SLIPPED CAPITAL FEMORAL EPIPHYSIS: DEMOGRAPHIC CORRELATES OF A CONTRALATERAL SLIP

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Slipped Capital Femoral Epiphysis: Demographic Correlates of a Contralateral Slip

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Background: Slipped Capital Femoral Epiphysis (SCFE) is the most common hip disorder among adolescents. A controversial subset of SCFE patients are those who experience a unilateral slip, followed by a slip on the opposite hip, known as a ‘contralateral’ slip. To prevent the development of a contralateral slip, some physicians prophylactically pin the unaffected hip of patients they suspect may eventually develop a contralateral SCFE. However, there is no definitive protocol with which to predict if a child will develop a contralateral slip. The goal of this retrospective study was to develop a clinical tool to assist physicians and patients in deciding whether or not to perform prophylactic contralateral hip pinning after first diagnosis of SCFE.

Methods: A retrospective medical record review was conducted to gather information about patients who were treated for SCFE at the Rady Children’s Hospital, San Diego, between 1997 and 2009. Demographic information was collected from all participants who were treated for SCFE and only patients with two or more years of post-operative care were included in the study.

Results: A total of 299 participants were included in the study, of whom 162 (54%) had a unilateral SCFE, 39 (13%) presented with an initial unilateral slip and further developed a contralateral SCFE, 47 (16%) had a unilateral SCFE and underwent prophylactic pinning for the unaffected hip, and 51(17%) had simultaneous bilateral slips. A sub-analysis was performed with the 201 patients who had unilateral involvement. After simultaneous adjustment for age, endocrine condition, and slip type, the following associations were observed: increasing age was found to be protective of contralateral SCFE (OR=0.72, 95% CI 0.56-0.93), presence of underlying endocrine condition was associated with an increase in contralateral SCFE (OR=3.94, 95% CI 1.02-15.21) and acute on chronic slips had higher odds of contralateral SCFE development than acute or chronic slips (OR=2.98, 95% CI 1.14-7.77).

Conclusions: Results from this study can be incorporated into the clinical arena to use as a tool for assisting physicians in determining whether or not to prophylactically pin a patient with a unilateral SCFE. For clinical decision making, this model should not be used as an independent assessment tool; rather, it should be considered as a reference to consult in conjunction with the other published studies and decision models.
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CHAPTER 1

INTRODUCTION

Slipped Capital Femoral Epiphysis, abbreviated as SCFE, is the most common hip disorder among adolescents, affecting between 2.13 to 10.08 per 100,000 adolescents (Jerre, Karlsson, & Henrikson, 1996; Kelsey, Keggi, & Southwick, 1970; Lehmann, Arons, Loder, & Vitale, 2006). In a broad sense, SCFE is a disorder involving the proximal femoral growth plate (Jerre et al., 1996). To best understand the dynamics of the disorder, it is necessary to be familiar with the anatomy and physiology of the femur. Figure 1 displays the anatomy of a normal femoral head.

![Figure 1. Anatomical view of normal femoral head.](image)

The femoral head is a round, smooth, cartilage covered ‘ball’ that lies inside of the hip socket, or acetabulum. The femoral head is composed of the epiphysis and the growth plate (also called the physis). The epiphysis is the rounded cartilaginous tip of the bone where ossification occurs, whereas the physis is a cartilaginous layer between the epiphysis and the metaphysis where the growth of the femur is modulated. The combined region of the epiphysis and growth plate is termed the capital femoral epiphysis. From an anatomical perspective, the condition of slipped capital femoral epiphysis is a misnomer (Loder, Aronsson, Dobbs, & Weinstein, 2000). The term implies that the femoral epiphysis is displaced; but rather, when the slip occurs through the growth plate, the epiphysis remains in
the acetabulum, while the metaphysis is shifted anteriorly (Loder et al., 2000; Segal, Weitzel, & Davidson, 1996; Shapiro, 2002). Figure 2 is a radiographic representation of a child with SCFE. In the affected right hip, the femoral head is contained within the acetabulum while the metaphysis exhibits severe anterior displacement. In addition to radiographic indicators, diagnosis of SCFE is also based on corresponding clinical symptoms of hip or knee pain, the presence of a limp, or inability to bear weight (Loder et al., 2000; Loder et al., 2008; Shapiro, 2002).

![Figure 2. Pelvic radiograph of a 10 year old female with slipped capital femoral epiphysis (SCFE) on the right side.](image)

From a public health perspective, quick diagnosis and treatment of SCFE leads to a better prognosis for patients. Long term follow up for patients who received surgical intervention for SCFE has resulted in good clinical and radiographic outcomes in more than 80% of cases (Bellemans, Fabry, Molenaers, Lammens, & Moens, 1996). Potential complications that can result from an untreated SCFE include abnormal gait, degenerative hip disease, chondrolysis\(^1\), and avascular necrosis (AVN)\(^2\) (Loder et al., 2000; Loder, 2001; Shapiro, 2002).

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\(^1\) Chondrolysis is the erosion of femoral head cartilage.

\(^2\) Avascular Necrosis (AVN) is bone tissue death that results from temporary or permanent loss of the blood supply to the femoral head.
Loder et al., 2008; Manoff, Banffy, & Winell, 2005; Palocaren, Holmes, Rogers, & Kumar, 2010). Long term consequences of these secondary disorders often lead to the need for a total hip replacement. Therefore, identifying and treating SCFE at onset is essential in preventing additional hip pathologies.

**STATEMENT OF THE PROBLEM**

SCFE can occur unilaterally or bilaterally, and there are important differences in the treatment of SCFE for each condition. A controversial subset of SCFE patients are those who experience a unilateral slip, followed by a slip on the opposite hip, which is termed a ‘contralateral’ slip. Patients who experience a contralateral slip typically undergo two separate surgical procedures. Previous studies have reported that up to 40% of patients with unilateral slips develop a subsequent contralateral slip (Boyer, Mickelson, & Ponseti, 1981; Carney, Weinstein, & Noble, 1991; Klein, Joplin, Reidy, & Hanelin, 1953). Most contralateral slips (80-90%) usually occur within the first 18 months following the initial diagnosis of SCFE (Hägglund, Hansson, & Ordeberg, 1984; Loder, Aronson, & Greenfield, 1993; Loder, 1996). To prevent the development of a contralateral slip, some physicians prophylactically pin the unaffected hip of patients they suspect may eventually develop a contralateral SCFE. However, there is no definitive protocol with which to predict if a child will develop a contralateral slip.

**PURPOSE OF THE STUDY**

This study was designed to address the general ambiguity surrounding the treatment of contralateral slips. There is a wealth of information about potential risk factors leading to the development of SCFE. Age, gender, race, obesity, and endocrine abnormalities (hypothyroidism, hypogonadism, hypopituitarism, and growth hormone disorders) have all been linked to the occurrence of SCFE. However, these risk factors have not been collectively examined to successfully develop a model for predicting contralateral slips. By comparing the characteristics of SCFE patients with unilateral and contralateral slips, it may be possible to identify specific determinants that contribute to or predict the future occurrence of SCFE in a contralateral hip. Decisions regarding prophylactic pinning are currently made on a case-to-case basis. However, the development of a comprehensive
predictive tool might create a more informed decision-making process for physicians and patients when deciding whether or not to pin a normal hip.

primary purpose of this study was to estimate the prevalence of suicidal ideation in a representative HIV+ cohort in the post-HAART era. The secondary purpose of this study was to assess the extent of overlap between HIV infection, suicidal ideation, and neuropsychological impairment and to evaluate the correlates of neuropsychological impairment in the CHARTER cohort. The results obtained from this study will help to

**GOALS AND HYPOTHESES**

The overall goal of this project is to develop a possible protocol to assist physicians and patients in deciding on prophylactic contralateral hip pinning after first diagnosis of SCFE.

