Patient-Reported Health Outcomes After in Situ Percutaneous Fixation for Slipped Capital Femoral Epiphysis
An Average Twenty-Year Follow-up Study

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Background: Percutaneous in situ fixation is the gold-standard treatment for stable slipped capital femoral epiphysis (SCFE). While numerous studies have documented good to excellent long-term clinical and radiographic outcomes, few have documented long-term patient-reported outcomes of patients with this condition.

Methods: This retrospective study was performed to document long-term patient-reported outcomes of a cohort of sixty-four patients with SCFE (ninety-one affected hips) and determine whether the slip angle was associated with poorer health outcomes as measured with the Short Form-12 (SF-12) Physical Component Summary (PCS) and Mental Component Summary (MCS) scores, modified Harris hip score (mHHS), and University of California at Los Angeles (UCLA) Activity Scale.

Results: The mean age at presentation was 12.6 years, and the mean duration of follow-up was 19.6 years. At the time of follow-up, the cohort reported higher rates of diabetes, obesity, and hypertension than the general U.S. population. The mean body mass index (BMI) had increased by 10.2 kg/m², with 72% of the subjects meeting the criteria for obesity (BMI > 30 kg/m²) at the time of follow-up. The mean age and sex-adjusted PCS and MCS scores were 49.6 and 50.0, respectively, and the mean mHHS was 84.9. Multivariable general linear modeling revealed no association between the initial slip angle and the PCS, MCS, mHHS, or UCLA Activity Scale score. Male sex and a lower BMI were the only predictors of better long-term PCS, mHHS, and UCLA Activity Scale scores. Subjects with a bilateral slip had outcomes similar to those with unilateral disease.

Conclusions: The general self-reported health of this cohort was poor compared with that of the general population. The slip angle on presentation did not correlate with any patient-reported outcome measure collected for this study. Higher BMI was one of the only clinical predictors of patient-reported outcomes.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Disclosures: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete Disclosures of Potential Conflicts of Interest submitted by authors are always provided with the online version of the article.
non-anatomic position. The residual non-anatomic position has been associated with abnormal joint kinematics and femoroacetabular impingement, which may lead to premature onset of osteoarthritis in the long term. Several realignment osteotomies have been described to correct this residual deformity after successful union of the physis, with good results and relatively low rates of complications.

There has been increasing interest in new open reduction techniques to improve the anatomic alignment of unstable and, in some series, stable slips. Unfortunately, the duration of follow-up in the literature to date is insufficient to support the claim that reducing femoroacetabular impingement will prevent the long-term development of degenerative osteoarthritis. Early reports were encouraging, with restoration of alignment of the proximal femoral epiphysis and low rates of complications such as osteonecrosis, but more recent publications have documented higher complication rates and have tempered enthusiasm for this procedure.

Despite numerous publications reporting good clinical outcomes, there remains a lack of long-term patient-reported outcomes after percutaneous in situ fixation for SCFE. In order to guide our understanding of both currently available techniques and future innovations in the management of SCFE, we must improve our understanding of patient-reported health outcomes after treatment for this condition. Thus, the purposes of this study were (1) to describe the long-term patient-reported outcomes of a cohort treated with in situ fixation for SCFE and (2) to determine whether the slip angle magnitude and other clinical and demographic factors were associated with these patient-reported health outcomes.

**Materials and Methods**

**Study Design**

This is a retrospective cohort study. After institutional review board approval, surgical and administrative databases were searched to identify patients who had undergone in situ percutaneous screw fixation for SCFE at our institution between January 1, 1978, and December 31, 1995. Inclusion criteria were a diagnosis of SCFE and treatment with in situ fixation under fluoroscopic guidance without reduction of the slip. A variety of implants were used during the study period, including multiple smooth Steinmann pins, and single or multiple solid or cannulated screws with and without washers. We excluded children who had undergone surgery at an outside institution but had been referred to our institution for follow-up (n = 20), had a medical comorbidity that predisposed them to SCFE (n = 8), or had missing or incomplete medical records (n = 59). The records of the remaining 200 patients were retrospectively reviewed for demographic data, clinical information, and previous radiographs. Attempts were made to contact all patients and invite them to attend a clinical, radiographic, and survey evaluation. Contact was made with seventy-three patients or their families; seven patients had died and two had undergone total hip replacement since their initial presentation and were subsequently excluded from the study group. The remaining sixty-four patients (32.0%) returned for outpatient follow-up and constitute our final study group. Comparison between eligible patients who did and did not return for outpatient follow-up revealed no significant difference in sex distribution (p = 0.18), mean age at presentation (p = 0.25), or body mass index (BMI) at presentation (p = 0.53).

