Prediction of Contralateral Slipped Capital Femoral Epiphysis Using the Modified Oxford Bone Age Score

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Background: The purpose of the present study was to determine whether the modified Oxford bone score can be used as a predictor for the risk of developing contralateral slipped capital femoral epiphysis (SCFE) in children who present with a unilateral slip.

Methods: We identified 260 patients treated for unilateral SCFE between 1980 and 2002 and followed them up to skeletal maturity or until development of contralateral slip. Exclusion criteria included patients with endocrine or metabolic disorder, Down syndrome, and those with radiographs inadequate to determine the modified Oxford bone score. The initial radiographs were given a score ranging from 16 to 26. Statistical analysis was used to determine whether the modified Oxford bone score was predictive of future development of contralateral slip. A linear regression model was used to estimate the probability of future development of a contralateral slip as related to the modified Oxford bone score.

Results: Of the 260 patients, 64 (24%) developed a contralateral slip, at an average of 10 months after initial presentation. Race, sex, age, and weight at initial presentation were not predictive of the development of contralateral slip. The modified Oxford score and a triradiate score of 1 were found to be significant ($P < 0.0001$) predictors, with the modified Oxford score a better overall predictor.

Conclusions: The modified Oxford bone age score is the best predictor of the risk of development of a contralateral SCFE in patients presenting with a unilateral slip. Controversy exists regarding prophylactic pinning of a normal hip in patients presenting with unilateral SCFE. The benefits of prophylactic pinning must outweigh risk. This study provides probability data for predicting a contralateral slip based on the modified Oxford bone maturity score that can be shared with families and allows physicians to decide their threshold for prophylactically pinning the contralateral hip in patients presenting with a unilateral slip.

Level of Evidence: Therapeutic level IV, Case series.

Key Words: slipped capital femoral epiphysis, modified Oxford bone score, contralateral slipped capital femoral epiphysis

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Controversy exists regarding prophylactic pinning of a radiographically normal, asymptomatic hip in otherwise normal children who present with a unilateral slipped capital femoral epiphysis (SCFE). This is largely because of our inability to predict who will go on to develop a subsequent slip. The frequency of developing a contralateral slip has been reported to be between 25 and 40% (Fig. 1).[1–4]

The relatively high risk of developing an SCFE has prompted many researchers to recommend prophylactic pinning of the contralateral, asymptomatic, apparently normal hip in patients presenting with a unilateral slipped epiphysis. However, uniform prophylactic pinning subjects a large number of children to unnecessary surgery, as 60% to 75% of those presenting with a unilateral slip never go on to develop a contralateral slip.[2–5] Prophylactic pinning also carries at least slight risks for infection, implant breakage, soft tissue irritation associated with the implant, chondrolysis, and subtrochanteric femur fracture.[6–11]

Stasikelis et al[12] showed a linear distribution between the modified Oxford bone score and the risk of contralateral SCFE. They also showed that, in boys, the age at the time of the initial slip was predictive of a contralateral slip. However, their study did not stratify risk according to score. That fact and unfamiliarity with the relatively complex scoring scheme explain the infrequent application of their data on clinical practice in our experience.

The purpose of our study was to determine whether the modified Oxford bone age can be used as a predictor for risk of developing a contralateral SCFE in children who present with a unilateral slip.

METHODS

After IRB approval was obtained, we reviewed the charts and radiographs of all children treated at the senior author's institution for a unilateral SCFE from 1980 to 2002. Patients who had endocrine or metabolic disease, Down syndrome, bilateral slips at presentation, prophylactic pinning of the contralateral side or initial slip treated elsewhere, or a slip diagnosed clinically but with no radiographic evidence were excluded from the study. To be included in the study, patients had to have adequate initial radiographs to assess their modified Oxford bone maturity age and be followed up to either development of a contralateral slip or skeletal maturity. A total of

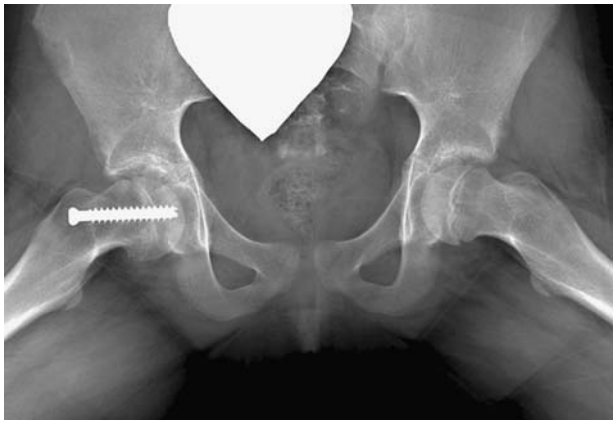


FIGURE 1. Development of subsequent contralateral slipped capital femoral epiphysis.

