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Original Research

A New Look on the Epidemiology of Slipped Capital Femoral Epiphysis: A Topic Revisited

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Abstract

Background: Slipped capital femoral epiphysis (SCFE) is a common hip pathology affecting adolescents mostly in the rapid growth phase. Previous studies have presented epidemiological data to inform practitioners on its etiology to improve diagnosis, treatment, and prevention. However, in recent years national databases have been redesigned, which may change previously published information on SCFEs. The purpose of this study is to evaluate SCFE epidemiology using the 2019 Kids' Inpatient Database (KID) and HCUPnet, Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, in conjunction with U.S. Census Data.

Methods: The Kids' Inpatient Database (KID) reflects data on 5.9 million pediatric discharges in 2019 and was combined with U.S. Census data to produce epidemiologic data regarding SCFEs in the pediatric population. KID regional data was then overlayed with National Oceanographic and Atmospheric Administration (NOAA) data to assess the associations between climate patterns and UV indices with SCFE incidence.

Results: Overall incidence of SCFE in the U.S. was 2.66/100,000 children 9-16 years of age. The average age at presentation with SCFE was 12.3 years with males being older at presentation (12.8 vs. 11.6 years; $P<.001$; $r=0.34$). Males were significantly more likely to develop a SCFE than females (OR 1.73; 95% CI, 1.51-1.97). Black patients were significantly more likely to present with a SCFE than all other races (OR 1.66; 95% CI, 1.40-2.97). Obesity (23.2%) was the most common metabolic and endocrine comorbidity followed by severe obesity (7.5%). Geographical regions with colder temperatures and lower UV indexes had higher SCFE rates, while regions with higher temperatures and higher UV indexes had lower SCFE rates.

Conclusion: This study determined a lower SCFE incidence rate than previously reported but shows similar distributions of SCFEs amongst different races. Age of onset was increased compared to previous studies. The rate of obesity also continues to increase while the incidence of SCFEs has experienced a gradual decrease over time. It is plausible that environmental factors and race (skin tone) may have a more influential effect on the development of this pathology.

Level of Evidence: III – Cross-sectional study of non-consecutive patients

Key Concepts

- SCFE incidence rates are lower than previously reported.
- Obesity continues to increase while SCFEs have remained stable.
- Cold climate regions (with lower UV-indexes) may be a risk factor for SCFEs, while areas with hot climate regions (with higher UV-indexes) could be protective.

Introduction

Slipped capital femoral epiphysis (SCFE) is a hip pathology affecting pediatric patients mostly in the adolescent years. SCFE has been purported as the most common hip pathology affecting adolescents.[1] Previous epidemiologic studies have provided valuable data regarding etiologies of SCFE with hopes of improving the prevention and treatment of this pathology. However, while our understanding of SCFE's pathophysiology and treatment algorithms have improved, prevention of this pathology seems to be lacking. Studies following these patients over time have shown that timely and accurate diagnosis reduces the morbidity associated with this condition.[2] However, the understanding of the etiology of SCFE still remains incomplete, which makes identification of those at most risk using current and accurate epidemiological data imperative in the prevention of this pathology.

Historically, SCFE pathophysiology has been described as a weakening of the proximal femoral physis and shearing stress from excessive body weight. Weakening of the physis happens during the rapid growth phase in the adolescent years, but not all adolescents will be destined to develop SCFE. Therefore, it is important to identify other factors that can differentiate the adolescent that ultimately will develop SCFE either acutely or chronically. Multiple mechanical and endocrine factors can be found throughout the literature. Mechanical factors include obesity, perichondral ring complex thinning, acetabular/femoral retroversion, and physis inclination.[3] Endocrine factors include hypothyroidism, growth hormone administration, hypovitaminosis D, and chronic renal failure.[4] Many studies examining the aforementioned risk factors are derived from single-institution cohorts that are difficult to apply to larger populations.

Previous epidemiological studies have been completed regarding SCFE data at the State and regional levels, but only one study has used a national database.[1] This study serves as a 20-year follow-up to the landmark article published by Lehmann et al.[1] to evaluate SCFE epidemiology using the 2019 Kids' Inpatient Database (KID) and HCUPnet, Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, in conjunction with U.S. Census Data. The inception of the KID for the years 1997 and 2000 had limited State data available; however, the most recent 2019 KID was expanded to include previously excluded States. The working hypothesis for this study is a decrease in SCFE incidence with more State data available and an increasing population. However, the

expectation is the incidence and distribution regarding race, sex, and geographic region will remain unchanged.