The mean ages at presentation and follow-up for the final study group were 12.6 years (interquartile range [IQR] = 11.6 to 13.7 years) and 32.3 years (IQR = 28.9 to 35.5 years), respectively, with a mean duration of follow-up of 19.6 years (IQR = 16.3 to 22.2 years). There was no significant difference (p > 0.05, β = 0.80) in the mean age at presentation, mean age at the time of follow-up, or mean duration of follow-up between unilateral and bilateral cases. Fifty-six percent (n = 36) of the cohort was male. The history obtained at the time of presentation was consistent with a chronic slip in 47% (n = 43), acute-on-chronic in 37% (n = 34), and acute in 15% (n = 14). According to the criteria of Loder et al., the slip was classified as stable in 74% (n = 67) and unstable in 26% (n = 24). The slip grade was mild in 56% (n = 51), moderate in 40% (n = 36), and severe in 4% (n = 4). 59% (n = 38) of the cohort had a unilateral slip. Of the 42% (n = 27) with a bilateral slip, 37% (n = 10) presented with the two slips simultaneously and 63% (n = 17) presented in a staged fashion.

**Outcome Measures**

Seventy-three patients or their families were contacted by telephone. Sixty-four patients (ninety-one affected hips) consented to participate in this study and attended our institution for evaluation. Height and weight were recorded by a registered nurse to calculate BMI (kg/m²). A non-validated self-reported general health questionnaire was administered to collect information on overall health, presence or absence of comorbidities (hypertension, diabetes, shortness of breath, sleep apnea, chest pain with exertion, and kidney disease), recent hospitalizations and surgical procedures, exercise history, smoking history, and whether the ability to work had been affected by the patient’s general health.

Previous radiographs obtained at the time of presentation were reviewed. The Southwick slip angle was calculated by subtracting the epiphysial-shaft angle of the normal side from the epiphysial-shaft angle of the affected hip as measured on frog-leg anteroposterior pelvic radiographs. For patients who presented with a simultaneous bilateral slip, the slip angle was recorded as the epiphysial-shaft angle minus 12° as originally described by Southwick. For patients who presented with staged bilateral disease, the contralateral hip acted as its own control: the last normal epiphysial-shaft angle prior to the development of the second slip was subtracted from the epiphysial-shaft angle at the time of presentation with the second slip. The slip grade was based on the slip angle and defined as mild (<30°), moderate (30° to 60°), or severe (>60°). The measurements were performed by a pediatric orthopaedic fellow (B.G.E.) who was blinded to all patient-reported outcome scores at the time of measurement. Patient-reported outcomes were obtained at their clinical visit with the Medical Outcomes Study Short Form-12 (SF-12), the modified Harris hip score (mHHS), and the University of California at Los Angeles (UCLA) Activity Scale. The SF-12 is an abbreviated twelve-item variant of the SF-36 patient-reported health status measure. It consists of eight scaled scores of general health (vitality, physical function, bodily pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning, and mental health). These scaled scores are often combined into two component summary scores—physical (PCS) and mental (MCS)—representing an aggregate physical component summary score and mental component summary score, respectively. SF-12 component scores in this study were adjusted using U.S. population norms to generate age and sex-adjusted scores valued from 0 to 100, with higher values representing better health. Standardized PCS and MCS scores have a mean of 50 points each (1 standard deviation [SD] = 10 points). The mHHS is an eight-question patient-reported hip-specific functional questionnaire that evaluates pain and physical function. It was modified from the original Harris hip score by removing the clinician-based range-of-motion measurements, which have been shown to be prone to high interobserver variability. The mHHS is scored from 0 to 100, with higher values representing better function. Use of the mHHS for patients with bilateral disease has not been validated. The UCLA Activity Scale is an ordinal patient-reported activity measure scored from 1 to 10, with higher levels representing more active pursuits. It has been shown to be valid and reliable in musculoskeletal populations.

