Review Article

The Epidemiology and Demographics of Slipped Capital Femoral Epiphysis

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The etiology of slipped capital femoral epiphysis (SCFE) is unknown with many insights coming from epidemiologic/demographic information. A systematic medical literature review regarding SCFE was performed. The incidence is 0.33/100,000 to 24.58/100,000 children 8 to 15 years of age. The relative racial frequency, relative to Caucasians at 1.0, is 5.6 for Polynesians, 3.9 for Blacks, and 2.5 for Hispanics. The average age is 12.0 years for boys and 11.2 years for girls. The physiologic age when SCFE occurs is less variable than the chronologic age. The average symptom duration is 4 to 5 months. Most children are obese: >50% are >95th percentile weight for age with average BMI is 25–30 kg/m². The onset of SCFE is in the summer when north of 40°N. Bilaterality ranges from 18 to 50%. In children with bilateral involvement, 50–60% present with simultaneous SCFEs and those who present with a unilateral SCFE and subsequently develop a contralateral SCFE do so within 18 months. The age at presentation is younger for those who present with a unilateral SCFE and later develop a contralateral SCFE. The age-weight, age-height, and height test are useful to differentiate between an idiopathic and atypical SCFE.

1. Introduction

Slipped capital femoral epiphysis (SCFE) is an adolescent hip disorder with displacement of the capital femoral epiphysis from the metaphysis through the physis. Most SCFEs are varus (medial and posterior epiphyseal displacement relative to the metaphysis) but can occasionally be valgus (lateral and superior epiphyseal displacement) [1–4]. The vast majority are “idiopathic”; atypical SCFEs are those that occur due to an endocrine disorder [5–7], renal failure osteodystrophy [8], or radiation therapy [7, 9, 10]. The literature regarding the epidemiology and demographics of SCFE first requires a general knowledge of the disorder.

SCFE is classified both clinically and by severity. The traditional clinical classification was acute, chronic, and acute on chronic [12–16], based on the patient’s history, physical examination, and roentgenograms. An acute SCFE is defined as those with symptoms for <3 weeks with an abrupt displacement through the proximal physis [12]. Chronic SCFEs present ≥3 weeks of symptoms and account for 85% of all SCFEs [17]. Acute-on-chronic SCFEs are those with chronic symptoms initially and the subsequent development of acute symptoms. Newer classifications are more clinically useful, depend upon physeal stability, and predict the prognosis regarding subsequent avascular necrosis. There are two such classifications: one clinical and one radiographic. The clinical classification depends upon the ability of the child to ambulate [18]. A stable SCFE is defined as one where the child is able to ambulate, with or without crutches. An unstable SCFE is defined as one where the child cannot ambulate, with or without crutches. The radiographic classification depends upon the presence or absence of a hip effusion on ultrasonography [19, 20]. The absence of physeal remodeling and the presence of an effusion define an unstable SCFE; physeal remodeling and the absence of an effusion define a stable SCFE. Unstable SCFEs have a much higher incidence of avascular necrosis (up to 50% in some series) compared to stable SCFEs (nearly 0%) [18].
Radiographs demonstrate an inferior and posterior slip of the proximal femoral epiphysis relative to the metaphysis. The gradual slip demonstrates radiographic signs of remodeling on the superior and anterior femoral metaphysis, and periosteal new-bone formation at the epiphyseal-metaphyseal junction posteriorly and inferiorly. In the early slip, the changes can be subtle with only posterior displacement [21]. As such it is usually seen early only on the lateral view, and both anteroposterior and lateral radiographs must be obtained. Other radiographic signs of an early SCFE are the metaphyseal blanch sign of Steel [22] and Klein’s line [11]. The metaphyseal blanch sign of Steel is a radiographic double density seen on the anteroposterior view at the level of the metaphysis; this double density reflects the posterior cortical lip of the epiphysis as it is beginning to slip posteriorly and is radiographically superimposed upon the metaphyseal density. Klein’s line is drawn along the anterior or superior aspect of the femoral neck; the epiphysis should normally intersect this line. In an early SCFE the epiphysis will be flush with or even below this line (Figure 1).

SCFE severity is described by two different methods. The first is the amount of displacement of the epiphysis on the metaphysis (Figure 2). A mild SCFE is defined as epiphyseal-metaphyseal displacement <1/3 the width of the metaphysis; a moderate SCFE 1/3–1/2; a severe SCFE >1/2 (Figure 2(a)) [23]. This method is less accurate than angular measurement since distinct landmarks are difficult to determine due to metaphyseal remodeling in the gradual stable SCFE [24]. Angular measurement uses the epiphyseal-shaft angle on the frog-lateral radiograph [25] (Figure 2(b)) and is categorized into 3 groups: mild <30°, moderate 30–50°, and severe >50° [16]. This classification is important for long-term prognosis as mild and moderate slips have a much better long-term prognosis than severe slips which demonstrate a more rapid development of degenerative hip disease [26, 27]. CT scan measurements are no more accurate than those using conventional radiographs [28].

2. Materials and Methods

A systematic review of SCFE was performed. SCFE has been known by many different names since its first description in the late 19th and early 20th centuries. Prior to the last 40 years or so, the accepted name for this condition had been very inconsistent. Even now there is no actual MESH (Medical Subject Headings) term for slipped capital femoral epiphysis (SCFE). Users must combine “epiphyses, slipped” and “femur head”. The modern, most used, frequently used term “slipped capital femoral epiphysis” or SCFE, must be searched as a keyword phrase. To ensure capture of all the published literature, older terms were also searched as keywords or keyword phrases. Therefore the terms used to search for SCFE were slipped capital femoral epiphysis, slipped epiphysis, epiphysiolysis, and epiphysiolyses. The last strategy was to combine these two sets of terms: (slipped OR slipping OR sliding OR displaced OR displacement OR detached OR detachment OR separated OR separation) combined with (femur OR head OR capitis OR epiphysis OR epiphyseal OR epiphysiolysis OR epiphysiolyses).

