Slipped capital femoral epiphysis (SCFE) is the most common disorder affecting the hip during adolescence and involves displacement of the upper femoral epiphysis. Obesity has been implicated as a risk factor for the development of SCFE. It has been suggested that the biomechanical forces in overweight children may cause disruption of the growth plate by shearing forces which are further amplified by decreased femoral anteversion.

Previous studies have suggested a racial variation in the incidence of SCFE, with several ethnic minorities in North America having a higher incidence than the white population. These included an African-American cohort with a 4.6-fold increased relative incidence, and a Hispanic and a Native-American cohort each had a 2.2-fold increased incidence. An increased incidence of SCFE has also been reported in the New Zealand indigenous Maori population with respect to the Caucasian population, and similar data have been reported for various Pacific Island communities.

The prevalence of obesity has become a global health issue and young Australians are not exempt from this epidemic. Data show that rates of obesity among young Australians have tripled between 1970 and 2000, and this increase has been observed in both genders and across all age groups. Recent data indicate that at least one in four Australian youths is overweight or obese. There are several causes for this, including an increase in sedentary behaviour, a decline in physical activity, and the more widespread availability of cheap, energy-dense foods, often high in fats and sugars. The incidence of obesity is increasing at an alarming rate in the indigenous population, and it is inversely proportional to high socioeconomic status.

Despite an abundance of international data examining the links between SCFE, obesity and race, there are no published data relating to an Australian population and its indigenous cohort. This study examines the epidemiology of SCFE in South Australia and illustrates the changing incidence and characteristics of the South Australian patient with this condition.

Patients and Methods

We conducted a retrospective review of all patients who presented to South Australian metropolitan hospitals with clinically diagnosed SCFE. International Classification of Diseases (ICD) codes specific for SCFE were used to identify patients at the Women's and Children's Hospital (WCH) and Flinders Medical Center (FMC) between January 1988 and December 2007. These two tertiary facilities serve a large catchment area of approximately 980,000 km² and 1.6 million people. A small number of patients were included. The prevalence of obesity has become a global health issue and young Australians are not exempt from this epidemic.
244 patients underwent a total of 351 operations on the hip. Parameters recorded included age at diagnosis, race, gender, medical comorbidity status, unilateral/bilateral SCFE at the time of presentation, length of hospital stay, surgical treatment, secondary contralateral slip and complications. Weight was the only morphological measurement always recorded, as this is a pre-anesthetic requirement for calculation of the dose of drugs; height was frequently unreported.

The Department of Applied Anthropometry at the University of South Australia provided percentile information regarding the weight and age of the general South Australian adolescent population from 1985 to 2007. The Australian Bureau of Statistics was also consulted for general census data on the South Australian population between ten and 19 years of age. Patients were divided arbitrarily into three chronological time periods to allow a clearer definition of the changing chronological incidence of weight and SCFE: 1988 to 1993, 1994 to 2000 and 2001 to 2007. This allowed for graphical comparison and subsequent analysis of the particulars of the South Australian SCFE cohort.

**Statistical analysis.** Data were analysed using Intercooled Stata 10.1 (StataCorp, College Station, Texas) for Windows. Poisson Regression Analysis was used to determine the changing incidence of SCFE over the study’s time period (the census population at each year was used as the exposure variable). For normally distributed dependent variables i.e. age at diagnosis, one-way analysis of variance (ANOVA) and linear regression analysis were used to determine any associations with categorical predictor variables. The Kruskal-Wallis Rank Test was used with significantly skewed predictor variables e.g. weight. Pearson’s chi-squared analysis or Fisher’s exact test (if any expected cell counts were less than five) were used to test for associations between categorical variables. A p-value < 0.005 was considered statistically significant.

**Results**

Of the 244 patients identified between 1988 and 2007, 154 (63%) were male and 90 (37%) female, representing a male predominance ratio of 1.71:1 (Table I). The general health of the patients was acceptable, with 239 of 244 (98.0%) having an ASA score ≤ 2.

Twenty-three patients presented with bilateral SCFE and underwent bilateral internal fixation. Of the 221 patients presenting with unilateral SCFE, 37 underwent prophylactic pinning of a contralateral normal hip and therefore
had bilateral internal fixation procedures. A total of 47 patients with unilateral SCFE underwent fixation of the affected hip and subsequently re-presented with SCFE of the contralateral hip at a later date within the 20-year period. This brought the total number of hip procedures performed on the cohort to 351. This figure was used to determine the nature and rate of complications.