**Statistical Analysis**

Baseline patient demographics and clinical factors are described for the entire cohort. Demographic and clinical factors were compared between patients with unilateral and bilateral disease using an unadjusted t test for continuous variables and chi-square analysis for categorical variables. The association between slip angle and each health outcome measure was evaluated using scatter plots and multivariable general linear regression analysis with statistical adjustment.
for relevant demographic and clinical factors. The mHHS was obtained for both hips of patients with bilateral disease so mixed-model regression was utilized to prevent bias from repeated measures. All multivariable analyses were repeated using the slip grade as the primary predictor. The results of the repeat analyses will not be reported as they yielded similar findings.

Source of Funding
This study was performed without external funding support.

Results
At the time of follow-up, 23% of the cohort (n = 15) reported their health as “excellent”; 61% (n = 39), as “good”; 13% (n = 8), as “fair”; and 3% (n = 2), as “poor.” A diagnosis of diabetes was reported by 8% (n = 5) of the cohort, with an additional 9% (n = 6) reporting a previous high blood sugar reading; 16% (n = 10) reported being diagnosed with hypertension, and 8% (n = 5) reported chest pain with exertion. In addition, 23% (n = 15) of the cohort reported that their health interfered with their job performance. The mean BMI was 26.9 kg/m² (IQR = 23.4 to 29.7 kg/m²) at the initial presentation and 37.1 kg/m² (IQR = 29.8 to 42.2 kg/m²) at the time of follow-up.

Overall, the mean SF-12 PCS and MCS scores for the cohort were 49.6 (standard error of the mean [SE] = 1.2, IQR = 43.7 to 56.2) and 50.0 (SE = 1.3, IQR = 41.5 to 58.6), respectively. The mean mHHS was 84.9 (SE = 1.7, IQR = 75.1 to 96.2), and the mean UCLA Activity Scale score was 7.3 (SE = 0.3, IQR = 6.0 to 10.0). No significant differences in any patient-reported outcomes were seen between unilateral and bilateral cases (p > 0.05, β = 0.80).

PCS scores showed positive associations with male sex and lower BMI at the time of follow-up but no significant associations

### TABLE I Multivariable Linear Regression Analysis of Demographic and Clinical Predictors of SF-12 PCS Score (N = 64)*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>SE</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M versus F)</td>
<td>4.88</td>
<td>2.36</td>
<td>0.14, 9.60</td>
<td>0.04</td>
</tr>
<tr>
<td>Slip angle (deg)</td>
<td>0.07</td>
<td>0.08</td>
<td>−0.08, 0.23</td>
<td>0.33</td>
</tr>
<tr>
<td>Age at follow-up (yr)</td>
<td>0.20</td>
<td>0.29</td>
<td>−0.39, 0.79</td>
<td>0.49</td>
</tr>
<tr>
<td>Bilateral slip (Y versus N)</td>
<td>2.81</td>
<td>2.45</td>
<td>−2.1, 7.72</td>
<td>0.26</td>
</tr>
<tr>
<td>BMI at follow-up (kg/m²)</td>
<td>−0.34</td>
<td>0.11</td>
<td>−0.56, −0.11</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*i² = 0.24, df = 63. SE = standard error, CI = confidence interval, and df = degrees of freedom.