The databases searched were PubMed (1947–2010) (http://www.ncbi.nlm.nih.gov/pubmed/), Ovid Medline (1947–2010), EMBASE (1947–2010), WorldCat (1880–2010) (books and theses) (http://firstsearch.oclc.org/), Google Scholar (1880–2010) (http://scholar.google.com/), Web of Knowledge (1987–2010), and IndexCat (1880–1961) (Index Catalogue of the Library of the Surgeon-General’s Office) (http://www.indexcat.nlm.nih.gov/). Exclusion criteria were those manuscripts discussing surgery, therapy, rehabilitation, and any foreign language articles without an English abstract. Individual orthopaedic journals were also searched for articles published prior to 1966 that predate electronic Medline indexing, including Journal of Bone and Joint Surgery (American and British), Clinical Orthopaedics and Related Research, and Acta Orthopaedica Scandinavica. Age groups were limited to those <18 years old; duplicate citations were removed.

This search resulted in 1407 unique citations. These 1407 manuscripts were reviewed to find those that discussed any of the topics regarding SCFE and epidemiology, demographics, incidence, prevalence, race, gender, family history, inheritance, genetics, age, bone age, weight (either birth weight or normal weight), height, growth, maturation, any other anthropometric characteristics, seasonal variation, hormone, endocrine, congenital anomalies, collagen, immunoglobulin, and opposite hip. Of these 1407 manuscripts, 114 provided ample information and are the contents of this paper.

3. Results

3.1. Incidence. Conventional quotation for SCFE incidence in the literature is the number of cases per 100,000 (usually for the age range 8 to 15 years old, although some use <25 years of age) and is used throughout this paper. The incidence (Table 1) ranges from 0.2 per 100,000 in eastern Japan [36] to 17.15 in the Northeastern United States [31]. Recent studies indicate that the overall incidence in the
A mild SCFE is defined as epiphyseal-metaphyseal displacement $<1/3$ the width of the metaphysis, a moderate SCFE $1/3$–$1/2$; a severe SCFE as $>1/2$ [23]. In this case the SCFE is mild. The position of the epiphysis in a moderate SCFE is represented by the solid semicircle and in a severe SCFE by the hatched semicircle. (b) The lateral epiphyseal shaft angle measurement as described by Southwick [25] on the frog lateral radiograph. The frog lateral radiograph of the case in Figure 1 is shown. Both the normal hip (nl) and SCFE hip (SC) are measured. Line 1 is the line between the anterior and posterior physeis, line 2 is a perpendicular to line 1, and the intersection of line 2 with an axial line along the shaft of the femur (line 3) is the epiphyseal shaft angle. The slip angle is calculated by subtracting the epiphyseal shaft angle of the normal hip from the slip side. Those less than 30 degrees are considered mild, between 30 and 50 degrees moderate, and greater than 50 degrees severe. The severity of the SCFE is the lateral epiphyseal shaft angle of the normal hip subtracted from the SCFE hip. In this example the slip angle is $25^\circ$–$10^\circ$ or $15^\circ$.

In the USA there are differences by geographic region. In a recent study [31] the highest incidence was in the Northeast at 17.15 and the lowest in the Midwest at 7.69. This is similar to an earlier study [37] where the incidence in the Northeast was 10.08 and 2.13 in New Mexico.

3.2. Race/Ethnicity. There is significant racial variability with SCFE (Table 2). Race is classified using the definitions of Eveleth and Tanner: Caucasians, Africans in Africa and of African Ancestry, Asiaties (Amerindians, Hispanics, Indonesian-Malays), Indo-Mediterraneans (inhabitants of the Near East, North Africa, and Indian subcontinent), and Australian Aborigines and Pacific Island peoples [53]. The relative racial frequency (RRF) of SCFE, with Whites at 1.0, is 4.5 for Pacific Islanders, 2.2 for Africans, 1.05 for Amerindian (Native Americans and Hispanics), 0.5 for Indonesian-Malay (Chinese, Japanese, Thai, Vietnamese, etc.), and 0.1 for Indo-Mediterranean peoples (Near East, North African, or Indian subcontinent ancestry) [30]. More recent data indicates that these numbers, relative to Caucasians, is 5.6 for Polynesians, 3.9 for Blacks, and 2.5 for Hispanics (Figure 3(a)) [29, 31]. In New Zealand the RRF was 5.6 for the Maori peoples and 4.2 for other Pacific Islanders [29]. In Singapore the RRFs, relative to Chinese, are 9.6 for Indo-Mediterraneans (Indian), 2.8 for Malay, and 3.0 for mixed (Eurasians) (Figure 3(b)) [33]. Thus Indo-Mediterraneans
| Study                  | Year | City, Country   | Region            | Ethnicity        | Incidence |
|-----------------------|------|-----------------|-------------------|------------------|-----------|
| Kelsey et al. [37]^A  | 1970 | Connecticut and New Mexico | All: <25 years old | Connecticut 3.41 |           |
|                       |      |                  |                   | New Mexico 0.71  |           |
|                       |      |                  |                   | Connectic: 10.08 |           |
|                       |      |                  |                   | New Mexico 2.13  |           |
|                       |      |                  |                   | White            |           |
|                       |      |                  |                   | Male 4.74        |           |
|                       |      |                  |                   | Female 1.64      |           |
|                       |      |                  |                   | African          |           |
|                       |      |                  |                   | Male 7.79        |           |
|                       |      |                  |                   | Female 6.68      |           |
|                       |      |                  |                   | White            |           |
|                       |      |                  |                   | Urban 3.19       |           |
|                       |      |                  |                   | Other 3.19       |           |
|                       |      |                  |                   | African          |           |
|                       |      |                  |                   | Urban 7.95       |           |
|                       |      |                  |                   | Other 1.35       |           |
| Bosch et al. [32]     | 2008 | New Mexico      | North America     | All 6.05         |           |
|                       |      |                  |                   | White 2.59       |           |
|                       |      |                  |                   | Hispanic 5.49    |           |
|                       |      |                  |                   | Native American 5.49|       |
|                       |      |                  |                   | African 11.57    |           |
| Lehmann et al. [31]   | 2006 | United States   | North America     | All 10.80        |           |
|                       |      |                  |                   | Male 13.35       |           |
|                       |      |                  |                   | Female 8.07      |           |
|                       |      |                  |                   | White 6.24       |           |
|                       |      |                  |                   | Hispanic 15.80   |           |
|                       |      |                  |                   | Native American 5.13|     |
|                       |      |                  |                   | African 24.58    |           |
|                       |      |                  |                   | Asian/Pacific Islanders 10.11| |
|                       |      |                  |                   | Northeast 17.15  |           |
|                       |      |                  |                   | Midwest 7.69     |           |
|                       |      |                  |                   | South 8.12       |           |
|                       |      |                  |                   | West 12.70       |           |
| Study                  | Year | City, Country       | Region     | Ethnicity | Incidence |
|-----------------------|------|---------------------|------------|-----------|-----------|
| Larson et al. [39]    | 2010 | Minnesota, North America | All        |           | 8.8       |
| Jerre et al. [42]     | 1996 | Gothenburg, Sweden  | Scandinavia| All       | 7.1       |
|                       |      |                     |            | Male      | 9.0       |
|                       |      |                     |            | Female    | 5.1       |
| Henrikson [43]        | 1969 | Gothenburg, Sweden  | Scandinavia| All       | 8.2       |
|                       |      |                     |            | Male      | 7.1       |
|                       |      |                     |            | Female    | 5.3       |
| Häggglund et al. [34] | 1984 | Southern Sweden     | Scandinavia| Rural     |           |
|                       |      |                     |            | Male      | 7.5       |
|                       |      |                     |            | Female    | 2.2       |
|                       |      |                     |            | Urban     |           |
|                       |      |                     |            | Male      | 4.8       |
|                       |      |                     |            | Female    | 3.8       |
| Murray and Wilson [40]| 2008 | Scotland, Europe    | All        |           |           |
|                       |      |                     |            | 1981      | 3.78      |
|                       |      |                     |            | 2000      | 9.66      |
| Noguchi and Sakamaki [38] | 2002 | Japan, Asia        | All        |           |           |
|                       |      |                     |            | Male      | 2.22      |
|                       |      |                     |            | Female    | 0.76      |
| Lim et al. [33]       | 2008 | Singapore, Asia     | All        |           | 1.2       |
| Ninomiya et al. [36]  | 1976 | Japan, Asia        | All        |           | 0.25      |
| Song et al. [44]      | 2009 | Korea, Asia         | All        |           | 0.33      |
|                       |      |                     |            | Male      | 0.50      |
|                       |      |                     |            | Female    | 0.14      |