Materials and Methods

The Healthcare Cost and Utilization Project (HCUP) is an aggregate of healthcare databases sponsored by the Agency for Healthcare Research and Quality (AHRQ).[5] HCUP is comprised of the National Inpatient Sample (NIS) and KID, which are the two largest publicly available all-payer inpatient care databases and can yield national estimates of all hospital inpatient stays.[6,7] The NIS contains data from approximately 7 million hospital stays each year and when weighted, it estimates approximately 35 million hospitalizations nationally.[6] The 2019 KID contains data from approximately 4,000 hospitals and 3 million pediatric inpatient records across 48 states and the District of Columbia.[7] When weighted, this estimates approximately 5.9 million pediatric discharges.[7]

NIS and KID data are available from 1988 and 1997 to present; however, both databases have undergone significant redesigns to improve national estimates. The NIS and KID initially started with eight and 22 states, respectively, and have increased to 48 states and the District of Columbia. In 2000, KID underwent major changes, including revising strata data element definitions, excluding rehabilitation hospitals, and changing calculations for discharge weights.[7] In 2012, the NIS was redesigned to produce more precise estimates, reduce sampling errors, and improve the weighting design.[4] By comparison, many estimates and confidence intervals under the present design are approximately half the length of the confidence intervals of its predecessor.[4] This enhancement, with the increase in the number of participating states, allowed the NIS and KID to cover more than 97% of the U.S. population.[6]

Inclusion criteria consisted of patients diagnosed with SCFE using the ICD-10 M93.0 series (M93.0-M93.074), ages 1-17 years in the 2019 KID database. Patient metabolic and endocrine comorbidities were also identified using ICD-10 codes. To capture longitudinal SCFE trends in association with comorbidities, patients aged 1-17 years in the HCUPnet NIS database were also used. Patient ages 1-17 years were included as previous publications have varied age ranges; this range was chosen to include the majority of SCFEs as well as atypical outliers. To compare with previously established incidence rates, 2019 KID data for patients aged 9-16 were coupled with the U.S. Census Bureau's 2019 American Community Survey 1-Year Estimate data to determine 20-year differences in incidence rates per 100,000 population.[8]

To evaluate seasonal and geographic variations as possible risk factors for the diagnosis of SCFE, data from the National Centers for Environmental Information (NCEI) at the National Oceanic and Atmospheric Administration (NOAA) was used to assess climate patterns in the respective KID database regions. The KID database is stratified into four geographic regions which roughly cover nine climatically consistent regions identified by the NCEI across 88 years of research.[9] NOAA's Climate Prediction Center provided UV Index data for 2019 as daily maximum ultraviolet ray index across 58 U.S. cities to evaluate possible SCFE patterns related to climate.

Statistical analyses were performed with IBM SPSS Statistics v28 (IBM Corporation, Armonk, NY). Tests were conducted 2-tailed, and a $P<0.05$ defined statistical significance. Estimates are reported as mean (standard deviation). Logistic regression was used to determine associations between patient characteristics and SCFEs. Comparisons were conducted with the Mann-Whitney U test. Effect size r less than 0.3 indicates a small effect, a medium effect is between 0.3 and 0.5, and a large effect is greater than 0.5.

Results

The overall SCFE incidence was 2.66/100,000 for children ages 9-16 in the 2019 KID. The average rate was 2.53/100,000 (SD, 0.50) for children ages 1-17 across 24 years (Figure 1). The majority (61.5%) of SCFEs were non-elective hospital admissions compared to elective admissions (38.5%). SCFEs were more prevalent in