The objectives and hypothesis of this study were as follows:

1. Identify the demographic and clinical factors that differ between patients with a unilateral slip and patients who experienced a contralateral slip.
   - The null hypothesis is that there are no demographic or clinical differences between patients with a unilateral slip and patients who develop a subsequent contralateral slip.
   - The alternative hypothesis is that there are demographic or clinical differences between patients with a unilateral slip and patients who develop a subsequent contralateral slip.

2. Determine which demographic and clinical factors can be used to predict a contralateral slip among patients with an initial unilateral slip.
   - The null hypothesis is that there are no demographic or clinical differences that can predict a contralateral slip among patients with an initial unilateral slip.
   - The alternative hypothesis is that there are demographic or clinical differences that can predict a contralateral slip among patients with an initial unilateral slip.

**THEORETICAL BASIS**

Prophylactic pinning remains a controversial issue because there is no standard method to determine if a contralateral slip will occur after initial diagnosis of SCFE. Theoretically, if all patients with unilateral SCFE underwent prophylactic pinning of the unaffected hip, 65% to 85% of these surgeries would be unnecessary (Loder, 2006). However, in the subset of unilateral patients who eventually develop a contralateral slip,
treating the slip prophylactically yields a more favorable prognosis compared to treating the subsequent slip after it occurs (Loder, 2006; Schultz, Weinstein, Weinstein, & Smith, 2002). Determining which patients would benefit most from the procedure remains an enigma. A few studies have determined that younger patients are more likely to develop a contralateral slip (Bidwell & Stott, 2006; Castro, Bennett, & Doulens, 2000; Stasikelis, Sullivan, Phillips, & Polard, 1996), and decision trees concerning prophylactic pinning based on these probabilities have been created (Kocher et al., 2004; Schultz et al., 2002); however, a true multivariate predictive model has not been described. There remains a critical need for such a model to assist in decision making regarding which unilateral SCFE patients would benefit from prophylactic pinning of the contralateral hip.

**BASIC ASSUMPTIONS**

This analysis assumes that all retrospective data provided in this data set were accurately collected and recorded. Furthermore, the results reported from the sample population of SCFE patients treated at a local hospital are intended to be representative of SCFE patients throughout San Diego and can be generalized to all SCFE patients throughout the United States.

**DEFINITIONS**

**Slipped Capital Femoral Epiphysis (SCFE)** – A common adolescent disorder involving the femoral growth plate; a slippage of the growth plate causes the epiphysis to remain in the acetabulum while the metaphysis is shifted anteriorly.

- **Acetabulum** – Medical term for the ‘hip socket’ where the femoral head is contained.
- **Epiphysis** – The cartilaginous tip of a bone where growth and ossification occurs.
- **Physis (epiphyseal plate, or growth plate)** – a cartilaginous layer that is responsible for bone growth; the physis is the site of slippage in SCFE.
- **Metaphysis** – The site where bone growth is modulated.
- **Chondrolysis** – The erosion of articular cartilage from the femoral head
- **Avascular Necrosis (AVN)** – the loss of blood supply to the femoral head which leads to bone tissue death.
**Contralateral (or Staggered) slip** – A subsequent occurrence of SCFE in the opposite hip, occurring at a time point after an initial unilateral slip.

**Prophylactic Pinning** – The surgical treatment of an asymptomatic hip to prevent the development of SCFE

**In Situ Pinning** – A surgical treatment of SCFE that involves placing a screw through the femoral head to hold it in place to prevent further slipping.
CHAPTER 2

LITERATURE REVIEW

SCFE is a disorder that has been around for centuries. First described by Ambrose Paré in 1572, he noted that “the epiphysis of the head of the femur sometimes becomes disjointed and separates (Paré, 1572).” Petit further elucidated in 1709 that slips occurred only in young patients where the cartilage that joins the epiphysis has not yet ossified. During the 1800’s, it was discovered that trauma alone was an insufficient cause of the disorder. By 1888, Mueller had accurately characterized SCFE and recognized that it caused limb shortening as a result of physeal disruption (Howorth, 1966; Mueller, 1888). Coincidently, this is the same year that Keetley performed the first surgical treatment for SCFE (Howorth, 1966; Keetley, 1888). Since then, general knowledge about SCFE has increased tremendously, and there is well documented information about the classification, epidemiology, demographics, etiology, and subsequent treatment for the disorder.

CLASSIFICATION

Patient history, clinical exam results, and radiographic findings are used to categorize SCFE according to slip characteristics (Loder et al., 2000; Shapiro, 2002). Besides noting unilateral or bilateral hip involvement, there are additional categorization schemes that can provide relevant information about a SCFE and its prognosis with treatment. SCFE can be classified according to type, stability, and severity, with each of these characteristics providing important diagnostic and prognostic information.

The current classification system of slip type consists of four categories: pre-slip, acute, chronic, and acute-on-chronic. A pre-slip is suspected when a patient presents with lower extremity weakness, knee or groin pain, or limping that results from prolonged activity. Clinical tests often find decreased internal hip rotation and radiographic images may reveal physeal widening and irregularity. A diagnosis of pre-slip does not mean that the femoral head has slipped; rather, a pre-slip indicates that a slip may occur in the future.
An acute SCFE is characterized by the classic SCFE symptoms of hip or knee pain, or limping, for a period of less than three weeks. Diagnosis also includes clinical findings of decreased hip range-of-motion and confirmed radiographic indications of displacement through the physis (Loder et al., 2000). Acute slips account for approximately 10% to 15% of slips (Boyer et al., 1981; Loder, Aronson, & Greenfield, 1993).

In contrast to an acute SCFE, when the symptoms of thigh, groin, or knee pain, and accompanying limp, range from a month up to several years in duration, the diagnosis is a chronic SCFE. Often, patients experience an exacerbation and remission of symptoms. Abnormal gait and decreased hip range of motion are the clinical signs of chronic SCFE. In severe cases where patients have failed to seek treatment, individuals may have natural external rotation of the hip, or even a limb-length discrepancy. Chronic slips are by far the most common, and about 85% of SCFE cases are classified as chronic in nature (Loder, Aronson, & Greenfield, 1993). However, not every SCFE meets the clear definition of an acute or chronic slip. Patients with chronic symptoms, who experience an acute exacerbation of symptoms corresponding to a significant increase in the degree of slip, are diagnosed with an acute-on-chronic slip. Of these four classification categories, only three (acute, chronic, and acute-on-chronic) include true cases of physician diagnosed SCFE. Additionally, this categorical classification system is dependent on a patient or parental recall of symptoms, which may not always be accurate (Loder, Aronson, & Greenfield, 1993; Loder et al., 2000; Loder, 2006).