### TABLE II Multivariable Linear Regression Analysis of Demographic and Clinical Predictors of SF-12 MCS Score (N = 64)*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>SE</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M versus F)</td>
<td>2.26</td>
<td>2.83</td>
<td>−3.41, 7.93</td>
<td>0.43</td>
</tr>
<tr>
<td>Slip angle (deg)</td>
<td>−0.09</td>
<td>0.09</td>
<td>−0.27, 0.10</td>
<td>0.35</td>
</tr>
<tr>
<td>Age at follow-up (yr)</td>
<td>−0.04</td>
<td>0.35</td>
<td>−0.74, 0.67</td>
<td>0.92</td>
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<tr>
<td>Bilateral slip (Y versus N)</td>
<td>−0.67</td>
<td>2.94</td>
<td>−6.56, 5.22</td>
<td>0.82</td>
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<tr>
<td>BMI at follow-up (kg/m²)</td>
<td>0.01</td>
<td>0.13</td>
<td>−0.26, 0.28</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*i² = 0.03, df = 63. SE = standard error, CI = confidence interval, and df = degrees of freedom.

### TABLE III Multivariable Linear Regression Analysis of Demographic and Clinical Predictors of mHHS (N = 91)*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Estimate</th>
<th>SE</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M versus F)</td>
<td>11.23</td>
<td>3.07</td>
<td>5.09, 17.36</td>
<td>0.0005</td>
</tr>
<tr>
<td>Slip angle (deg)</td>
<td>0.003</td>
<td>0.10</td>
<td>−0.19, 0.20</td>
<td>0.97</td>
</tr>
<tr>
<td>Age at follow-up (yr)</td>
<td>0.39</td>
<td>0.38</td>
<td>−0.38, 1.15</td>
<td>0.32</td>
</tr>
<tr>
<td>Bilateral slip (Y versus N)</td>
<td>4.90</td>
<td>3.18</td>
<td>−1.47, 11.26</td>
<td>0.13</td>
</tr>
<tr>
<td>BMI at follow-up (kg/m²)</td>
<td>−0.50</td>
<td>0.29</td>
<td>−1.09, 0.08</td>
<td>0.007</td>
</tr>
</tbody>
</table>

*i² = 0.32, df = 63. SE = standard error, CI = confidence interval, and df = degrees of freedom.
with slip angle, age at the time of follow-up, or bilateral disease (Table I). There were no significant associations between MCS scores and any of the variables included in our model (sex, slip angle, age at the time of follow-up, bilateral disease, or BMI at the time of follow-up) (Table II). Similar to the PCS scores, the mHHS showed positive associations with male sex and lower BMI at the time of follow-up but no significant associations with slip angle, age at the time of follow-up, or bilateral disease (Table III). Finally, UCLA Activity Scale scores showed a positive association with lower BMI (Table IV). The association between UCLA Activity Scale scores and male sex approached but did not reach significance (p = 0.07) as did their associations with slip angle and bilateral disease (p = 0.12).

Discussion

Sixteen percent of the patients in our cohort rated their health as fair or poor. They also had higher reported rates of comorbid illness compared with the general population. In addition, the rate of mortality (9.9% of those whose status was known) greatly exceeded the crude accumulated U.S. mortality rate between the ages of twelve and thirty-two years (1.4%)20. Our patients’ reported rate of diabetes was 4.9 times higher than the national average (1.6%) for people forty-four years of age or younger21. The true prevalence of diabetes in our cohort may well be higher considering that an additional 9.4% of patients reported previous “high blood sugar” but did not identify themselves as diabetic. The rate of hypertension in our cohort was 2.7 times higher than the national average (5.8%) for adults twenty to thirty-four years of age22.

High BMI, a well-known risk factor for SCFE24-26, increased significantly (by 10.2 kg/m²) between the initial presentation and time of follow-up for this study. While a minority of patients (20.3%) were classified as obese at the time of the SCFE, the overwhelming majority (71.9%) were classified as obese at the time of follow-up. The obesity rate at the time of follow-up was 2.4 times higher than the U.S. average for adults twenty to thirty-nine years of age (30.3%)27. Even more alarming, according to the World Health Organization criteria28, 48.4% of the cohort were severely obese (BMI of 35 to 40 kg/m²) or very severely obese (BMI > 40 kg/m²), a rate that is 8.6 times higher than the U.S. national average for adults twenty to thirty-nine years of age (5.6%)27. Whether the weight change was the result of a decrease in physical activity related to altered anatomy and joint kinematics post-SCFE, a genetic or host predisposition to higher body mass, or both, cannot be inferred from this study design. What is clear, however, is that a higher BMI proved to be the only consistent predictor of poorer patient-reported outcomes (PCS, mHHS, and UCLA Activity Scale) in our study.