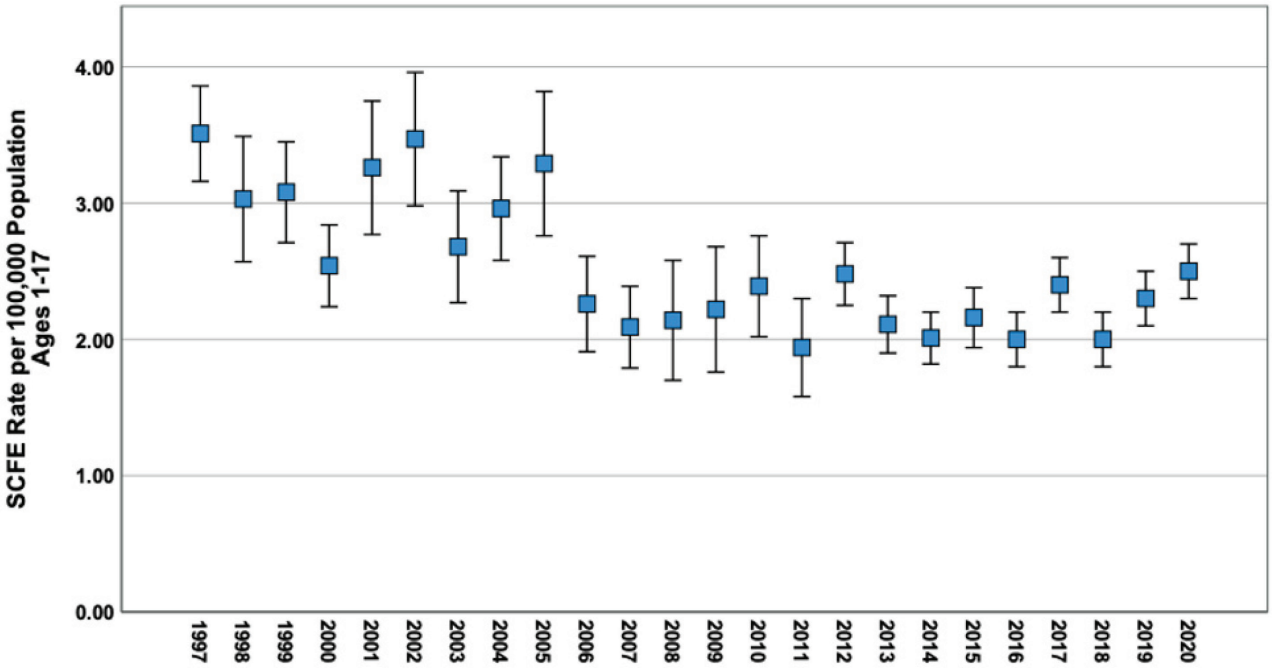

Figure 1. *SCFE incidence rate ages 1-17 between 1997 and 2020, according to HCUPnet NIS Database (ICD-9-CM and Clinical Classification Software Refined coded). Box represents estimate, whiskers represent standard error.*

the left hip (59.7%) than the right hip (52.0%). Chronic SCFEs were most common (59.7%), followed by unspecified SCFEs (35.0%), stable acute SCFEs (9.2%), and stable acute on chronic SCFEs (7.8%).

Average patient age at presentation was 12.3 (1.9) years, range 6-17 years (Figure 2). There were no SCFEs in patients younger than age 6 years. At age of onset, males were older (12.8 [1.8] years) than females (11.6 [1.8] years) (median 13 vs. 11 years; $P<.001$; $r=0.34$) (Figure 3). Non-elective admissions were younger (12.0 [1.6] years) than elective admissions (12.9 [2.2] years) (median 12 vs. 13 years; $P<.001$; $r=0.19$) (Figure 4).

Males were more likely to develop a SCFE than females (OR 1.73; 95% CI, 1.51-1.97; $P<.001$). Incidence for males was 3.27/100,000 compared to 2.02/100,000 for females between ages 9-16.

The incidence of SCFE was considerably greater in Blacks, Hispanics, and Native Americans compared to Caucasians (Table 1). Asian/PI were least likely to develop a SCFE. Between ages 9-16, Blacks had the highest SCFE incidence (4.32/100,000), followed by Hispanics (2.38/100,000), Native Americans (2.37/100,000), Caucasians (1.45/100,000), and Asian/PI (0.99/100,000). Black and Hispanic males had the highest incidence of all races and sexes (4.84/100,000 and 3.41/100,000). Asian/PI females had the lowest incidence of all races and sexes (0.47/100,000). When comparing elective vs. non-elective admission rates, Blacks were twice as likely to have a non-elective hospital admission for SCFEs than Caucasians (OR 2.08; 95% CI, 1.44-2.99; $P<.001$). Hispanics (OR 1.24; 95% CI, 0.87-1.76; $P=.22$), Asian/PI (OR 0.77; 95% CI, 0.30-1.95; $P=.58$), and Native Americans (OR 0.39; 95% CI, 0.09-1.72; $P=.21$) had varying likelihoods of non-elective hospital admission for SCFEs compared to Caucasians.

In the 2019 KID, 23.2% of the SCFE patients were diagnosed as obese, 7.5% as severely obese, and 2.7% had hypothyroidism. When comparing the incidence of obesity, severe obesity, and hypothyroidism to SCFE rates, these metabolic comorbidities consistently increased while SCFE rates remained stable (Figure 5). SCFE incidence ranged from 1.94 to 3.51/100,000 between ages 1-17 across 19-years of longitudinal data.