To address the problem of inconsistent patient recall, an additional classification system was developed based solely upon a clinical examination of a child’s gait. This classification system has only two categories: stable and unstable. A stable SCFE is diagnosed when a patient is able to bear weight on the affected side and walk with or without the assistance of crutches (Loder et al., 2000). An unstable SCFE, on the other hand, is defined by a child’s inability to bear weight or ambulate with or without assistance on the affected side. Often, unstable slips are most commonly found to be associated with acute slips, while stable slips generally coincide with chronic slips. Ultrasound procedures can also be used to provide additional information about the stability of the hip. Based on
ultrasonography, if there is no metaphyseal remodeling\textsuperscript{3} and if an effusion\textsuperscript{4} is present, the SCFE is deemed unstable, and an acute slip is likely to have occurred. On the contrary, if there is metaphyseal remodeling\textsuperscript{1} and no effusion\textsuperscript{2} is present, then an acute event has not occurred, and the SCFE is considered stable (Loder et al., 2000; Palocaren et al., 2010). Classifying the stability of the hip is important because it can help with prognosis (Yildirim, Bautista, & Davidson, 2007). An unstable SCFE is associated with an increased development of AVN; as many as 50\% of treated unstable slips develop AVN. This condition is due to vascular injury which occurs at the time of the slip. In contrast, very few stable slips result in AVN (Loder, Richards, Shapiro, Reznick, & Aronson, 1993; Yildirim, et al., 2007).

The severity of SCFE can be evaluated by two different radiographic methods. The first technique involves measuring the amount of displacement of the epiphysis on the metaphysis. Mild displacement is categorized as epiphyseal-metaphyseal displacement that is less than one-third the width of the femoral neck; moderate displacement is one-third to one-half the femoral neck width; and severe displacement exceeds one half the width of the femoral neck. The second method for assessing the severity of a slip is the measurement of the epiphyseal-shaft angle based on a frog-lateral radiograph, known as the Southwick angle (Southwick, 1967). An angle measuring less than 30 degrees is considered a mild slip; an angle between 30 to 50 degrees is a moderate slip; and an angle measuring more than 50 degrees is a severe slip (Boyer et al., 1981). The Southwick angle has also been demonstrated to have a high prognostic value (Loder et al., 2000). Mild and moderate slips have excellent long-term results after surgical treatment, whereas severe slips have been associated with increased complications (Carney, Weinstein, & J, 1991; Loder, Aronsson, Dobbs, & Weinstein, 2000).

In clinical practice, most physicians consistently document the type of SCFE (acute, chronic, or acute-on-chronic), stability (stable or unstable), and severity (mild, moderate, or severe) and use these tools to pattern surgical procedures.

\textsuperscript{3} Metaphyseal remodeling is the natural reshaping of the metaphysis in response to SCFE.
\textsuperscript{4} An effusion is the accumulation of excess synovial fluid in the hip joint.
The incidence of SCFE varies among different populations. In the United States, the collective incidence is relatively low, with only 10.8 cases occurring per 100,000 adolescents per year (Kelsey et al., 1970; Lehmann et al., 2006). However, incidence varies according to gender, age, race, body mass index (BMI), and geography.

**Gender**

Early Swedish data from 1910-1982 indicated that 90% of SCFE cases were among males (Hansson, Hägglund, & Ordeberg, 1987). However, additional studies within the past two decades have revealed that SCFE is approximately one and a half times more prevalent in males than females (Larson et al., 2010; Loder, 1996; Murray & Wilson, 2008). A comprehensive U.S. study utilized pediatric hospital discharge data from 1997 to 2000, and census data to estimate population-based estimates of SCFE incidence. It was found that there were significantly more boys (13.3 cases/100,000 per year) than girls (8.07 cases/100,000 per year, p < 0.001) who were affected by SCFE (Lehmann et al., 2006).

**Age**

SCFE primarily occurs during the pubertal growth spurt (Harris, 1955). During the 1990’s, the average age at diagnosis was 13.5 years for males and 12.0 for females, with a typical range for both genders from 9-16 years (Loder, 1996). In a later study, it was found that the average age at onset for boys was 12.7 years and 11.2 years for girls (Lehmann et al., 2006). These lower ages may be indicative of a downward trend in the age of onset (Hägglund et al., 1984; Loder, 1996), but also may result from earlier pubertal development of children in recent decades. (Lehmann et al., 2006; Loder et al., 2008).

Physiologically younger children at initial presentation of unilateral SCFE are at higher risk for development of a contralateral SCFE (Loder et al., 2008). In a study performed by Riad, Bajelidze & Gabos (2007), it was confirmed that chronological age is a significant predictor of subsequent contralateral slip. In their study, 100% of boys younger than 12 years and girls younger than 10 years developed a contralateral SCFE. As a result, Riad and his co-authors recommend that children in those age categories with unilateral SCFE should be strongly considered for prophylactic fixation of the contralateral hip (Riad et al., 2007). A similar study in New Zealand by Bidwell and Stott (2006) indicated that patients under 12 years of age.
age who presented with a unilateral SCFE were 3.8 (95% CI 1.631-8.891) times more likely to experience a contralateral slip compared to patients over the age of twelve. These authors also suggested prophylactic pinning of patients with a unilateral slip under the age of twelve (Bidwell & Stott, 2006).

**Race**

The incidence of SCFE among different racial groups varies significantly. The highest incidence of SCFE has been reported among Pacific Islanders. An international multicenter study by Loder (1996) discovered that compared to whites, the racial frequency of SCFE was 4.5 among Pacific Islanders, 2.2 among blacks, and 1.05 among Amerindians (Hispanics and Native Americans). Recent data indicate an increase in SCFE frequency in Polynesians, blacks and Hispanics between the 1990’s and the first decade of the 21st century (Loder et al., 2008). A recent U.S., population-based study conducted between 1997 and 2000 indicated that the incidence frequency of SCFE was 5.6 for Polynesians, 3.94 for black children, and 2.53 for Hispanic children compared to white children (1.0) (Lehmann et al., 2006). Conversely, the racial frequency of SCFE among Indonesian-Malay individuals (Chinese, Japanese, Thai, Vietnamese, etc.) is 0.5 and 0.1 for Indo-Mediterranean individuals (North African, Indian), compared to whites (Loder, 1996). The current hypotheses used to explain the differing incidence of SCFE among racial groups is that the incidence of SCFE is proportional to the average weight for each racial group. Since Pacific Islanders, Blacks, and Hispanic/Native Americans tend to have a higher BMI relative to other nationalities, this may account for the increased rates of SCFE among these racial groups (Loder, 1996; Stott & Bidwell, 2003). However, variations in incidence of SCFE among different racial groups requires further study to determine if there are genetic causes for the disorder (Lehmann et al., 2006).