The surgical treatment was in situ fixation for the majority of patients (348 of 351, 99.1%), with two hips requiring open reduction and internal fixation and one hip needing internal fixation following ‘inadvertent reduction’. The surgical technique was developing during this period: between 1988 and 1994 fixation was achieved using two Knowles pins (46 of 351, 13.1%). Thereafter, the use of cannulated AO screws predominated, with a single screw being used in most cases. Two screws were used in 23 patients (6.6%), and 282 (80.3%) patients fixation with a single screw. Two patients underwent rotational osteotomy as primary treatment.

Incidence. We found that the incidence of SCFE in South Australia increased from 2.8 cases per 100 000 to 8.2 per 100 000 over the 20 years of the study, despite an essentially unchanged adolescent population, census data showing that the total South Australian adolescent population (ten- to 19-year-olds) in 1991, 1996, 2001 and 2006 remained between 235 351 and 239 264. Poisson regression analysis revealed that for every chronological year after 1988 the incidence of SCFE in the study population increased by a multiplicative factor of 1.056 (p < 0.001), an approximately threefold increase over this time. Figure 1 demonstrates the trend of increasing frequency of SCFE.

Australian indigenous patients made up 9% (22 of 244 cases) of the study population (Table I). The 2006 census figures showed that the South Australian indigenous population represented 3.1% of the total South Australian population between seven and 18 years of age. There was therefore an almost three-fold increase in the incidence of SCFE in the indigenous population (p < 0.0001).

Age. Of the total study population, 236 (96.7%) patients were aged between ten and 19 years at the time of initial presentation, with eight (3.3%) being aged under ten years. There were no reported cases of children with SCFE below the age of ten occurring before 1993. Six of the eight cases reported under the age of ten were female. There were no associated endocrinopathies in the subgroup of patients presenting before ten years of age, nor in any patients presenting in the late teenage years. In the entire cohort there were only two patients with an endocrinopathy, one with panhypopituitarism and one with hypothyroidism. The mean age at diagnosis for the study population between 1988 and 2007 was 12.9 years (SD 1.82), with age normally distributed (Fig. 2). The mean age at diagnosis between 1988 and 1993 was 13.5 years (SD 1.85). This decreased to 12.7 years (SD 1.97) between 1994 and 2000. The mean age between 2001 and 2007 was 12.8 years (SD 1.65). There was a statistically significant change in the mean age at diagnosis between these time frames: using linear regression, the mean age in the second period was lower by 0.80 years (p = 0.02) than in the first period, and in the third period was lower by 0.67 years (p = 0.04) compared to the first period. There was no statistical difference between the second and third time frames with respect to age at diagnosis (p = 0.61). When gender was taken into account the significance of these differences in age at diagnosis between the different time periods was weakened (p = 0.067, between time 1 and time 2; and p = 0.086, between time 1 and time 3).

The mean age at diagnosis with respect to gender revealed that females presented at an earlier age than males. The mean age of diagnosis of SCFE in girls was 11.9 years (SD 1.52), compared with 13.5 years (SD 1.73) in boys; this difference was statistically significant (p < 0.0001, one-way analysis of variance).

Weight. According to percentile data from the University of South Australia, the average weight of a South Australian adolescent in 1985 to 1993 was 47 kg, increasing to 50 kg in 1994 to 2000 and again to 51.2 kg in 2001 to 2007. Studies on obesity in South Australian adolescents have also shown an increase in adiposity from 1997 to 2002, primarily in boys and in girls of low socioeconomic status.20 Figures 3 to 8 show gender-separated data from South Australia for time intervals 1985 to 1993, 1994 to 2000 and 2001 to 2007, comparing the SCFE cohort to weight-for-age percentile data. The data demonstrate that patients with SCFE are generally overweight.