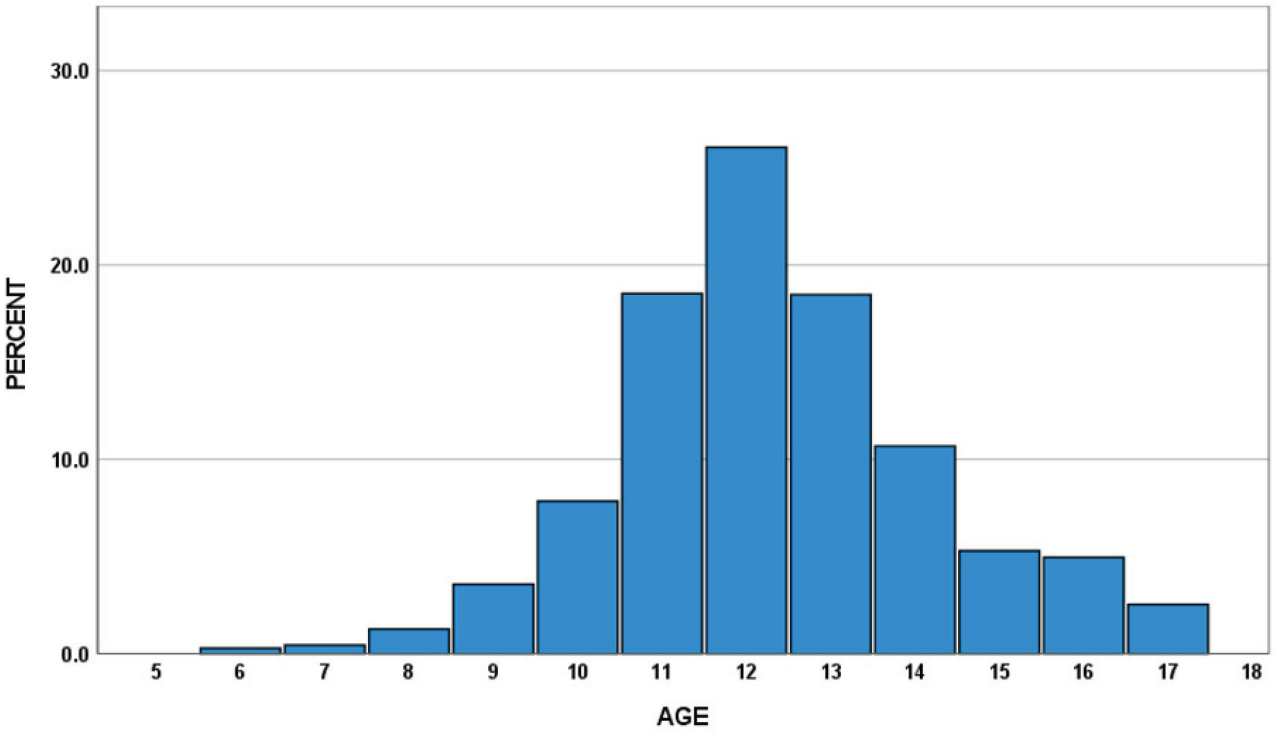

Figure 2. *Distribution of ages at admission for SCFE.*

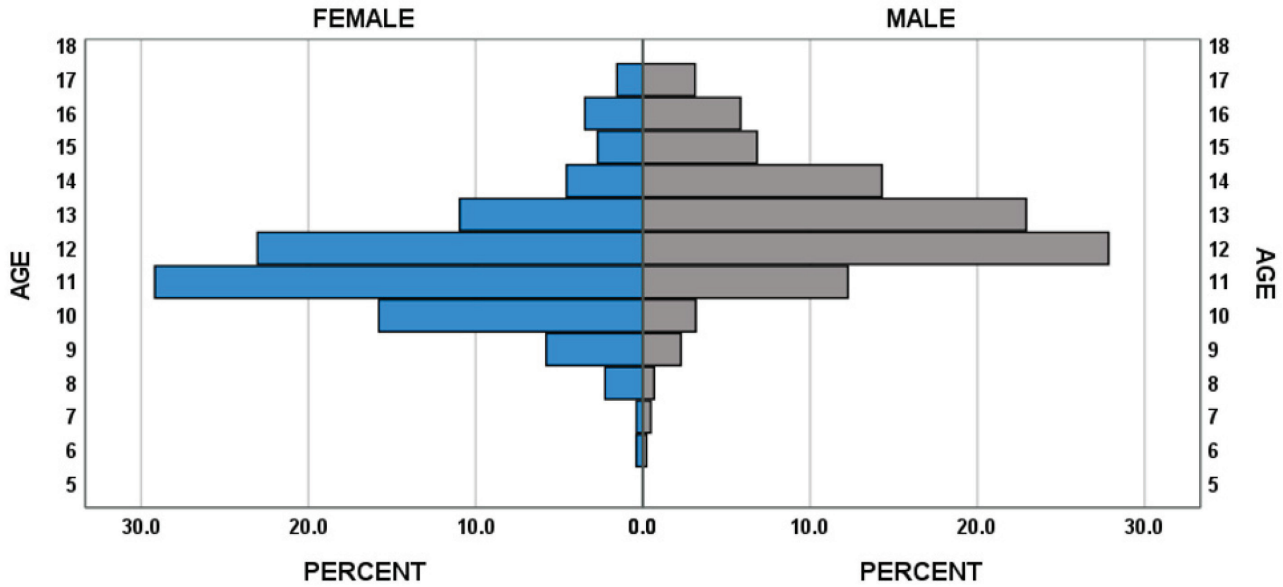

Figure 3. *Age at admission for male and female SCFE patients.*

Obesity rates ranged from 13.04 to 50.60/100,000, severe obesity from 2.90 to 12.18/100,000, and hypothyroidism from 5.33 to 19.74/100,000.