**Geography**

Regional differences in the incidence of SCFE exist throughout the world (Andrén & Borgström, 1959; Ninomiya, Nagasaka, & Tagawa, 1976), as well as within the United States (Kelsey et al., 1970; Lehmann et al., 2006). Kelsey and others first reported geographical differences in the incidence of SCFE in 1970, noting that children in Connecticut experienced an incidence rate of 10.08 cases per 100,000 per year, while children in New
Mexico had an incidence rate of 2.13 cases per 100,000 per year (Kelsey et al., 1970). A more recent study by Lehmann et al. (2006) discovered significantly higher rates of SCFE in the Northeast and Western areas of the United States compared with the Midwestern and Southern regions (p<0.001). Average annual incidence of SCFE in the Northeast was 17.15 cases per 100,000 and 12.7 cases per 100,000 in the West, while annual incidence of SCFE in the Midwest was 7.60 cases per 100,000 and 8.12 cases per 100,000 in the South. These geographical differences remained, even with stratification by race and gender. The study further revealed that there were also seasonal variations in SCFE. In locations north of 40 degrees latitude, over half of the SCFE cases (57.4%) occurred during the summer months, while approximately the same amount of SCFE cases (57.3%) occurred during the winter months in areas that were south of 40 degrees latitude N (Lehmann et al., 2006). The combined effects of these regional and seasonal variations, in conjunction with racial differences in SCFE, suggest that both genetic and environmental factors may influence the onset of SCFE; however, further research is warranted to investigate how these factors contribute to the development of SCFE (Kelsey et al., 1970; Lehmann, et al., 2006).

**Body Mass Index (BMI)**

Most individuals who are diagnosed with SCFE are obese, with over 50% of affected children having a BMI above the 95th percentile based on their respective age (Kelsey, Acheson, & Keggi, 1972; Loder, 1996). In the pediatric population, BMI is calculated by dividing a child’s weight (in kilograms) by their height (in meters) squared and comparing the results to growth charts based on child’s age and gender. Current criteria for obesity specify that children and adolescents weighing above the 95th percentile are considered overweight/obese; children between the 85th and 95th percentile are ‘at risk’ for being overweight or obese; children ranging between the 5th and 85th percentile are classified as normal; and children below the 5th percentile are deemed underweight (Styne, 2001; Kuczmarski et al., 2000). In SCFE patients, the age of onset decreases with increasing obesity. The average age at onset for patients with a BMI above the 95th percentile is 12.4 years of age, compared to an average age at onset of 14.3 years for patients below the 10th percentile for weight based on age (Loder, 1996).
Manoff et al. attempted to retrospectively quantify the level of obesity in 106 SCFE patients compared to 46 normal controls without SCFE. Among the SCFE patients, they found that 86% of SCFE patients had a BMI above the 95th percentile and were classified as obese, and another 14.2% of patients had a BMI between the 85th and 95th percentile and categorized as at risk for obesity. Conversely, the control group had 41.3% of patients above the 95th BMI percentile, 8.7% of patients between the 85th and 95th percentile. Furthermore, there was no SCFE in children with BMI below the 5th percentile. Based on their results, children with BMI above the 95th percentile are at a higher risk for developing SCFE. They suggest that classification of obesity by BMI can assist in identifying individuals at risk for the development of SCFE (Manoff et al., 2005).

A study performed in Scotland by Murray and Wilson (2008) showed a correlation between increasing incidence of SCFE and greater numbers of obese children from 1981 to 2005. In 1981, the incidence of SCFE was 3.78 per 100,000 population, and in 2000, incidence of SCFE had increased to 9.66 per 100,000 (R=0.85). This translated to a two and half times increase in incidence over two decades. During this period, the authors indicated that the percentage of overweight and obese children doubled from 15% in 1981 to over 30% in 2005. Furthermore, the age of onset for SCFE decreased from 13.4 to 12.6 years in boys and 12.2 to 11.6 years in girls (Murray & Wilson, 2008). This decrease in age of onset further corroborates findings by Loder (1996). Given that the prevalence of obesity among children and adolescents doubled in the past two decades (Krebs & Jacobson, 2003; Murray & Wilson, 2008), and that obesity has been established as a risk factor for SCFE (Kelsey et al., 1972; Loder, 1996; Manoff et al., 2005), it is not surprising that the incidence of SCFE is increasing and occurring at a younger age (Murray & Wilson, 2008).

**ETIOLOGY**

SCFE is categorized as atypical or idiopathic (McAfee & Cady, 1983). Atypical slips are associated with endocrine disorders such as hypothyroidism, hypogonadism, hypopituitarism, and growth hormone deficiency (Burrow, Alman, & Wright, 1998; Loder, Wittenberg, & DeSilva, 1995). Metabolic disorders including renal osteodystrophy and osteomalacia (Loder & Hensinger, 1997), as well as radiation treatment, are also causes of SCFE (Loder et al., 1998). These conditions retard bone maturation and delay growth plate
closure, contributing to an increased incidence of SCFE among growth hormone-deficient patients (Loder et al., 1995). Although an undiagnosed endocrinopathy or genetic predisposition may be present, the majority of SCFEs have an idiopathic etiology (Loder et al., 2000) and are hypothesized to result from a combination of biomechanical and biochemical factors which weaken the physis and lead to a slip (Loder et al., 2008; Weiner, 1996). Obesity (Kelsey et al., 1972; Loder, 1996; Murray & Wilson, 2008), femoral retroversion (Galbraith et al., 1987; Gelberman et al., 1986), and increased physeal obliquity (Mirkopulos, Weiner, & Askew, 1988) are mechanical aspects that have been implicated as contributing factors in the development of the disorder. On average, an individual with a normal body mass index (BMI) will have at least 10.6° of anteversion; comparatively, average anteversion is 0.4° or less in obese patients (Galbraith et al., 1987). Figure 3 depicts normal anteversion of 20° compared to decreased anteversion of -1° as found in patient with obesity and SCFE.

![Figure 3. Comparison between normal anteversion and abnormal retroversion found in SCFE patients.](image)

Decreased anteversion, in conjunction with excess body weight, creates increased mechanical forces on the physis (Pritchett & Perdue, 1988). Furthermore, children with SCFE tend to have greater physeal obliquity in which their physis is more vertical by factor of 8° to 11°, relative to children without SCFE. Together, increased mechanical forces and increased physeal slope are likely to contribute to the development of SCFE.
TREATMENT

The goals of SCFE treatment are to prevent progression of the slip by stabilizing the epiphysis and to avoid complications such as osteonecrosis and chondrolysis. Internal fixation with a single screw in situ has been the most popular treatment method in North America for SCFE. Following surgery, the patient begins partial weight bearing with crutches and gradually advances to full weight bearing without crutches within 4 to 6 weeks. Advantages of this method include a high success rate, low incidence of further slippage, and a relatively low incidence of complications. (Loder et al., 2000).