The overall breakdowns by gender and race (unrestricted) are given as incidence per 100,000 for all <25 years of age, while the other numbers are for boys 10–17 years old and girls 8–15 years old.

*incidence for children 8–15 years of age.

(Indian) had a 9-fold increased incidence compared to Indo-Malay (Chinese). This is in contrast to another study [30] where Indo-Mediterraneans had a 5 times lower frequency of SCFE compared to Indo-Malays (all groups—Japanese, Thai). These racial differences most likely reflect the average body weights for each racial group and further support the significant role that obesity and mechanical stress plays in the etiology of SCFE [30]. A less likely explanation is racial variability in acetabular depth and femoral head coverage; the acetabulae in African children were deeper than White children in one study [54], but not in another study [55].

3.3. Gender and Age. Most series demonstrate a male predominance. Early in this century 90% occurred in males [57] but has now decreased to ~60%. In a review of 4343 children, 64.3% were boys and 35.7% girls (Table 3). There are differences in gender by race, with Indo-Mediterraneans having the highest proportion of boys (90%) and Polynesians an equal male/female ratio [30].

SCFE is a disease of prepubescence and early adolescence. Early in this century the average age was much higher with a gradual decrease over time (Figure 4(a)). Fifteen years ago the average age was 13.5 years for boys and
Table 2: (a) relative racial frequencies of SCFE\(^a\), (b) relative racial frequencies of SCFE\(^b\).

(a)

| Study                      | Year | City, Country | Region     | Race          | RRF  |
|---------------------------|------|---------------|------------|---------------|------|
| Kelsey et al. [37]        | 1970 | North America |            | African       | 2.31 |
|                           |      |               |            | White         | 1.0  |
|                          |      |               |            | African       | 4.47 |
|                          |      |               |            | Hispanic      | 2.12 |
|                          |      |               |            | Native American | 2.12|
|                          |      |               |            | White         | 1.0  |
| Bosch et al. [32]         | 2008 | New Mexico    | North America | African       | 4.47 |
|                          |      |               |            | Hispanic      | 2.12 |
|                          |      |               |            | Native American | 2.12|
|                          |      |               |            | White         | 1.0  |
| Lehmann et al. [31]       | 2006 | United States | North America | African       | 3.94 |
|                          |      |               |            | Hispanic      | 2.53 |
|                          |      |               |            | Asian/Pacific Islanders | 1.62|
|                          |      |               |            | White         | 1.0  |
| Stott and Bidwell [29]    | 2003 | New Zealand   | Australia/NZ | New Zealand Maori | 5.6  |
|                          |      |               |            | Pacific       | 4.2  |
|                          |      |               |            | White         | 1.0  |
|                          |      |               |            | NA/Pacific Islanders | 4.5 |
|                          |      |               |            | African       | 2.2  |
|                          |      |               |            | Hispanic/Native American | 1.05|
|                          |      |               |            | White         | 1.0  |
|                          |      |               |            | Indo-Malay    | 0.5  |
|                          |      |               |            | Indo-Med      | 0.1  |

\(^a\) using Caucasian as a baseline frequency of 1.0.

(b)

| Study                  | Year | City, Country | Region | Race             | RRF  |
|------------------------|------|---------------|--------|------------------|------|
| Lim et al. [33]        | 2008 | Singapore     | Asia   | Indian           | 9.6  |
|                        |      |               |        | Mixed            | 3.0  |
|                        |      |               |        | Malay            | 2.8  |
|                        |      |               |        | Chinese          | 1.0  |

\(^b\) using Chinese as a baseline frequency of 1.0.