The South KID region covered the two NOAA climate regions with the hottest average annual temperature and highest UV index (Figure 6). Blacks, Hispanics,

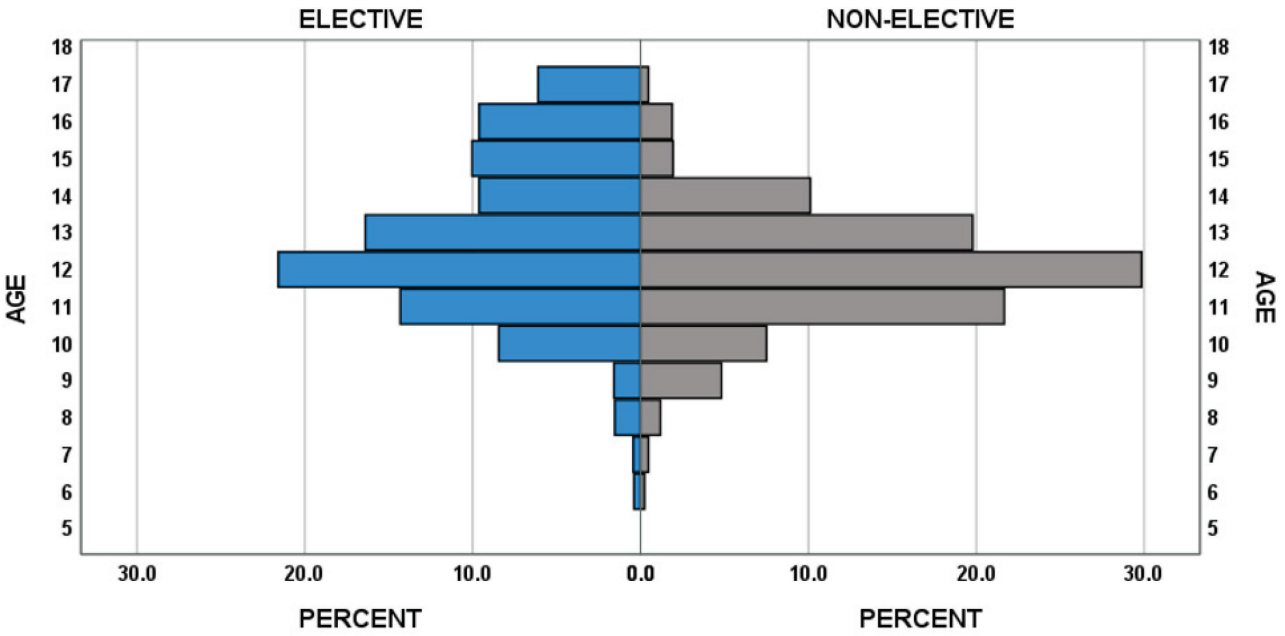

Figure 4. *Age of SCFE patients at elective vs. non-elective admission.*

Table 1. Likelihood and Incidence Rates of SCFE Among Races

	OR (95% CI)	P value	Per 100,000 Ages 9 to 16
Black	1.66 (1.40 to 2.97)	<.001	4.32
Hispanic	1.27 (1.07 to 1.51)	.005	2.38
Native American	1.10 (0.54 to 2.21)	.78	2.37
Caucasian	Reference	-	1.45
Asian/PI	0.78 (0.49 to 1.24)	.30	0.99

Caucasians, Asian/PI, and Native Americans were all less likely to develop SCFEs in this region. When compared to each race group's hospital admission base rate, likelihood of SCFE hospital admission was the least in Caucasians (26.4% vs. 37.0%), followed by Hispanics (29.7% vs. 36.9%), Blacks (43.4% vs. 49.6%), and Asian/PI (15.8% vs. 19.7%).

All race groups were more likely to develop SCFEs in the West KID region, which included the NOAA climate regions with the coldest average annual temperature and lowest UV index. All Native American SCFEs occurred in this region (100.0% vs. 46.1%) as well as most Asian/PI (78.9% vs. 45.3%) and Hispanic (49.5% vs. 39.1%) SCFEs. Caucasians (22.4% vs. 17.8%) and Blacks (10.5% vs. 8.0%) were more likely to be admitted for SCFEs than their hospital admission base rate.

The Northeast and Midwest KID regions covered the four NOAA climate regions with the coldest annual average temperature and lowest aggregate UV index. Blacks (27.4% vs. 18.0%) and Caucasians (23.3% vs. 16.2%) were more likely to develop SCFEs in the Northeast KID region. This was the highest SCFE incidence found among any region for both races. Hispanics were marginally less likely (15.1% vs. 16.3%) compared to their hospital admission base rate.