Prophylactic Fixation

Prophylactic pinning remains a controversial issue. When a patient presents with a unilateral slip, a physician has two options: observe the normal contralateral hip or proceed with prophylactic pinning of the unaffected hip. The advantage of observation is the potential for good prognosis, while the advantage of prophylactic in situ pinning is the possibility of preventing a contralateral SCFE and the subsequent risk of osteoarthritis and other associated morbidities (Kocher et al., 2004). Previous studies have reported that up to 40% of patients with unilateral slips develop a subsequent contralateral slip (Boyer et al., 1981; Carney et al., 1991; Klein, Joplin, Reidy, & Hanelin, 1953). Most contralateral slips (80-90%) usually occur within the first 18 months following the diagnosis of the unilateral SCFE (Loder, 1996; Hägglund et al., 1984; Loder, Aronson, & Greenfield, 1993). Children under the age of 12 have also been determined to have a greater risk of contralateral slip development (Bidwell & Stott, 2006; Riad et al., 2007). Based on review of 325 studies performed between 1931 and 1998, Castro et al. concluded that children with a unilateral SCFE were 2,335 times more likely to develop a contralateral SCFE compared to a child of the same age and sex developing an initial SCFE (Castro et al., 2000). However, if all patients with unilateral slips underwent prophylactic pinning of their unaffected hip, then 65% to 85% of surgeries would be unnecessary (Loder, 2006). In a decision analysis developed by Kocher et al. (2004), the most effective SCFE management strategy was determined to be observation, if the probability of contralateral slip development was 19% or below. However, if the risk of contralateral slip exceeded 27%, then contralateral pinning would be the optimal decision strategy (Kocher et al., 2004). Given the wide variability of
contralateral slip occurrence of up to 40%, this model cannot be easily applied to the general population; furthermore, this model did not take into account risk factors such as gender, age, ethnicity, or obesity. Despite the studies that have been performed, physicians still face the enigma deciding whether or not to prophylactically pin a normal hip.

Complications

Long term follow up for patients who received surgical intervention for SCFE has resulted in good clinical and radiographic outcomes in more than 80% of cases (Bellemans et al., 1996). Research indicates that patients with mild SCFE appear to have a favorable prognosis; however, patients with moderate and severe SCFE have a high incidence of complications (Loder et al., 2008).

AVN of the femoral head is a complication that can result from SCFE. Partial or total collapse of the femoral head as seen on radiograph is evidence of AVN. Patients who have surgery for SCFE should be followed carefully postoperatively. If patients develop AVN, it usually occurs within the first year in 95% of patients. In a study by Yildirim et al. (2007), a correlation was found between unstable slip and the formation of AVN. Those patients receiving treatment for an unstable slip degree should be monitored more closely for AVN development (Yildirim et al., 2007). A further study by Palocaren et al. (2010) found that AVN following fixation to treat an unstable SCFE was more prevalent with the magnitude of the preoperative slip angle and female sex. There was a 4% increase of AVN for every 1 degree of increase in slip magnitude. As girls approach puberty, hormonal changes causing increased physeal width and shear forces could be the explanation for their increased risk. Additionally, among demographic factors, race was a significant risk factor for AVN, with blacks being 7 times more likely to develop AVN than whites (Palocaren et al., 2010).

Chondrolysis is another complication that may occur following SCFE. It involves narrowing of the joint space due to the breakdown of cartilage. It occurs in patients with SCFE at a rate of 1-7% (Aronson, Peterson, & Miller, 1992; Loder et al., 2008). The treatment for avascular necrosis and chondrolysis are similar with non-weight-bearing walking with crutches, range-of-motion exercises, and anti-inflammatory medications to help alleviate symptoms. In severe cases, hip arthrodesis may be needed. Hips with the complications of AVN or chondrolysis often develop rapid deterioration with degenerative
changes. If a slipped capital femoral epiphysis is left untreated, there is risk of additional slip progression. Long term, there is the likelihood of developing degenerative joint disease, especially in cases when the disorder is of a moderate or severe nature (Loder et al., 2000; Loder et al., 2008).
CHAPTER 3

METHODS

A retrospective medical record review was conducted to gather information about patients who were treated for SCFE at the Rady Children’s Hospital, San Diego between 1997 and 2009. The study was approved by the Institutional Review Boards at the Rady Children’s Hospital, San Diego (RCHSD), and at San Diego State University.

STUDY POPULATION

Study participants were identified by a computerized search of RCHSD billing records according to the ICD-9 code 732.2, corresponding to treatment for SCFE. All patients who received surgical treatment for SCFE at RCHSD were included in the study. Referral patients from local San Diego hospitals and international patients from Mexico, in addition to patients who were initially treated at an outside institution, were also included in the study. All patients must have undergone at least one surgical procedure for SCFE treatment and received a minimum of two years post-operative care at RCHSD. Individuals who presented to the hospital for medical treatment advice, but did not receive surgical treatment at RCHSD, were not included in the study. Additionally, patients who were surgically treated at RCHSD, but received follow-up care at another medical center, were also excluded from the study.

DATA COLLECTION

Data for this study were obtained from retrospective chart reviews of patients who met inclusion criteria. The following information was collected for each patient: age at first diagnosis, race, gender, BMI, family history of SCFE, presence of underlying endocrine disorder, type of slip (acute, acute on chronic, chronic), slip stability (stable, unstable), first involved side (left, right, bilateral), occurrence of contralateral slip, use of prophylactic pinning, and length of follow up. Upon completion of data entry, the data were checked for accuracy prior to analysis.
VARIABLES

This study assessed both categorical and continuous variables. Gender, race, family history of SCFE, endocrine abnormalities, slip type, slip stability, and first involved side were all classified as categorical variables. The following variables were classified into two categories: Gender (male/female), family history (yes/no), endocrine abnormalities (yes/no), slip stability (stable/unstable), and first involved side (right/left). Slip type consisted of three categories (acute, chronic, or acute on chronic), and race was divided into four distinct categories (White, Black, Hispanic, and other). Age and BMI were considered continuous variables. The dichotomous outcome variable for this study was the occurrence of a contralateral slip (classified as yes/no).

STATISTICAL ANALYSIS

Prior to data collection, a power calculation was performed, and results indicated that a sample size of 272 participants was required to obtain statistical significance with a power of 80% (alpha = 0.05, two-tail). Data were analyzed with using the statistical software SAS, Version 9.1 (SAS Institute Inc., Cary, NC). The data were checked for normality and equal variances. Descriptive statistics were calculated for all patients included in the study. However, further analysis was performed using data from only patients who presented with an initial unilateral slip; patients who underwent prophylactic pinning were excluded since they were prevented from developing a contralateral slip. A univariate analysis was performed, within the subset of unilateral SCFE patients, to assess associations between patient characteristics and the development of a contralateral slip. Variables from the univariate analysis that proved to be significant, at p ≤ 0.15 were included in the development of the multivariate logistic regression model. Variables in the full multivariate logistic regression model were assessed for confounding and interaction, and only variables that were determined to be significant at p < 0.05 were included in the final model.
CHAPTER 4

RESULTS

Hospital records indicated that between the years of 1997 and 2009, there were 299 patients (389 individual hips)\(^5\) treated for SCFE at RCHSD who met the inclusion criteria for this retrospective study. The eligible population was comprised of 219 (72.5\%) males and 82 (27.5\%) females. The average age of all patients was 12.4±1.9 years, and the average BMI of all participants was 29.4± 7.4 kg/m\(^2\). The overall racial distribution of patients was 13\% White, 15\% Black, 53\% Hispanic, and 19\% ‘other’. Within the study population, 6 (2\%) individuals had a documented positive family history for SCFE, whereas 17 (6\%) patients were identified as having an underlying endocrine disorder such as hyperthyroidism, hypothyroidism, or precocious puberty. The majority of patients (65\%) experienced chronic slips, 21\% of patients were diagnosed with an acute slip, and 13\% of patients had a slip that was classified as acute on chronic\(^6\). Slip stability\(^7\) was also assessed; 84\% of patients had stable slips, 14\% of patients presented with unstable slips, 2\% of bilateral cases had one stable slip and one unstable slip, and 1 patient’s stability was unknown. The average length of follow-up for patients after the date of diagnosis was 2 years.