Male sex was positively associated with both the PCS score and mHHS and showed a trend toward a positive association with the UCLA Activity Scale score. The cause of this association cannot be determined from this study but may represent sex differences in self-perception of physical function, pain tolerance, or hip anatomy (e.g., acetabular depth or version) that affect the ability to compensate for the residual proximal femoral deformity.

The slip angle was not associated with any of the patient-reported outcomes collected for this study. These results are similar to those presented by Larson et al.29, who studied a cohort of eighty-four patients at an average of twenty-three years after SCFE fixation. However, Larson et al. presented univariable comparisons without an attempt to adjust for age, sex, or bilateral disease. There are several theories that may explain this lack of association. First, the possibility of remodeling after in situ fixation for SCFE has been proposed by several authors25-28 who identified partial correction of the SCFE deformity after in situ fixation27 and improvement in internal hip rotation with proximal femoral remodeling25. Proposed mechanisms of proximal femoral remodeling include local resorption and ap positional bone formation25. Findings in the literature have been inconsistent, however, as Sibi´nski et al.29 and Jones et al.30 found remodeling to be more likely with mild slips (Southwick slip angle < 30°) and relative skeletal immaturity (an age of less than twelve years and open triradiate cartilage) whereas Bellemans et al.31 reported greater remodeling with higher-grade slips. Second, it is possible that the deformity and altered hip kinematics lead to self-imposed reduction in activity, which would mask more subtle functional deficits or pain associated with the post-SCFE deformity. The UCLA Activity Scale scores in our cohort support this theory, as nearly two-thirds of our patients reported engaging in only lower-impact activities such as housework, shopping, swimming, golf, or cycling. Third, it is possible that the outcome instruments used in this study are not sensitive enough to detect differences in the general health and function of this population. This seems less likely, however, given the favorable measurement properties of the SF-1225, mHHS35, etc.
and UCLA Activity Scale\textsuperscript{19} for patients undergoing total hip arthroplasty. Lastly, it is possible that the adverse effects of abnormal joint kinematics after SCFE may take longer than twenty years to manifest. Only two patients in the group contacted for inclusion had undergone total hip replacement at the time of follow-up; these operations had been performed eighteen and twenty years after treatment for SCFE.

Strengths of this study include a large sample size, use of a wide variety of patient-reported outcomes that have been validated for use for patients with other hip disorders, and robust statistical analysis. Limitations include a retrospective design that can limit inferences of causality, use of a nonvalidated general health survey, and a duration of follow-up that may not yet capture the long-term effects of SCFE on hip function and health. Since this was a convenience sample gathered without an a priori sample size calculation, it is possible that the regression analysis was underpowered to detect significant associations. However, the regression point estimates for the associations between slip angle and PCS, mHHS, and UCLA Activity Scale scores were small and thus are not likely to be clinically relevant.

In summary, the slip angle was not found to be associated with patient-reported health outcomes twenty years after in situ fixation for SCFE. Lower BMI and male sex were the only factors found to be associated with better patient-reported outcomes. This study suggests that patients with SCFE are at high risk of gaining weight in the years following the slip. This is potentially worrisome in the context of rising rates of obesity in today’s youth and should be discussed with patients after fixation of a slip. Weight management in this patient population may help reduce the risk of staged bilateral SCFE\textsuperscript{19}, improve patient-reported outcomes, and reduce other negative obesity-related sequelae\textsuperscript{26}, but successful approaches to achieve weight loss in this population after they first present with SCFE have not yet been reported. The results of this study will be valuable to compare with other published studies of patient-reported outcomes after realignment procedures to help determine if improved anatomic alignment can improve patient-reported outcomes and function. We concluded that it is the health status of the patient that is most at risk at twenty years after presentation of SCFE regardless of the severity of the SCFE at the time of presentation. In addition to monitoring and addressing the radiographic proximal femoral deformity, time should also be spent promoting improvements in general health and weight management to improve the long-term health of this group of patients.

References