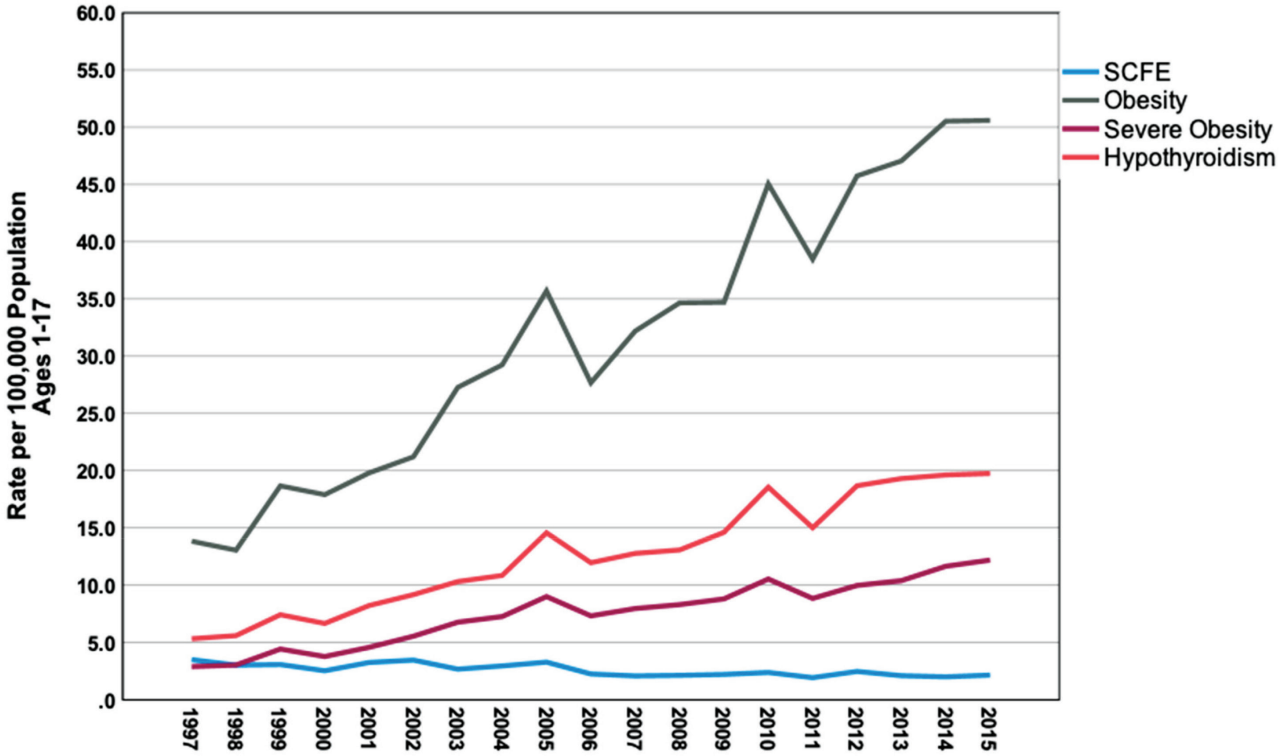

Figure 5. *Incidence rates of SCFE and metabolic comorbidities, according to HCUPnet NIS Database (ICD-9-CM coded).*