Figure 3: (a) Relative racial frequencies of SCFE normalized to Caucasian children. The New Zealand data is from [29], worldwide data from Loder [30], USA data from Lehmann et al. [31], and New Mexico data from Benson et al. [32]. (b) Relative racial frequencies of SCFE within the Indo-Malay and Indo-Mediterranean groups, normalized to Chinese children. Data from [33] was used to calculate the relative racial frequencies using previously described methods [30].
Table 3: Age and gender in 4343 children with SCFE.

| Study                  | Year | City/State/Country          | Region        | Race        | Age  | Age-M | Age-F | M  | %M | F  | %F |
|------------------------|------|----------------------------|---------------|-------------|------|-------|-------|----|----|----|----|
| Stott and Bidwell [29] | 2003 | Auckland, New Zealand       | All           | White       | 11.82| 12.46 | 11.05| 115| 54.5| 96 | 45.5|
|                        |      |                            |               | Maori       | 12.33| 13.00 | 11.59| 30 | 52.6| 27 | 47.4|
|                        |      |                            |               | Pacific Islanders | 11.51| 12.18 | 10.69| 33 | 55.0| 27 | 45.0|
| Noguchi and Sakamaki [38] | 2002 | Japan                      | Indo-Malay (Japanese) | 11.73| 11.83 | 11.42| 237| 75.5| 77 | 24.5|
| Jerre et al. [42]      | 1996 | Gothenburg, Sweden         | Scandinavia   | White       | 13.07| 13.60 | 12.10| 113| 64.6| 62 | 35.4|
| Henrikson [43]         | 1969 | Gothenburg, Sweden         | Scandinavia   | White       | 12.91| 13.50 | 11.80| 53 | 65.4| 28 | 34.6|
| Hägglund et al. [34]   | 1984 | Southern Sweden            | Scandinavia   | White       | 12.86| 12.20 | 14.40| 372| 69.9| 160| 30.1|
| Loder [30]             | 1996 | Worldwide                  | Worldwide     | White       | 12.95| 13.60 | 12.10| 435| 56.7| 332| 43.3|
|                        |      |                            |               | African     | 12.88| 13.80 | 11.70| 225| 56.1| 176| 43.9|
|                        |      |                            |               | Amerindian  | 12.80| 13.40 | 11.90| 164| 60.3| 108| 39.7|
|                        |      |                            |               | Indo-Malay  | 12.09| 12.30 | 11.50| 89 | 74.2| 31 | 25.8|
|                        |      |                            |               | NA/PI       | 11.85| 12.00 | 11.70| 17 | 50.0| 17 | 50.0|
|                        |      |                            |               | Indo-Med    | 12.99| 13.20 | 11.00| 19 | 90.5| 2  | 9.5 |
|                        |      |                            |               | All         | 12.86| 13.50 | 12.00| 959| 58.8| 671| 41.2|
| Aronson and Loder [45] | 1992 | Detroit, Michigan          | North America | All         | 12.53| 13.42 | 11.08| 46 | 62.2| 28 | 37.8|
| Ninomiya et al. [36]   | 1976 | Eastern Japan              | Asia          | All         | 12.49| 12.75 | 11.00| 58 | 85.3| 10 | 14.7|
| Loder et al. [46]      | 2006 | Michigan and Indiana       | North America | All         | 12.60| 159   | 65.4| 84 | 34.6|
| Lim et al. [33]        | 2008 | Singapore                  | Asia          | All         | 12.20| 12.40 | 11.10| 53 | 80.3| 13 | 19.7|
| Bosch et al. [32]      | 2008 | New Mexico                 | North America | All         | 12.20| 12.50 | 11.50|  |
| Burrows [47]           | 1957 | London, England            | Europe        | All         | 14.70| 16.53 | 11.95| 60 | 60.0| 40 | 40.0|
| Carlioz et al. [48]    | 1984 | Paris, France              | Europe        | All         | 13.19| 14.00 | 12.50| 31 | 46.3| 36 | 53.7|
| Aronson and Carlson [13]| 1992 | Detroit, Michigan          | North America | All         | 31   | 70.5  | 13   | 29.5|
| Aronson et al. [49]    | 1992 | Detroit, Michigan          | North America | All         | 12.85| 13.50 | 11.70| 35 | 63.6| 20 | 36.4|
| Carney et al. [26]     | 1991 | Iowa                       | North America | All         | 12.98| 13.40 | 11.30| 99 | 79.8| 25 | 20.2|
| Dreghorn et al. [50]   | 1987 | Glasgow, Scotland          | Europe        | All         | 12.98| 13.50 | 12.25| 45 | 58.4| 32 | 41.6|
| Kulick and Denton [51] | 1982 | New York                   | North America | All         | 12.62| 13.00 | 12.00| 58 | 61.7| 36 | 38.3|
| Weiner et al. [35]     | 1984 | Akron, Ohio                | North America | All         | 13.05| 13.40 | 12.20| 113| 71.1| 46 | 28.9|
| Koval et al. [52]      | 1989 | New York                   | North America | All         | 12.10| 37    | 61.7| 23 | 38.3|
| Song et al. [44]       | 2009 | South Korea                | Indo-Malay    | 12.67| 12.83 | 12.00| 175| 75.8| 56 | 24.2|

**Averages**

|              |      |      |      |      |      |
|--------------|------|------|------|------|------|
| Age          | 11.96| 12.05| 11.21| 2806 | 64.3 |
| %            | 35.7 |

The averages are weighted to account for the number of children in each series. The overall age was used in those series where ages are given by ethnicity [29, 30].
12.0 years for girls [30] and is now 12.0 years for boys and 11.2 years for girls (Table 3). In Scotland, the age has dropped from 13.4 to 12.6 years over a 20-year period [40]. These younger ages reflect the earlier maturation of today’s children [31]. Obese children present earlier than nonobese children (Figure 4(b)). One study demonstrated different ages at presentation by racial group (Figure 4(c)) [30]. The physiologic age range during which SCFE occurs is less variable than the chronologic age range (Figure 5), termed the “narrow window” [56, 63].

3.4. Symptom Duration. The average symptom duration for stable SCFEs is 4 to 5 months (with minimal difference by gender). In 2482 children, the average symptom duration was 4.3 months; 4.5 months for boys and 3.6 months for girls (Table 4). Two recent studies have noted a decrease in symptom duration to 2-3 months [46, 88].