The median weight of a patient with SCFE between 1988 and 1993 was 58 kg (IQR = 17), compared to 60.8 kg (IQR = 20) between 1994 and 2000 and 64 kg (IQR = 17.9) between 2001 and 2007. It was found that male SCFE patients were heavier than female SCFE patients on presentation (medians of 65.6 kg (IQR = 19) and 57.1 kg (IQR = 17.5), respectively). Using the Kruskal-Wallis rank test, it was determined that there was a difference in weight between the three different time periods of
diagnosis observed (p < 0.047): specifically, using linear regression with weight transformed on a natural logarithmic scale, showed that the median weight of SCFE patients in the third period (2001 to 2007) increased by a factor of 1.079 compared to the first period (1988 to 1993) (p = 0.075). When gender was taken into account, weight in the third period (2001 to 2007) increased by a factor of 1.096 (p = 0.024) compared to the first period (1988 to 1993). It was found that there was no statistically significant difference in the median weight of non-indigenous versus Australian indigenous patients (59.5 kg (IQR = 13) and 61.5 kg (IQR = 19), respectively) (p = 0.51, Kruskal-Wallis Rank Test).

**Laterality.** A total of 23 of the 244 patients (9.4%) presented with bilateral SCFE, including 4 of 22 (18.2%) indigenous patients and 19 of 222 (8.6%) non-indigenous patients. Aboriginals were therefore more than twice as likely as non-indigenous Australians to present with bilateral SCFE (18.2:8.6 = 2.09:1), although this conclusion was not statistically significant (p = 0.14, Pearson chi-square analysis). Patients with bilateral SCFE tended to be more overweight than those who presented with unilateral SCFE. The median weight of the bilateral cohort was 65.3 kg (IQR = 20.2), whereas the median weight of the unilateral cohort was 61 kg (IQR = 18.1), although again this did not reach statistical significance (p = 0.09, Kruskal-Wallis Rank Test). Of the bilateral cohort, 20 out of 23 (87%) were boys (Table II).

A total of 221 (90.6%) of patients presented with a unilateral SCFE, and 37 (16.7%) of these underwent prophylactic pinning of the contralateral hip. This included eight of the 18 (44.4%) indigenous patients who had a unilateral SCFE. The total non-indigenous cohort who received prophylaxis can be expressed as 29 of 203 (14.3%). Australian indigenous patients were thus more than three times as likely (44:14 = 3:1) as non-indigenous patients to have unaffected hips prophylactically pinned (p = 0.004, Fisher's exact test), indicating a significant association between race and prophylactic fixation.

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**Fig. 3**

Weight-for-age percentile data and mean weight of slipped capital femoral epiphysis (SCFE) for boys between 1988 and 1993.

**Fig. 4**

Weight-for-age percentile data and mean weight of slipped capital femoral epiphysis (SCFE) for girls between 1988 and 1993.
Of the remaining 184 patients who presented with unilateral SCFE and did not have a prophylactic fixation of the contralateral hip, 47 subsequently required fixation of the contralateral hip after developing symptoms or signs. This represented 25.5% of all patients presenting with unilateral SCFE.

Complications. The overall surgical complication rate for the cohort was 11.4%. This excludes elective removal of the pins, including removal for symptoms or patient/family preference (19 of 351, 5.4%). Complications included avascular necrosis of the femoral head (7 of 351, 2.0%) and infection (5 of 351, 1.4%). Implant problems, including intra-articular penetration and fracture, were the most common complications (20 of 351, 5.7%). Table III lists the complications of the cohort. There was no difference in the rate of complications between indigenous and non-indigenous patients, ($p = 0.14$, Fisher’s Exact Test).

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**Table II.** Laterality of the 244 patients with slipped capital femoral epiphysis compared with gender and race

<table>
<thead>
<tr>
<th>Number (%)</th>
<th>Gender (n, %)</th>
<th>Race (n, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Unilateral</td>
<td>221 (91)</td>
<td>87 (40)</td>
</tr>
<tr>
<td>Bilateral</td>
<td>23 (9)</td>
<td>3 (13)</td>
</tr>
</tbody>
</table>

**Table III.** Complications of the surgical treatment of slipped capital femoral epiphysis

<table>
<thead>
<tr>
<th>Incidence</th>
<th>Total complications</th>
<th>40 (11.4%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avascular necrosis</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Implant problem</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Our study demonstrates associations between weight and the incidence of SCFE using weight-for-age percentile data. The concept of the Paediatric Obesity Criterion supports the assessment methods that we used, defining obesity as a weight above the 95th percentile, with ‘at-risk’ children weighing in the 85th to 95th percentile bracket. The use of body mass index (BMI) to assess obesity in adults is well defined, but there is controversy over the suitability of BMI as a measure of obesity in children. Daniels et al stated that BMI is not an equivalent measure of body fat percentage in children, especially when gender, race and age are compared.