In order to perform comparisons among SCFE patients, all subjects were classified according to hip involvement: 54\% had a unilateral SCFE, 13\% presented with an initial unilateral slip and further developed a contralateral SCFE, 16\% had a unilateral SCFE and underwent prophylactic pinning for the unaffected hip, and 17\% had simultaneous bilateral slips. Table 1 displays the demographic characteristics of each category of hip involvement.

\(^5\) For consistency, each individual patient was considered as one SCFE case, rather than examining each hip individually. Under these conditions, a patient with bilateral slips would be considered as one SCFE case.

\(^6\) Slip type was categorized according to the first affected hip in unilateral and contralateral slips. Bilateral slips were categorized as acute if at least one hip was acute, acute on chronic if at least one hip was acute on chronic, and chronic if both hips were chronic in nature.

\(^7\) Slip stability categorization for unilateral and contralateral slips was based on the first affected hip. Bilateral slips were categorized as stable if both hips were stable, unstable if both hips were unstable, and stable/unstable if one hip was stable and one hip was unstable.
Table 1. Demographic Characteristics of SCFE Patients according to Hip Involvement (n = 299)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hip Involvement Category [n(% or mean±SD)]</th>
<th>Unilateral (n=162)</th>
<th>Contralateral (n=39)</th>
<th>Unilateral w/ Prophylactic Pin (n=47)</th>
<th>Bilateral (n=51)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.048</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>125 (77)</td>
<td>31 (79)</td>
<td>29 (62)</td>
<td>32 (63)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>37 (23)</td>
<td>8 (21)</td>
<td>18 (38)</td>
<td>19 (37)</td>
<td></td>
</tr>
<tr>
<td>Age (years) at first slip</td>
<td></td>
<td>12.7±1.7</td>
<td>11.9±1.3</td>
<td>11.5±1.7</td>
<td>12.6±2.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.642</td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td>86 (53)</td>
<td>22 (56)</td>
<td>25 (53)</td>
<td>27 (53)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td></td>
<td>22 (13.5)</td>
<td>5 (13)</td>
<td>9 (19)</td>
<td>8 (16)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td>22 (13.5)</td>
<td>6 (15.5)</td>
<td>8 (17)</td>
<td>3 (6)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>32 (20)</td>
<td>6 (15.5)</td>
<td>5 (11)</td>
<td>13 (25)</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td>29.6±7.5</td>
<td>28.9±7.8</td>
<td>29.7±7.1</td>
<td>28.7±7.1</td>
<td>0.875</td>
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<tr>
<td>Family History of SCFE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.214</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td>1 (0)</td>
<td>2 (5)</td>
<td>1 (2)</td>
<td>2 (4)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>161 (100)</td>
<td>37 (95)</td>
<td>46 (98)</td>
<td>49 (96)</td>
<td></td>
</tr>
<tr>
<td>Endocrine Condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.055</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td>6 (4)</td>
<td>5 (13)</td>
<td>1 (2)</td>
<td>5 (10)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td>156 (96)</td>
<td>34 (87)</td>
<td>46 (98)</td>
<td>46 (90)</td>
<td></td>
</tr>
<tr>
<td>1st Involved Side</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.226</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td>64 (40)</td>
<td>21(54)</td>
<td>20 (43)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td></td>
<td>98 (60)</td>
<td>18 (46)</td>
<td>27 (57)</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Slip Stability*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.738</td>
</tr>
<tr>
<td>Stable</td>
<td></td>
<td>138 (85)</td>
<td>31(79.5)</td>
<td>38 (81)</td>
<td>45 (88)</td>
<td></td>
</tr>
<tr>
<td>Unstable</td>
<td></td>
<td>24 (15)</td>
<td>7 (18)</td>
<td>9 (19)</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Stable/Unstable</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>5 (10)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td>0</td>
<td>1 (2.5)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Slip Type++</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.073</td>
</tr>
<tr>
<td>Acute</td>
<td></td>
<td>38 (23.5)</td>
<td>6 (15.5)</td>
<td>13 (28)</td>
<td>6 (11)</td>
<td></td>
</tr>
<tr>
<td>Acute on Chronic</td>
<td></td>
<td>19 (11.5)</td>
<td>9 (23)</td>
<td>3 (2)</td>
<td>8 (16)</td>
<td></td>
</tr>
<tr>
<td>Chronic</td>
<td></td>
<td>105 (65)</td>
<td>22 (56.5)</td>
<td>31 (70)</td>
<td>37 (73)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td>0</td>
<td>2 (5)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*Slip stability applies to the first affected hip in unilateral and contralateral slips. Bilateral slips were categorized as stable if both hips were stable, unstable if both hips were unstable, and stable/unstable if one hip was stable and one hip was unstable.

**Slip type applies to the first affected hip in unilateral and contralateral slips. Bilateral slips were categorized as acute if at least one hip was acute, acute on chronic if at least one hip was acute on chronic, and chronic if both hips were chronic in nature.
There were significant differences noted between the hip involvement groups with respect to patient sex (p=0.048) and age (p<0.001), and marginal differences observed in regards to underlying endocrine problems (p=0.055) and slip type (p=0.073).

The goal of this study was to focus specifically on patients who presented with an initial unilateral slip to determine if any characteristics were associated with the development of a subsequent contralateral slip. The final unilateral study sample was derived by eliminating patients with initial bilateral involvement, as well as patients who underwent prophylactic pinning of the contralateral hip (Figure 4).

![Figure 4. Derivation of final unilateral study population for the assessment of risk factors associated with the development of a contralateral SCFE.](image)

Univariate analyses of associations between patient demographics and the development of a contralateral slip in unilateral SCFE patients was performed (Table 2). Of the 201 patients with unilateral involvement, 39 (19.4%) developed a contralateral slip. Age (p=0.007) and underlying endocrine disorders (p=0.035) were significantly associated with the development of a contralateral slip. Age was inversely related to contralateral slip involvement; the odds of developing a contralateral SCFE were 0.728 times less likely (95% CI 0.6-0.9) for every 1 year increase in age. Additionally, those with a contralateral slip were
Table 2. Univariate Analysis of Associations between Patient Demographics and the Development of a Contralateral Slip\(^a\) in SCFE Patients with an Initial Unilateral Slip (n = 201)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
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<td></td>
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<tr>
<td>Male</td>
<td>1.147</td>
<td>0.486-2.709</td>
<td>0.754</td>
</tr>
<tr>
<td>Female</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years) at first slip</strong></td>
<td>0.728</td>
<td>0.579-0.916</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>0.833</td>
<td>0.221-3.138</td>
<td>0.650</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.938</td>
<td>0.339-2.593</td>
<td>0.926</td>
</tr>
<tr>
<td>Other</td>
<td>0.688</td>
<td>0.196-2.12</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>0.987</td>
<td>0.935-1.043</td>
<td>0.926</td>
</tr>
<tr>
<td><strong>Family History of SCFE</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8.703</td>
<td>0.769-98.546</td>
<td>0.081</td>
</tr>
<tr>
<td>No</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
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<tr>
<td><strong>Endocrine Condition</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3.824</td>
<td>1.103-13.258</td>
<td>0.035</td>
</tr>
<tr>
<td>No</td>
<td>1.0(^b)</td>
<td>-</td>
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</tr>
<tr>
<td><strong>1st Involved Side</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1.786</td>
<td>0.884-3.612</td>
<td>0.106</td>
</tr>
<tr>
<td>Left</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Slip Stability</strong></td>
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<tr>
<td>Unstable</td>
<td>1.298</td>
<td>0.514-3.283</td>
<td>0.581</td>
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<tr>
<td>Stable</td>
<td>1.0(^b)</td>
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<td><strong>Slip Type</strong></td>
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<td></td>
</tr>
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<td>0.284-2.000</td>
<td>0.131</td>
</tr>
<tr>
<td>Acute on Chronic</td>
<td>2.261</td>
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<td>Chronic</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)The dependent variable is categorized according to occurrence of a contralateral slip. The reference category was classified as no occurrence of contralateral slip.