Although there is a general correlation between symptom duration and SCFE severity [88] there is considerable variability (Figure 6(a)) [46]. For any given individual child, slip severity and symptom duration is unique; in a large population, there is a weak positive correlation with slip severity and symptom duration. Mild SCFEs have a shorter duration of symptoms than severe SCFEs (Figure 6(b)) which suggests that all SCFEs start at a similar age; those children with severe SCFEs just had a longer symptom duration and time to presentation than those with milder SCFEs. In a review of 328 stable SCFEs this was documented; a child with a stable SCFE was 2.0 times more likely to have a moderate or severe SCFE if > than 12.5 years at diagnosis.
Bone age pelvis (years) — Chronological age (years)

Figure 5: The pelvis bone age (Oxford score converted into years) as a function of chronologic age in 108 children with SCFE. The observed pelvis bone age is represented by the solid line, and is represented by the equation Pelvis Bone Age = 6.95 + 0.51 (Chronologic Age), \( r^2 = 0.47, P < 10^{-8} \). The dotted line represents what would be found if the pelvis bone age and chronologic age were the same. The slope of the linear correlation for the actual pelvis bone age, 0.51, is 1/2 that if the bone and chronologic ages were equal, supporting the concept of the narrow bone age window for proximal epiphyseal slipping, data from Loder et al. [56].

than if <12.5 years at diagnosis, and a child with a stable SCFE is 4.1 times more likely to have a moderate or severe SCFE if the duration of symptoms is > than 2 months than if \( \leq 2 \) months [46]. Other positive predictors of increasing time to diagnosis are knee/distal thigh pain, Medicaid coverage, lower family income, and a stable SCFE [88].

Slip severity and symptom duration is greater in children presenting with knee pain compared to other symptoms [88–91]. In a study of 45 children [89], 15 presented solely with knee pain having an average symptom duration of 8.5 months; 74% of the SCFEs were severe. The remaining 30 presented with other symptoms with an average symptom duration of 6.5 months; 24% of the SCFEs were severe. Rahme et al. [90] reviewed 87 children with stable SCFEs, 20 had a delayed diagnosis, with 8 (40%) being severe. In Leeds, England, those children with SCFE diagnosed in the emergency department compared to general practitioners had a shorter symptom duration (95 versus 119 days) and fewer severe SCFEs (8 versus 21%). One study, however, did not see a difference in symptom duration in SCFE children where the diagnosis had been initially missed due to the absence of hip pain (average symptom duration 127 days and 146 days in those whose diagnosis was and was not missed) [92].

It would seem reasonable that as symptom duration increases radiographic changes should concomitantly progress (more metaphyseal remodeling). The presence or absence of a positive Klein line and metaphyseal remodeling (superior and anterior smoothing, inferior and posterior buttressing) were directly correlated to symptom duration but with significant variability [93]. Those with more metaphyseal changes had higher BMIs, interpreted as the larger body mass per unit height resulting in more bony reaction/adaptation according to Wolf’s law.

Figure 6: (a) Symptom duration as a function of slip severity (lateral epiphyseal shaft angle) in 254 stable SCFEs. The best fit line is represented by the dotted line: symptom duration = 2.16 + 0.106 (slip angle), \( P < 0.0001, r^2 = 0.084 \), where the slip angle is expressed in degrees and the symptom duration in months. Data from Loder et al. [46]. (b) Average symptom duration in months (middle black line in the gray box) \( \pm \) one standard deviation (entire gray box) for mild, moderate, and severe stable SCFEs, data from Loder et al. [46]. (c) Categories of symptom duration in months (solid column) \( \pm \) one standard deviation (error bar) and age at onset of the SCFE defined as age at diagnosis minus symptom duration. There was no statistically significant difference in the age at onset for those children with different categories of symptom duration (ANOVA\(F_{2,250}, F = 0.56, P = 0.57\)), indicating a small age window at which the SCFE begins. The average age for each symptom duration group is noted, data from Loder et al. [46].
The age at diagnosis of the 1st SCFE correlates with SCFE severity and is also related to the narrow physiologic window [56, 63]. Subtracting the average symptom duration for the mild, moderate, and severe categories from the average age at presentation results in a similar average age at onset (Figure 6(c)), confirming the narrow bone age window.

3.5. Body Weight, Obesity, and BMI. The majority of children are obese; >50% of children with SCFE are >95th percentile weight for age [30, 94–96]. Age at diagnosis decreases with increasing obesity [30]; 12.4 years for those over the 95th percentile weight for age and 14.3 years for those under the 10th percentile weight for age. Recently body mass index (BMI) [97, 98] has been used to evaluate body habitus; the average BMI in SCFE children is 25–30 kg/m² or >85th percentile [39, 46, 99–102]. The average BMI of children with bilateral SCFE is higher than with unilateral SCFE (26.8 versus 31.1 kg/m²) [99].

Obese children have decreased femoral anteversion, and SCFE children have femoral retroversion even in the noninvolved hip [103, 104]. This, along with biomechanical studies demonstrating an increased physesal stress in retroverted hips and the many demographic studies associating obesity with SCFE, supports the theory that obesity is intimately involved in the development of most idiopathic SCFEs [105].

3.6. Seasonal Variation. In latitudes north of 40° SCFE presents more frequently in the late summer and autumn months (Figure 7(a)) [34, 58, 59, 61, 62, 106, 107]. Subtracting symptom duration from the time of presentation demonstrates that the SCFE onset is in the early summer/late spring months (Figure 7(b)).

3.7. Bilaterality. The reported proportion of bilaterality depends upon the study, method of radiographic measurement, race, and treatment (Table 5). Most series report 18 to 50% bilaterality [30] with recent follow-up studies into adulthood quoting 63% [34, 109, 110] and 66% [111]. Bilaterality is more frequent in Africans (34%) than Hispanics (17%), Whites (17%), or Asians (18%) [30]. Treatment may affect risk of bilaterality; bilaterality is 36% with in situ fixation and 7% spica cast treatment [112]. Close attention is mandatory to the opposite normal hip in those children with a unilateral SCFE treated by in situ fixation.