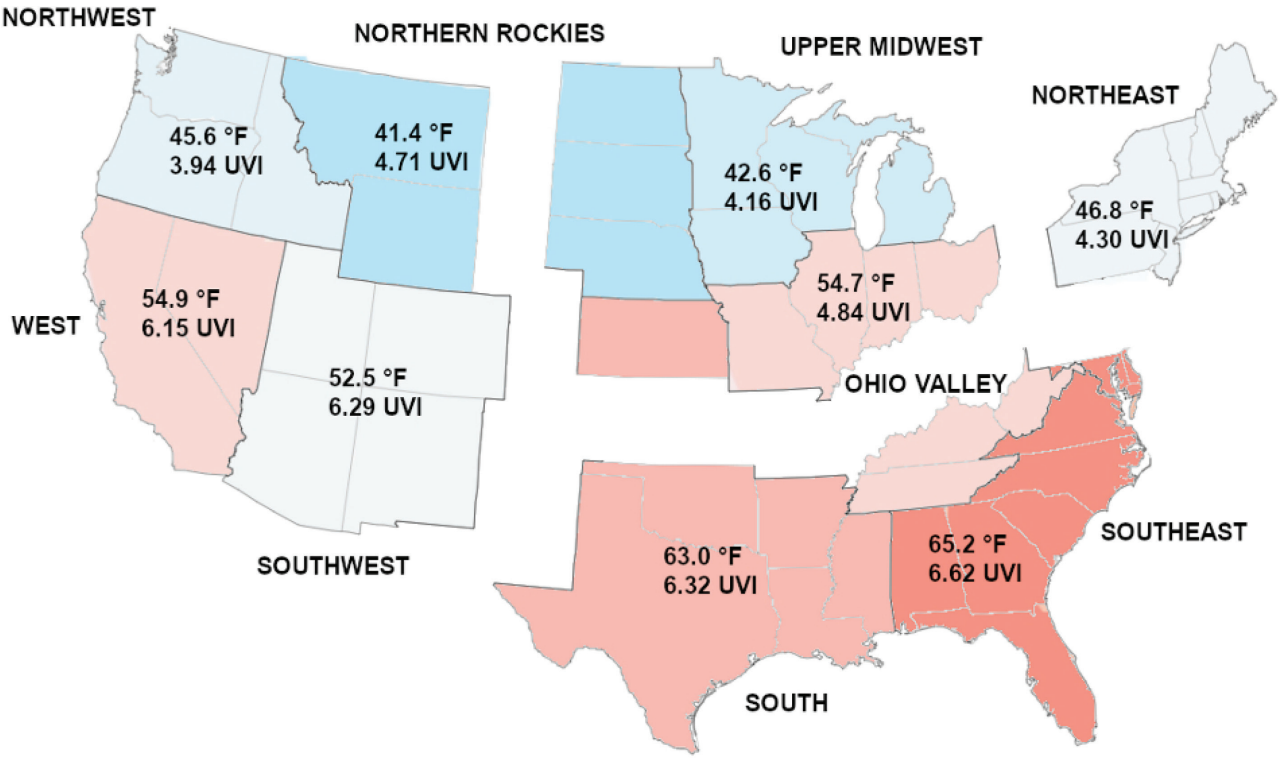

Figure 6. *United States divided into four KID hospital regions which are subdivided into nine NOAA CLEI climate regions (multiple colors). Each climate region is labeled with average annual temperature (°F) and average annual ultraviolet ray index (UVI). Red colors represent warmer temperatures, blue colors represent colder temperatures. Source: NOAA CLEI.*

In contrast, the Midwest KID region has a similar average annual temperature and UV index to the Northeast but lower SCFE incidence for all racial groups. Asian/PI patients were the least likely to have SCFEs compared to hospital admission base rate (5.3% vs. 14.8%), followed by Blacks (18.7% vs. 24.4%), Hispanics (5.7% vs. 8.7%), and Caucasians (27.9% vs. 29.0%).

A majority (53.4%) of SCFEs occurred in the summer with peak incidence in April (12.2%), July (9.4%), and August (8.3%). Caucasian SCFE peak incidences were in April (13.5%) and July (15.7%). Blacks in April (12.6%), May (10.6%), and September (10.1%). Hispanics in October (13.3%), June (12.3%), April (12.3%). Asian/PI in June (23.5%), September (17.6%), and January (17.6%) (Table 2).

Discussion

We found the overall incidence of SCFE was 2.66/100,000 children. This is discordant to previously published value of 10.8/100,000.[1] This value is also different from widely variable single State values published previously, which is expected because of the inclusion of a much larger sampling of U.S. children in this study. The discordance to previously published values may be attributed to the advancements in the administrative databases. The considerable increase in participating States and database redesigns reduced sampling errors and may produce more accurate results as shown by the narrower confidence intervals compared to previous designs.

The average age of SCFE presentation was 12.8 years for boys and 11.6 years for girls. This is similar ages reported by Lehman et al. previously (12.7 years for boys and 11.2 for girls). This difference in age is more narrow (1.2 years) than previously reported differences.[1,10] The overall age of presentation was 12.3 years, which counters a previously theorized downward trend in presenting age due to earlier maturation of children in present day.[1] Although longitudinal studies[11-13] are suggestive of earlier maturation of children presently, this does not seem to be affecting age of presentation in regards to SCFE. The theory behind physiologic changes occurring during the rapid pubescent growth period as a cause is still plausible, as the younger presentation of females can correlate to the start of this phase comparably to boys.

Boys were more likely to develop SCFEs (OR 1.73; 95% CI, 1.51-1.97; $P<.001$) than girls. This could be secondary to boys being more physically active than their counterparts from increased micro-trauma to the proximal epiphysis.[14] Anatomical variance between sexes could also be a reason for the increase in SCFE amongst boys.[15] Differences between sexes in the development of the pelvis, version, and acetabulum depth have been proposed, but causation is still lacking.[16,17]

The majority of SCFEs in this study were treated on a non-elective basis, which could possibly be skewed due to KID sampling only inpatient data. However, recent data suggest a trend toward outpatient treatment of these injuries provided equivocal complication and readmission rates.[18] The outpatient designation is likely due to discharge status on the same day of the procedure rather than a true outpatient surgery center. These patients would then still be captured by the database

Table 2. SCFE Incidence by Month and Season*

Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
8.1%	6.6%	7.3%	12.2%	8.1%	8.0%	9.4%	8.3%	7.4%	8.2%	5.4%	6.4%
Winter			Summer						Winter		
22.0%			53.4%						19.9%		
*4.7% missing monthly data											

in this study, most likely producing a reliable result of procedures taking place in hospital settings.