Body weight at presentation in patients with SCFE increased during the period of the study. Furthermore, there was a trend for marked obesity within the SCFE cohort in both genders and in all age groups. For example, the average female SCFE patient in the 1988 to 1993 cohort was on the 72nd percentile for weight, with 45% above the 98th weight percentile. Adhering to the Obesity Criterion, this demonstrates an association between obesity and SCFE.

A trend of decreasing age at diagnosis was noted in our SCFE cohort. This is consistent with the findings of Murray and Wilson, who noted an increased incidence of SCFE between 1981 and 2000 of 3.8 to 9.7 per 100 000 children, and a statistically significant decrease in the mean age at diagnosis from 13.4 to 12.6 years for boys (p = 0.007), and 12.2 to 11.6 years for girls (p = 0.047) in the Scottish population. As represented in Figure 6 (females 1994 to 2000), eight SCFE patients were diagnosed under the age of ten. One patient suffered from congenital aniridia and another from transposition of the great cardiac vessels, but there were no patients with an endocrinopathy associated with SCFE.

To the best of our knowledge there are no published data regarding the true nature of susceptibility of the Australian indigenous population to SCFE. Loder published an inter-
national multicentre study that purported to assess a Native Australian population, but in fact the data were drawn from a combined Native Australian/Pacific Island cohort of only 34 patients, with the majority (28) being of Maori Polynesian heritage. The findings of Loder’s study included a high rate of bilateral SCFE of 38%.23 The rate of bilateral disease in our indigenous Australian cohort was 18%.

The reasons for the threefold increase in the incidence of SCFE in the indigenous population may be both genetic and socioeconomic in nature. The mean weight of the indigenous cohort was slightly less than that of the Caucasian cohort, indicating that the increased incidence in indigenous patients cannot be explained by obesity. It is reported that, as a general population, indigenous Australians have a lower general health, wealth and education status17,24,25 and are at increased risk of being sedentary.24,25 Reduced physical activity is a risk factor for chronic conditions such as diabetes, heart disease and obesity.24 In 2005, 75% of the Australian indigenous population reported being sedentary or taking little exercise, representing a 7% increase from the 68% reported in 2001.25

In our study 16.7% of patients with unilateral SCFE underwent prophylactic contralateral pinning. This was usually reserved for patients who either were felt to be likely to be non-compliant or who were from rural and remote locations. Of the indigenous cohort, 44% underwent prophylactic contralateral hip pinning, compared with 16.7% of the total prophylactic pinning cohort.

There is a wide range of secondary contralateral SCFE fixation in the literature, from 25% to 66%.26,28 Our cohort of 184 patients with unilateral SCFE included 47 (26%) who subsequently developed contralateral SCFE. This low rate of subsequent slippage compared to that reported by others and would appear to justify our selective approach.

The data collected in this study indicate a weak association between increased weight and laterality (p = 0.09). This is consistent with the findings of Bhatia et al,5 who showed that the mean BMI of patients with bilateral SCFE was significantly higher than that of patients with unilateral disease. This may be consistent with the theory of increased shearing forces causing abnormal shifts in the femoral head physeal area, leading to SCFE. Although the small bilateral cohort precluded this finding from statistical significance, we believe that risk factors for bilateral SCFE are obesity and indigenous heritage. Clinicians should apply extra vigilance and a higher index of suspicion when evaluating these patients.

In this study, the decreasing mean age at diagnosis showed that South Australian female patients with SCFE are on average 1.6 years younger than their male counterparts. This is consistent with earlier puberty in females, and predictable biological changes, including increased height, weight and fat deposition. A number of international cohort studies also report a significant decrease in the mean age at diagnosis in females.7,29

In conclusion, we report on the South Australian adolescent population with new evidence of a threefold increase in the incidence of SCFE over a 20-year period and a threefold increase in the risk of SCFE in Australian indigenous children compared to non-indigenous children. Patients with SCFE are usually overweight or obese and appear to be getting younger and more overweight, and patients who are both morbidly obese and indigenous Australian are more likely to present with bilateral SCFE. The significant long-term morbidity associated with SCFE highlights the importance of public health initiatives to reduce obesity, and to identify subgroups of patients who have an increased susceptibility for the development of SCFE.

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

References


