{\circ}$ intra-observer variability for the lateral head-shaft angle (29).

To our knowledge, the reliability of the Murray's tilt-index or that of the femoral head-neck angle has not been addressed in previous studies. An extensive literature search revealed that the Murray's tilt-index has been used as a marker for previous slips at late follow-up only, but not for the assessment of actual slips (15, 16)

In conclusion, radiographic measurements for the assessment of slipped capital femoral epiphysis (SCFE) are relatively inaccurate, in particular between observers, but also for the same observer. We feel that a more rigorous standardization process between observers would have produced smaller observer variation for all measurements, in particular for the head-shaft and head-neck angles. If the measurements are to be used in clinical practice, then we would advise that individuals using the measurements would need thorough training on how to measure, or alternatively the measurements to be done by a single, experienced observer.

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Fig 1a. Frog leg view in an 18 year old male. Southwick's head-shaft angle, measured to be 17° in left hip. The angle is measured between a line perpendicular to the line through the physis and a line parallel to the femoral shaft.

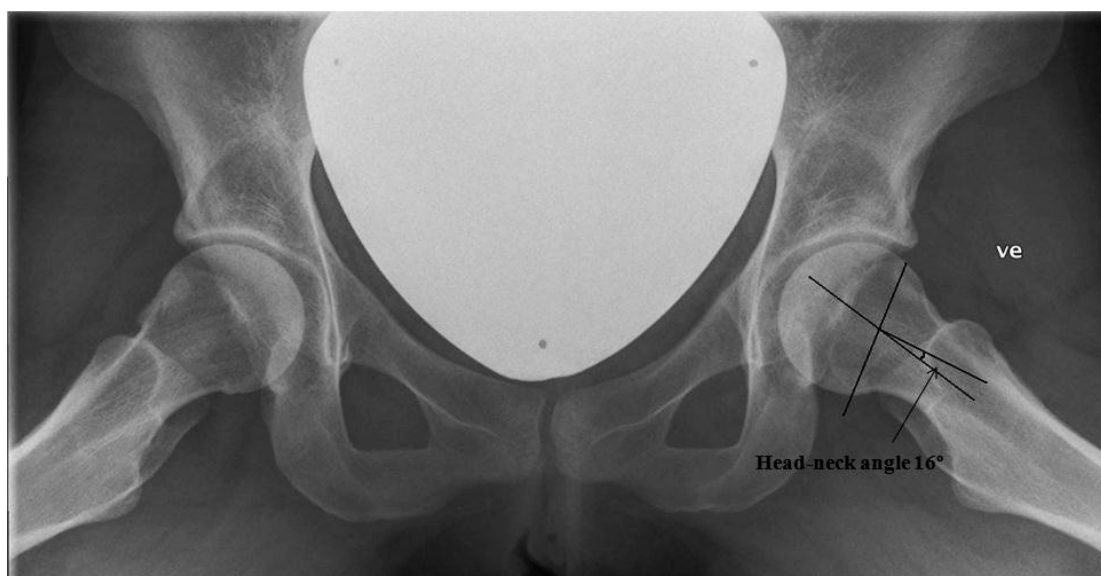


Fig 1b. Frog leg view in an 18 year old female. The angle between the femoral head and femoral neck, head-neck angle, measured to be 16° in left hip. The angle is measured between a line perpendicular to the line through the physis and a line parallel to the femoral neck.