\(^b\)Indicates reference category

3.824 times more likely (95% CI 1.103-13.258) to have an underlying endocrine condition compared to patients who did not develop a contralateral slip.

A logistic regression was performed to create a predictive model for the development of contralateral slips. Variables from the univariate analysis that had a significance of \( p \leq 0.15 \) were included in the full model (Table 3). After testing for confounding and interaction, insignificant variables (\( p \geq 0.05 \)) were removed from the full model (Table 4).
Table 3. Full Logistic Regression Model Examining Age and Other Covariates Associated with the Development of a Contralateral Slip\(^a\) in SCFE Patients with an Initial Unilateral Slip (n=201)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) at first slip</td>
<td>0.713</td>
<td>0.551-0.921</td>
<td>0.010</td>
</tr>
<tr>
<td>Family History of SCFE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10.587</td>
<td>0.879-127.524</td>
<td>0.063</td>
</tr>
<tr>
<td>No</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Endocrine Condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4.713</td>
<td>1.223-18.161</td>
<td>0.024</td>
</tr>
<tr>
<td>No</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1st Involved Side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1.685</td>
<td>0.771-3.681</td>
<td>0.191</td>
</tr>
<tr>
<td>Left</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Slip Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>0.631</td>
<td>0.220-1.806</td>
<td></td>
</tr>
<tr>
<td>Acute on Chronic</td>
<td>3.091</td>
<td>1.154-8.277</td>
<td></td>
</tr>
<tr>
<td>Chronic</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)The dependent variable is categorized according to occurrence of a contralateral slip. The reference category was classified as no occurrence of contralateral slip.

\(^b\)Indicates reference category.

Table 4. Final Logistic Regression Model Examining Age and Other Covariates Associated with the Development of a Contralateral Slip\(^a\) in SCFE Patients with an Initial Unilateral Slip (n=201)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) at first slip</td>
<td>0.723</td>
<td>0.562-0.930</td>
<td>0.012</td>
</tr>
<tr>
<td>Endocrine Condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3.936</td>
<td>1.019-15.205</td>
<td>0.047</td>
</tr>
<tr>
<td>No</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Slip Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>0.576</td>
<td>0.205-1.162</td>
<td></td>
</tr>
<tr>
<td>Acute on Chronic</td>
<td>2.977</td>
<td>1.141-7.768</td>
<td></td>
</tr>
<tr>
<td>Chronic</td>
<td>1.0(^b)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)The dependent variable is categorized according to occurrence of a contralateral slip. The reference category was classified as no occurrence of contralateral slip.

\(^b\)Indicated reference category.
After simultaneous adjustment for age, endocrine condition, and slip type, the following associations were observed: increasing age was found to be protective of contralateral SCFE, presence of underlying endocrine condition was associated with an increase in SCFE, and acute on chronic slips had higher odds of contralateral SCFE development than acute or chronic slips (Table 4).

An additional univariate analysis was performed to examine if there were any differences between patients who experienced a contralateral slip and patients who experienced bilateral slips. Results in Table 5 indicate that no significant associations were found; therefore, a logistic regression was not performed.

Table 5. Univariate Analysis of Associations between Patient Demographics and the Development of a Contralateral Slip\(^a\) in SCFE Patients with Contralateral or Bilateral Slips (n=90)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2.3</td>
<td>0.079-6.022</td>
<td>0.090</td>
</tr>
<tr>
<td>Female</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years) at first slip</strong></td>
<td>0.820</td>
<td>0.651-1.034</td>
<td>0.094</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td>0.381</td>
</tr>
<tr>
<td>Black</td>
<td>0.313</td>
<td>0.053-1.854</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.407</td>
<td>0.091-1.818</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.231</td>
<td>0.043-1.251</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>1.004</td>
<td>0.944-1.069</td>
<td>0.888</td>
</tr>
<tr>
<td><strong>Family History of SCFE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.324</td>
<td>0.178-9.844</td>
<td>0.784</td>
</tr>
<tr>
<td>No</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Endocrine Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.353</td>
<td>0.363-5.047</td>
<td>0.653</td>
</tr>
<tr>
<td>No</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Slip Stability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unstable</td>
<td>1.641</td>
<td>0.504-5.344</td>
<td>0.411</td>
</tr>
<tr>
<td>Stable</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Slip Type</strong></td>
<td></td>
<td></td>
<td>0.427</td>
</tr>
<tr>
<td>Acute</td>
<td>2.018</td>
<td>0.551-7.397</td>
<td></td>
</tr>
<tr>
<td>Acute on Chronic</td>
<td>1.682</td>
<td>0.580-4.874</td>
<td></td>
</tr>
<tr>
<td>Chronic</td>
<td>1.0 (^b)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)The dependent variable is categorized according to occurrence of a contralateral slip. The reference category was classified as no occurrence of contralateral slip.

\(^b\) Indicates reference category.
CHAPTER 5

DISCUSSION

This study was conducted to compare the characteristics of SCFE patients to identify specific variables that may be associated with the future occurrence of SCFE in a contralateral hip. The ultimate goal of this study was to develop a predictive model to assist in the decision of whether or not to prophylactically pin the unaffected hip of a patient with an initial unilateral SCFE. This goal was accomplished by conducting a retrospective medical chart review of patients treated for SCFE at RCHSD between the years of 1997 and 2009. Data from all patients who presented with an initial unilateral slip were analyzed to identify variables that were associated with a subsequent contralateral slip. Results indicated that in patient who presented with an initial unilateral slip, lower age of onset, underlying endocrine disorders, and acute on chronic slip type were significantly associated with the development of a contralateral slip.

SUMMARY OF FINDINGS

Age was inversely related to slip development; decreased age was associated with an increased likelihood of developing a contralateral slip. This finding was consistent with previous literature suggesting that younger children, especially those below age 12 who presented with a unilateral SCFE were more likely to develop a contralateral slip compared to older adolescents (Bidwell & Stott, 2006; Riad et al., 2007). Underlying endocrine conditions have also been implicated as a causal risk factor in the development of SCFE (Burrow et al., 1998; Loder et al., 1995); therefore, it is not surprising that after adjusting for age and slip type, patients who experienced a contralateral slip were almost 4 times more likely to have an underlying endocrine disorder compared to patients who did not develop a contralateral slip. Additionally, patients who developed a contralateral slip were also more likely to have had an initial acute on chronic slip (rather than an acute or chronic slip), when compared to those who did not develop a contralateral SCFE. Slip type has never before been implicated in the development of contralateral slips.
Since there were significant differences between patients with unilateral and contralateral slips, a second univariate analysis was performed to determine if any differences existed between contralateral and bilateral SCFE patients. No significant associations were discovered; hence, it is reasonable to consider patients with contralateral hip involvement as possessing similar characteristics to those patients who present with initial bilateral involvement.