The age at presentation is younger in children who present with a unilateral SCFE that later develops bilateral SCFEs compared to those who do not develop bilateral SCFEs [17, 50, 59, 113–116]. This age difference is seen in both chronologic age (12 versus 13 years of age) [17, 30, 115, 116] and bone age. In one study the overall difference in chronologic age in those with a unilateral SCFE that became bilateral compared to those that stayed unilateral was 1 year (12 versus 13 years) [17]; in another study 0.9 years for girls (11.0 versus 11.9 years) and 2.2 years (12.1 versus 14.2 years) for boys [115]; and in a 3rd study 11.5 versus 12.7 years, with those children aging <12 years having a unilateral SCFE demonstrated a 3.8 times increased risk of developing a contralateral SCFE [116]. In a study of 50 children with unilateral SCFE [113] using a modified Oxford hip bone age, a contralateral SCFE occurred in 85% of hips having a score of 16, 11% of hips having a score of 21, and never when the score was ≥22. Once the triradiate cartilage has closed, the risk of a contralateral SCFE is only 4% [117], although another study did not find any association between the status of the triradiate cartilage, other skeletal maturity markers, and subsequent bilaterality [118]. The risk of bilaterality is increased when the posterior slope angle of the capital femoral epiphysis is higher [119, 120].

In children with bilateral SCFEs, 50–60% present with simultaneous bilateral involvement. In those children with sequential bilateral SCFEs, 80–90% of the second SCFEs occur within the first 18 months after the first SCFE (Figure 8) [17, 29, 30, 34, 50, 67, 102, 121, 122]. In unilateral SCFEs, 60% involve the left hip.
3.8. Predictors of Idiopathic and Atypical SCFEs. Tests for a disease are evaluated in terms of sensitivity, specificity, positive predictive value, and negative predictive value [123]. Sensitivity is the proportion of individuals in a tested population who do not have a given disease and are identified as not having it with the test. Specificity is the proportion of individuals in a tested population who actually have the disease and are identified as having it with the test. The probability that a person with a positive result truly has the disease is the positive predictive value; the probability that a person with a negative test truly does not have the disease is the negative predictive value. When evaluating a child with a newly diagnosed SCFE, the underlying etiology immediately comes into consideration. This is for both diagnostic concerns with potential medical issues as well as orthopaedic treatment. The underlying medical issues involve significant anesthetic concerns [108]; treatment involves the question of prophylactic fixation of the opposite hip when the child presents with a unilateral SCFE. Any “test” that can give an accurate negative predictive value for a child with a SCFE not having an atypical SCFE is important. If the test has a high negative predictive value, the clinician can be confident that the SCFE is idiopathic. If the test is positive, further diagnostic investigation should be strongly considered.

Atypical SCFEs are those associated with endocrine/renal disorders or prior radiation therapy. The history of prior radiation therapy is usually discovered in the initial evaluation. However, many times it is the orthopaedic surgeon who picks up on an underlying medical problem as the etiology of the SCFE (e.g. endocrine dysfunction, renal osteodystrophy). In 2001 the age-weight test [108] was described to assist in the differentiation between an idiopathic and atypical SCFE. The age-weight test is defined as negative when age < 16 years and weight ≥ 50th percentile and positive when beyond these boundaries (Table 6). The “disease” is the child having an
### Table 5: Laterality in 3037 children with SCFE.

| Study              | Year | City/State/Country     | Region       | Race        | U   | %U | B   | %B | R   | %R | L   | %L |
|--------------------|------|------------------------|--------------|-------------|-----|----|-----|----|-----|----|-----|----|
| Stott and Bidwell  | 2003 | Auckland, New Zealand  | Australia/NZ | All         | 64  | 55.7| 51  | 44.3| 22  | 34.4| 42  | 65.6|
|                    |      |                        |              | White       | 28  | 49.1| 29  | 50.9| 10  | 35.7| 18  | 64.3|
|                    |      |                        |              | Maori       | 36  | 60.0| 24  | 40.0| 8   | 22.2| 28  | 77.8|
|                    |      |                        |              | Pacific Islanders | 47  | 52.8| 42  | 47.2| 18  | 38.3| 29  | 61.7|
| Noguchi and Sakamaki | 2002 | Japan | Asia | Indo-Malay (Japanese) | 270 | 86.0| 44 | 14.0| 127 | 47.0| 143 | 53.0|
| Jerre et al.       | 1996 | Gothenburg, Sweden     | Scandinavia  | White       | 173 | 98.9| 2  | 1.1 | 69  | 39.9| 104 | 60.1|
| Hägglund et al.    | 1984 | Southern Sweden        | Scandinavia  | White       | 451 | 84.8| 81 | 15.2| 171 | 33.5| 339 | 66.5|
| Loder              | 2006 | Worldwide              | Worldwide    | All         | 663 | 83.2| 134 | 16.8| 239 | 37.8| 394 | 62.2|
|                    |      |                        |              | African     | 264 | 65.8| 137 | 34.2| 109 | 41.3| 155 | 58.7|
|                    |      |                        |              | Amerindian  | 227 | 83.5| 45 | 16.5| 96  | 42.5| 130 | 57.5|
|                    |      |                        |              | Indo-Malay  | 98  | 81.7| 22 | 18.3| 49  | 50.0| 49  | 50.0|
|                    |      |                        |              | NA/PI       | 21  | 61.8| 13 | 38.2| 8   | 38.1| 13  | 61.9|
|                    |      |                        |              | Indo-Med    | 13  | 61.9| 8  | 38.1| 5   | 38.5| 8   | 61.5|
|                    |      |                        |              | All         | 1267| 77.7| 363 | 22.3| 510 | 40.3| 756 | 59.7|
| Loder et al.       | 1996 | Michigan and India     | North America | All         | 149 | 61.3| 94 | 38.7| 63  | 42.3| 86  | 57.7|
| Lim et al.         | 2008 | Singapore              | Asia         | All         | 42  | 79.2| 11 | 20.8| 25  | 45.5| 30  | 54.5|
| Burrows            | 1957 | London, England        | Europe       | All         | 77  | 77.0| 23 | 23.0| 29  | 37.7| 48  | 62.3|
| Carlioz et al.     | 1984 | Paris, France          | Europe       | All         | 54  | 80.6| 13 | 19.4| 22  | 40.7| 32  | 59.3|
| Aronson and Carlson| 1992 | Detroit, Michigan      | North America | All         | 30  | 68.2| 14 | 31.8|     |     |     |     |
| Aronson et al.     | 1992 | Detroit, Michigan      | North America | All         | 30  | 54.5| 25 | 45.5|     |     |     |     |
| Carney et al.      | 1991 | Iowa                   | North America | All         | 93  | 75.0| 31 | 25.0|     |     |     |     |
| Dreghorn et al.    | 1987 | Glasgow, Scotland      | Europe       | All         | 58  | 75.3| 19 | 24.7|     |     |     |     |
| Kulick and Denton  | 1982 | New York               | North America | All         | 63  | 67.0| 31 | 33.0|     |     |     |     |
| Koval et al.       | 1989 | New York               | North America | All         | 29  | 59.2| 20 | 40.8| 36  | 45.0| 44  | 55.0|
| Song et al.        | 2009 | South Korea            | Indo-Malay   | All         | 187 | 81.0| 44 | 19.0| 77  | 41.2| 110 | 58.8|
| **Totals**         |      |                        |              |             | 3037| 77.8| 866| 22.2| 1151| 39.9| 1734| 60.1|