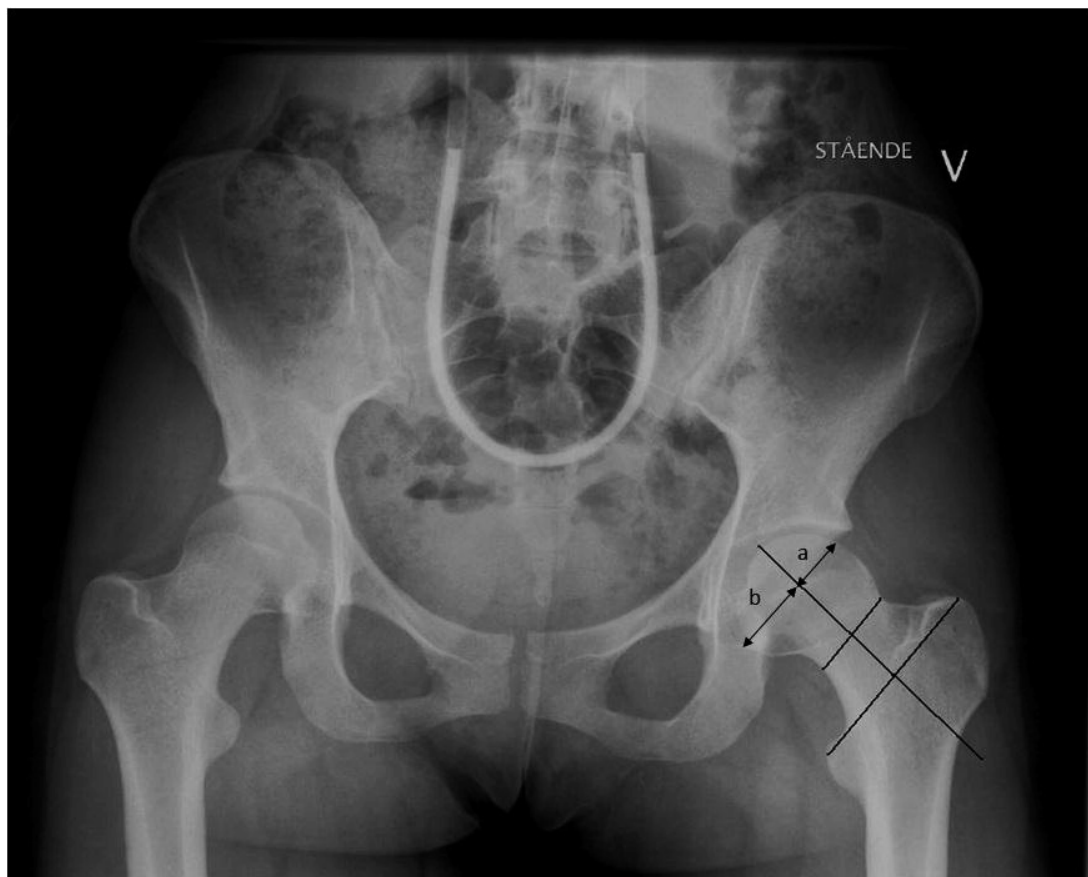


Fig 1c. Anteroposterior view of the pelvis in an 18 year old female. The Murray's tilt-index is defined as the ratio b/a , where a ratio higher than 1.35 is believed to be pathological. Tilt-index is 1.28 in this radiograph, $a=19.5$ mm, $b=25$ mm. A line is drawn through the mid-point between the superior-lateral margin of the greater trochanter and the most prominent edge of the lesser trochanter and the mid-point in the narrowest portion of the femoral neck and extended to divide the femoral head. In the femoral head the vertical distance to the line was measured both medially (b) and laterally (a) and the ratio calculated (Murray 1965)

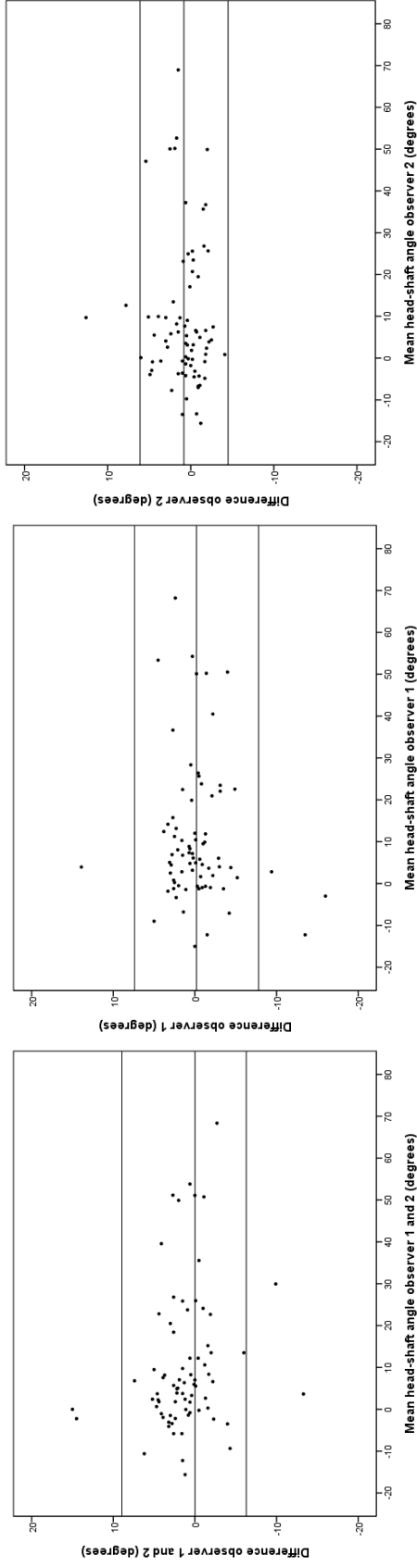


Fig 2. Differences in measurements with ± 1.96 SD (95% limits of agreement), plotted against the mean measurements between observer 1 and 2, observer 1 and observer 2 for Southwick's head-shaft angle.

Table 1. Intra and inter-observer variation for measurements used in the assessment of SCFE, with mean differences (SD) and 95% limits of agreement.

Measurement	Subjects	Observer 1		Observer 2		Observer 1 and 2	
		Mean difference (SD)	95% limits of agreement	Mean difference (SD)	95% limits of agreement	Mean difference (SD)	95% limits of agreement
Head-shaft angle, degrees	75	-0.2 (3.9)	-7.8 to 7.4	0.8 (2.7)	-4.5 to 6.1	1.3 (3.9)	-6.3 to 8.9
Murrays tilt-index	119	0.03 (0.16)	-0.28 to 0.34	-0.02 (0.08)	-0.18 to 0.14	-0.02 (0.15)	-0.31 to 0.27
Head-neck angle, degrees	109	0.2 (5.4)	-10.4 to 10.7	0.9 (4.0)	-6.9 to 8.7	-0.7 (6.5)	-13.4 to 12.0