**STRENGTHS**

There were several aspects of this study that made it both unique and applicable to other SCFE populations. First, since RCHSD is the primary children’s specialty hospital in San Diego County, most SCFE cases in the region were treated at this institution during the time frame of this study. Consequently, this study involved a relatively large sample size (n=299) in comparison to previously published single-center SCFE studies (Bidwell & Stott, 2006; Riad et al., 2007). Additionally, the RCHSD study population shared many similar characteristics to the SCFE cohorts described in published literature. For instance, the average age of patients in this study was 12.4±1.9, consistent with other studies that reported an average age of onset of 12.7 years for males and 11.2 years for females (Lehmann et al., 2006). BMI for RCHSD patients was an average of 29.4±7.4 kg/m², which corresponded to values that were typically above the 95th percentile for a patient’s respective age and sex. These findings were similar to those in the Manoff et al. study where 86% of SCFE patients had a BMI above the 95th percentile (Manoff et al., 2005). Furthermore, of the 201 patient with unilateral involvement that were examined in the RCHSD study, 39 (19.4%) developed a contralateral slip, which was similar to findings from other studies that reported the occurrence of a contralateral slip ranged from 19% to nearly 40% in patients with an initial unilateral slip (Boyer et al., 1981; Carney et al., 1991; Loder, 1996; Stasikelis et al., 1996). Lastly, the study population from RCHSD was comprised of 2.5 times more males than females. This was a slightly higher proportion of males relative to other published studies that reported a 1.5 to 2 times increased prevalence of SCFE among males (Larson, et al., 2010; Lehmann et al., 2006; Loder, 1996; Murray & Wilson, 2008); but nevertheless, there was a similar trend. Demographic consistency between data gathered from the RCHSD
study and other published literature provides a reasonable basis for applying findings from this study to other SCFE populations, with the possibility of obtaining similar results.

LIMITATIONS

There were potential methodological and classification biases that could not be overcome in this study. The first shortcoming was the retrospective nature of this study. Since information collected for this study was obtained from reviewing medical charts, there may have been undocumented information such as family history of SCFE that was not recorded by hospital personnel. Although, for the purpose of this study, it was assumed that information contained in each medical records was accurately classified and recorded. The only evident problem with the hospital record-keeping system was the documentation of a patient’s race. During the time period of this study, the hospital record keeping system classified patients according to four categories: white, black, Hispanic, and other. Consequently, it was impossible to perform a thorough analysis of racial categories, as presented in other studies. Lastly, within the RCHSD study population, there were 47 patients with unilateral slips who underwent prophylactic pinning; these patients were not included in the predictive analysis since it was impossible to determine how many of these patients would have experienced a subsequent contralateral slip if prophylactic pinning has not been performed. Hypothetically, if all 47 of these additional patients would have developed a subsequent slip, then the incidence of contralateral slips within the RCHSD population could have been as high as 86 of 248 (34.7%) or as low as 39 of 248 (15.7%) if none of the 47 prophylactically pinned patients would have developed a subsequent slip. Consequently, this study could not measure the true incidence of contralateral hip involvement among patients who presented with an initial unilateral slip due to the selective utilization of prophylactic pinning. Also, it was not a longitudinal study, which is what is needed to determine incidence in the population.

IMPLICATIONS

This study was successful in identifying three variables (age, endocrine disorder, and slip type) that were significantly associated with the development of a contralateral slip in patients who presented with an initial unilateral slip. Each of these characteristics has important clinical implications. With regard to age, a lower age of presentation has been
shown to be associated with the development of a subsequent slip; therefore, it may be
justifiable to prophylactically pin the hips of patients who present with SCFE and are below
the average age of onset which is 12.7 years for males and 11.2 years for females (Lehmann
et al., 2006). Additionally, prophylactic pinning may also be warranted for patients with an
underlying endocrine disorder such as hypothyroidism, hypogonadism, hypopituitarism, or
growth hormone deficiency. Findings from this study also indicated that patients with an
acute on chronic slip were more likely to develop a contralateral slip; however, the premise
for this finding is ambiguous. It is plausible that in this study, patients with moderate chronic
hip pain failed to seek the counsel of a physician, possibly as a result of financial constraints
or lack of healthcare availability; consequently, the child was not brought to the hospital until
they experienced an acute episode accompanied by debilitating pain. In the event that a child
meeting this criterion is treated for a unilateral SCFE, it may be worthwhile to consider
prophylactic pinning in order to prevent another acute on chronic SCFE, especially if the
child is below the average age of onset. Furthermore, if a child presented with more than one
of the identified predictors of SCFE as identified by this study, prophylactic pinning of the
opposite hip would be a recommended procedure.

From a public health perspective, there are both medical and financial benefits that
may result from prophylactic pinning for patients at risk for developing a contralateral slip.
Patients who undergo prophylactic pinning are subject to one only one major surgical
procedure, whereas patients who go on to have a contralateral slip require two such
procedures. Eliminating the need for a second surgery decreases the potential for post-
surgical complications, decreases anesthesia exposure for patients, and reduces the risk of
developing avascular necrosis or chondrolysis that may occur with a severe contralateral slip.
Furthermore, prophylactic pinning may then reduce the costs associated with a second,
separate surgical intervention and follow up. These costs include physician fees and hospital
expenses, as well as time spent by parents in support of the child’s recovery. However,
additional cost-benefit analyses are needed to fully assess the financial advantages of the
prophylactic surgical option.
RECOMMENDATIONS FOR FUTURE STUDY

This study provided a solid framework that could be important in the development of future studies. Results from this study identified three demographic characteristics that were associated with development of contralateral SCFE. However, demographic characteristics of patients are not the only variables that can be assessed among SCFE patients. Radiographic measurements or three-dimensional analytical hip software could be utilized to assess radiographs to provide more insight into the physical features that are involved in contralateral hip involvement. These radiographic assessments would strengthen the study and may lead to the discovery of additional predictive factors. Another aspect of SCFE that could be studied in the future is patient social economic status (SES). Examining patient SES would be a worthwhile procedure to determine if acute on chronic slips (which were found to be associated with contralateral slip development) are associated with a lower SES. This measurement that could be obtained by documenting a patient’s address or zip code. Lastly, another possibility for future studies would be the implementation of a prospective study. While SCFE is a relatively rare disease, it has been strongly associated with obesity. Therefore, a prospective study among obese patients might also yield additional information about additional risk factors for the disorder, in addition to providing information about predictors associated with contralateral slip development.

CONCLUSIONS

Results from this study can be incorporated into the clinical arena to use as a tool for assisting physicians in determining whether or not to prophylactically pin a patient with a unilateral SCFE. For clinical decision making, this model should not be used as an independent assessment tool; rather, it should be considered as a reference to consult in conjunction with the other published studies and decision models. While the findings of this study are important and do have clinical significance, the examination of additional radiographic parameters would strengthen and build upon the findings in this study and potentially contribute to the development of an independent SCFE assessment tool.
REFERENCES