### Table 6: The age-weight or age-height test in children with SCFE is determined by graphically visualizing 6 groupings (or “cells”) of children with SCFE: cell 1, <10 years of age and ≥50th percentile in weight/height; cell 2, ≥10, ≤16 years of age and ≥50th percentile in weight/height; cell 3, >16 years of age and ≥50th percentile in weight/height; cell 4, <10 years of age and <50th percentile in weight/height; cell 5, ≥10, ≤16 years of age and <50th percentile in weight/height; and cell 6, >16 years of age and <50th percentile weight/height. Children in cells 3–6 (bold print) are considered to have a positive age-weight or age-height test; children in cells 1 and 2 (italic calligraphy) are considered to have a negative age-weight or age-height test.

| Weight or height percentile | Age of patient with SCFE |
|-----------------------------|--------------------------|
| <10 years                   | 10–16 years              | >16 years     |
| ≥50th                       | **Cell 1 (− test)**      | **Cell 2 (− test)** | **CELL 3 (+ TEST)** |
| <50th                       | **CELL 4 (+ TEST)**      | **CELL 5 (+ TEST)** | **CELL 6 (+ TEST)** |
atypical SCFE, absence of “disease” is the child having an idiopathic SCFE. The demographics of 433 children (285 idiopathic, 148 atypical) with 612 SCFEs were studied to define predictors of atypical SCFEs. There was significant variability in both age and bilaterality between the atypical and idiopathic groups (Figure 9). Multiple logistic regression analysis demonstrated that age and weight were predictors of an atypical SCFE. For two patients of equal weight, those <10, or >16 years of age are 4.2 times more likely to have an atypical SCFE; for two patients of equal age, those <50th percentile weight are 8.4 times more likely. The probability of a child with a negative test having an idiopathic SCFE is 93%, and a child with positive test having an atypical SCFE is 52%. In the same year the age-weight test was described for all atypical SCFEs, Burrow et al. [124] showed that the height at diagnosis was an important predictor of an endocrinopathy. The sensitivity and negative predictive value of detecting an underlying endocrinopathy in a patient with an SCFE who was <10th percentile in height for age were 90.2% and 98%.

The age-weight test was further confirmed in 2006, along with the definition of the height and age-height tests [125]. The age-height test was defined using the same cells as the age-weight test except that the percentiles applied to height rather than weight. This test has a positive and negative predictive value of 30% and 98%. The height test is defined as positive if the child’s height is ≤10th percentile and negative if >10th percentile for age. It is the same test described by Burrow et al. [124] amplified to include all atypical SCFEs, not just those associated with an endocrinopathy. The height test has a positive and negative predictive value of 75% and 97%

Of these three tests, all have similar negative predictive values (93 to 98%). The height test has the best positive predictive value (75%). The height test is likely to be the most useful in the differentiation between a typical and atypical SCFE if the height of a child can be obtained. When the height cannot be obtained, the age weight test will result in a similar negative predictive value but with a lower positive predictive value. Thus the weight, and where possible, the height of any child newly diagnosed with a SCFE should be obtained to assist in the differentiation between an atypical and idiopathic SCFE.

3.9. Inheritance and Genetics. Little is known regarding the heredity and genetics of SCFE. Familial SCFE was first noted in the English language literature in 1940 [64] with many more subsequent descriptions [65–74, 76–80, 83–87]. Proposed patterns of genetic transmission include X-linked dominant, autosomal dominant with variable penetrance, and autosomal recessive [68, 71, 73, 77]. HLA phenotype studies in children demonstrate no common findings (Table 7) [74, 75, 79–82, 86].

3.10. Miscellaneous Associations/Findings

Other Skeletal Abnormalities. In most children with SCFE, femoral anteversion is decreased. In a 3-dimensional CT scan study of 30 SCFEs [126] there was a reduction in femoral anteversion from 12.7° to 7.0° as well as a reduction in the femoral neck shaft angle from 141° to 134°. In another CT scan study of 25 SCFEs [103] a reduction of femoral version 1° was noted in the involved hip and 7° in the uninvolved hip in unilateral cases. In a 3rd CT scan study of 25 SCFEs [127] femoral anteversion was 9.8° and 25° in a control group of children between the ages of 8 and 16 years. Reduced femoral anteversion in obese adolescents is well known [104]. Patients with acute SCFEs have less reduction

| Type of SCFE | Bilaterality of SCFE |
|-------------|----------------------|
| Renal       | 100                  |
| Endocrine   | 90                   |
| Idiopathic  | 80                   |
| Rad therapy | 70                   |