There has been a long-suggested association between obesity and SCFE. This study demonstrated an overall obesity rate of 30.7%, with 23.2% and 7.5% having obesity and severe obesity diagnoses when presenting with SCFEs. An unexpected finding was the divergent trend between adolescent obesity in the U.S. and SCFE rates for the same period (Figure 2). These results could support recent challenges of reported correlations between obesity and SCFEs. Previous studies have been small single institution cohorts that are difficult to generalize trends that lend causation of pathology.[19-22] According to the National Health and Nutrition Examination Survey (NHANES),[23] the prevalence of obesity in pediatric ages 2-19 during 2017–2020 was 19.7% (95% CI: 17.9–21.6%). Obesity was highest among Hispanics (26.2%) and Blacks (24.8%), followed by Caucasians (16.6%) and Asians (9.0%). Similarly, the 2018 National Center of Health Statistics (NCHS) reported obesity rate for 6-11 years was 20.3% (1.8) and 12-19 years 21.2% (1.3).[24] The obesity rate was 19.3% (1.0), including a severe obesity rate of 6.1% (0.7) for ages 2-19.[24] Recent studies have suggested a divergent relationship between SCFE incidence and increasing obesity rates.[25,26] Notably, a 27.5% decrease in SCFEs in the U.S. between 1997 and 2012[25] and a 34% decrease in SCFEs in Ontario, Canada, between 2002-2011.[26] The uncertainty around this relationship could be linked to the reliability of direct measurements and reporting of obesity by institutions. Additionally, national obesity estimates are based on a relatively small sample size of less than 3,000 children and adolescents.[24] Future studies may clarify this association with more advanced analytics and consider obesity's interactions with anatomical and biomechanical characteristics.

Seasonal variation, position in the country (latitude), and vitamin D metabolism have been suggested to have possible clinical links to developing SCFEs.[27-33] These likely are multifactorial and include activity outdoors, seasonal sports, skin color, and UV light exposure. The majority of human vitamin D3 is obtained through the interaction between sunlight (UVB) and 7-dehydrocholestol. Vitamin D can also be obtained naturally or through fortified foods. Vitamin D deficiency is prevalent even in healthy adolescents, despite effects to increase intake through health campaigns and food fortification.[34] Melanin, which gives skin its pigment, absorbs UVB that initiates vitamin D synthesis, decreasing production in darker skin individuals than less pigmented skin. The present study found SCFEs were more likely to occur in NOAA climate regions with the coldest average annual temperature and lowest UV index. In contrast, SCFEs were less likely to occur in NOAA climate regions with warmer average annual temperatures and higher UV indices. The most pronounced difference was found in Black, Hispanic, and Caucasian adolescents, as they were more likely to have SCFEs in colder climate regions with lower UV indexes and less likely to have SCFEs in warmer climate regions with higher UV indexes. Blacks were most likely to have SCFEs in the Northeast followed by Caucasians, and Hispanics in the West. Caucasians were least likely to have SCFEs in the South, followed by Blacks and Hispanics. Studies have shown that skin color can affect the metabolism of vitamin D with people of darker skin color producing low vitamin D.[35] This finding suggests a lower SCFE incidence rate among Caucasians, Blacks, Hispanics, and Asians in hotter climate regions with higher UV indexes. However, because so many environmental, cultural, and physiologic factors can influence sunlight-induced vitamin D synthesis, it is difficult to confirm these theories. Fortified foods may influence this fact as well if the assumption that an adolescent has a balanced diet. This is because, during low UV months and higher latitudes, dietary sources become imperative to supply essential vitamin D precursors. However, cross-sectional studies suggest that current fortification practices alone are not effective in preventing hypovitaminosis-D in these months and latitudes.[36,37] Therefore, this data may suggest: 1) UVB may have a protective effect against developing SCFEs in those with lighter skin tones, 2) Populations living

at higher latitudes have a higher incidence of SCFEs, 3) Areas with high climate temperature averages have higher incidence of SCFE.

There are limitations inherent to administrative databases that need to be discussed. One of the major limitations of administrative databases is that inaccurate coding can grant over-documentation or under-documentation, causing cohorts to be inaccurately skewed in either direction. Previously, there has been doubt on the reliability of ICD-9 documentation in previous database studies, which the improvements to the ICD-10 likely circumvents this issue. Also, the databases are collected from institutions, these tend to focus on the coding aspect of billing with a disconnect between what is transpiring in patient care and what is ultimately coded. Another limitation of nationwide data is the inpatient only data they provide. However, pertaining to this study, the assumption that a majority of SCFEs will mostly be treated at participating hospitals rather than at outpatient ambulatory centers. Finally, KID hospital regions include varying climate regions which limit definitive generalizability.

Conclusion

This study provides the most up-to-date national data regarding incidence estimates and risk factors for SCFE identified previously. In the current study, SCFE incidence is reported to be lower than previous while SCFE rates among different races and sex are similar to previously reported rates. Geographical climate variation (average temperature and UV index) within the U.S. appears to be associated with differing incidence of SCFE particularly as it interacts with patient race and presumed skin tone. The multifactorial aspects of this disease make diagnosing and identifying individuals at risk difficult. It is the hope of the study presented that it will be a catalyst to consider SCFE risk factors differently in the future.

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Disclaimer

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