Figure 9: (a) A histogram showing the age at diagnosis of SCFE. Note the narrow age range for children with idiopathic SCFE (92% 10–16 years of age), with a broader range for children with atypical SCFEs (those associated with renal failure, radiation therapy, or endocrinopathy). Data from the study of Loder and Greenfield [108]. (b) Frequency of bilaterality amongst different types of SCFE, data from Loder and Greenfield [108].
| Study                        | Year | Type of series | Number of cases | % familial incidence | Postulated inheritance | HLA Phenotype |
|-----------------------------|------|----------------|-----------------|-----------------------|------------------------|--------------|
| Thrap-Meyer [64]            | 1940 | Case report    | Father and son  | —                     | —                      | —            |
| Irwin [65]                  | 1946 | Case report    | Father and 2 twin sons | — | — | — |
| Smith [66]                  | 1955 | Case report    | 2 brothers      | —                     | —                      | —            |
| Wilson et al. [67]          | 1965 | Case series    | 12 of 240 cases | 5%                   | Recessive with low penetrance | — |
| Rennie [68]                 | 1967 | Case reports   | 12 children, 8 different families | 7% | Autosomal dominant with variable penetrance | — |
| Ochsner et al. [69]         | 1977 | Case report    | 10 members of one family | — | — | — |
| Gorin [70]                  | 1977 | Case report    | Identical twins | —                     | —                      | —            |
| Rennie [71]                 | 1982 | Retrospective review | 214 | 14.5% | Autosomal dominant with variable penetrance | — |
| Hägglund et al. [72]        | 1986 | Consecutive case series | 50 (40 families) | 8.1% in 1st degree relatives | — | — |
| Hägglund and Hansson [73]   | 1986 | Case report, 3 generations | 3 cases, 1 family | — | Autosomal dominant with variable penetrance | — |
| Gajraj [74]                 | 1986 | Case report, identical twins | 1 family, identical twins | — | — | A11, B12 |
| Mullaji et al. [75]         | 1993 | HLA testing of SCFE patients | 30 patients | — | — | B27 in 20%, > than in controls |
| Montskou and de Jonge [76]  | 1995 | Case report    | 1 family father and 5 siblings (3 M, 2 F) | — | — | — |
| Moreira et al. [77]         | 1998 | Case report    | 1 family, 4 cases | — | Autosomal dominant | — |
| Diwan et al. [78]           | 1998 | Case report    | 1 family, 2 generations | — | — | — |
| Bednarz and Stanitski [79]  | 1998 | Case report    | Identical twins | — | — | — |
| Allen and Calvert [80]      | 1990 | Case report    | Identical twins | — | — | A2, B12 |
| Günal and Ateş [81]         | 1997 | Case series    | 6 patients      | — | — | DR4 common to all; no other common phenotypes |
| Wong-Chung et al. [82]      | 2000 | Random case series | 7 cases, 6 M, 1 F | 2 were brothers | — | No common phenotypes |
| Siemon et al. [83]          | 2001 | Case report    | Identical twins | 2 brothers | — | A2 |
| Loder et al. [84]           | 2005 | Case series    | 9 cases—Amish   | 39% | — | — |
| Sebastianowicz et al. [85]  | 2005 | Case report    | Identical twins | 2 brothers | — | — |
| Flores et al. [86]          | 2006 | Case report    | Identical twins | — | — | A2, 23 (9), B44 (12), Bw4 Cw4, 12 DR103, DQ5 (1) |
| Lim et al. [87]             | 2007 | Case report    | Two brothers    | — | Multifactorial | — |
in anteversion compared to those with chronic SCFEs (9.3° versus –0.7°) in the involved hip and uninvolved hip (15.7° versus 11.8°), with an average difference in version in acute SCFEs of 6.7° and in chronic SCFEs of 13.9° [128]. SCFE has no influence on acetabular development [129, 130].

There are also no abnormalities in tibial torsion in children with stable SCFEs [131].

Genu recurvatum has been fleetingly described in SCFE [132, 133]. It is believed that this represents a gradual anterior slip of the proximal tibial epiphysis, with the physes perhaps universally weak or susceptible to large stresses from obesity. Surprisingly, tibia vara (Blount's disease) is very rarely associated with SCFE [134–136] even though both conditions typically occur in obese children. Peroneal spastic flatfoot has been associated in certain cases with SCFE [137].

Increase width of the symphysis pubis and unaffected hip joint cartilage space has been observed [138], suggesting an abnormality of cartilage formation or maturation on a macroscopic level rather than a microscopic level. Skewness of the symphysis joint has also been described on standing radiographs of the pelvis [139].

Other Nonskeletal Associations. Immune complexes in the synovial fluid and synovium of the hip, but not in the serum, have been found in a high percentage of SCFE cases [140, 141]. This is different from the synovitis of the knee or hip caused by other disorders where immune complexes are rarely found. Fluorides in the water, used to reduce dental caries, also strengthen the physes and metaphyseal bone; however, no difference in the incidence of SCFE was seen in children with or without fluoride exposure [142].

4. Conclusion

The current incidence of SCFE ranges from 0.33/100,000 to 24.58/100,000 children 8 to 15 years of age, depending upon gender and ethnicity. There is significant variability within racial groups and the relative frequency, relative to Caucasians at 1.0, is 5.6 for Polynesians, 3.9 for Blacks, and 2.5 for Hispanics. The average age is 12.0 years for boys and 11.2 years for girls; obese children present earlier than light weighted children. The physiologic age range during which SCFE occurs is less variable than the chronologic age range. The average symptom duration for stable SCFEs is 4 to 5 months. Although there is a general correlation between symptom duration and SCFE severity, there is considerable variability. The majority of children are obese with >50% of children >95th percentile weight for age; the average BMI in SCFE children is 25–30 kg/m² or >85th percentile. The onset of SCFE is in the summer months in latitudes north of 40°N. Bilaterality ranges from 18 to 50% and is more frequent in Africans compared to Hispanic, White, and Indo-Malay peoples. In children with bilateral involvement, 50–60% present with simultaneous SCFEs; 80–90% of those who present with a unilateral SCFE and subsequently develop a contralateral SCFE do so within 18 months after the first SCFE. The age at presentation is younger for those who present with a unilateral SCFE and develop contralateral involvement compared to those who do not develop a contralateral SCFE. The age-weight, age-height, and height test are useful to differentiate between an idiopathic and atypical SCFE.

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