305 patients met initial criteria for inclusion. Exclusions from this initial group included 22 patients because they had not reached skeletal maturity at their most recent follow-up, 15 patients for inadequate radiographs to determine the modified Oxford bone score, 7 patients because they had undergone pinning for development of symptoms without radiographic evidence of slip, and 1 patient for having undergone prophylactic pinning. This left a study group of 260 patients.

The demographic data obtained from the chart review included age and weight at presentation, sex, and ethnicity. We also recorded the side of the slip and whether it was a stable or unstable slip based on the criteria of Loder et al.[13]

All radiographs were scored using the modified Oxford bone maturity as described by Stasikelis et al.[12] The original Oxford method for assessing skeletal maturity uses maturation stages for 9 separate radiographic features visualized on anteroposterior radiographs of the pelvis and both hips. The original Oxford method utilizes the head of the femur, the greater trochanter, the lesser trochanter, the ilium, the ischium, the lip of the acetabulum, the junction of the ischial and the pubic rami, the pubis, and the triradiate cartilage.[14] Each feature is provided a "score" according to appearance, ranging from 0 to 8. The total score is tallied from the sum of the score assigned for each of the 9 categories and a skeletal age calculated using a conversion table.

The modified method incorporates only 3 consecutive stages of maturation for 5 of the features described in the full Oxford method: the femoral epiphysis, the greater trochanter, the lesser trochanter, the triradiate cartilage, and the ilium. The individual "point value" assigned within the complete Oxford bone score method is used in the modified method (thus the apparently illogical scoring sequence). The total score is determined by summation of the individual scores (Fig. 2). The head of the femur is given 5, 6, or 7 points, the greater trochanter 4, 5, or 6 points, the lesser trochanter 3, 4, or 5 points, the triradiate 1, 2, or 3 points, and the ilium 3, 4, or 5 points. Therefore, the scores for the modified system range from 16 to 26. We used both the AP and frog lateral radiographs to determine the score. All radiographs were scored by a single reviewer.

We confirmed that the modified Oxford bone maturity score was a reliable, predictable measurement by conducting a study in which we gave 30 AP and frog lateral pelvis films to 6 physicians (5 staff and 1 resident). They were given a copy of the modified Oxford bone maturity assessment and asked to score the 30 radiographs on 2 separate occasions. We found that the modified Oxford bone maturity score has very good interreliability and intrareliability, with weighted κ values of 0.69 and 0.76, respectively.

RESULTS

Of the 260 patients who presented with a unilateral slip, 64 went on to develop a contralateral slip (24%). For the entire study population, there were 174 male patients (67%) and 86 female patients (33%). With regard to ethnicity, there were 125 whites (48%), 101 African Americans (39%), 33 Hispanics (13%), and 1 subcontinental Indian (0.4%). The average time from initial presentation until development of a contralateral slip in the 64 patients who developed a contralateral slip was 10 months (range, 1 to 28 mo). Of the 64 patients who developed a contralateral slip, 42 were male patients (66%) and 22 (34%) were female patients. This was not statistically significant. The ethnic breakdown of those who developed a contralateral slip was also not significant: 33 (52%) whites, 19 (30%) African Americans, and 12 (18%) Hispanics.

The average age and weight of those patients who did not develop a contralateral slip were 13 + 1 (range, 9 + 1 to 16 + 5 y) and 73.7 kg (range, 36.8 to 145.5 kg), respectively. For the group that developed a contralateral slip, the average age at presentation was 11 + 8 (range, 8 + 7 to 14 + 11 y) and the average presenting weight was 61.5 kg (range, 36 to 91.8 kg). These values were statistically significant ($P < 0.0001$) but not found to be predictive of developing a contralateral slip. Unfortunately, height was not routinely measured, and thus no data regarding body mass index could be analyzed.

We did determine that the modified Oxford bone score was strongly predictive of whether a patient developed a contralateral slip. A linear regression model was used to determine whether this score was predictive (Table 1).

As many people seem to find the modified Oxford bone scoring system difficult to remember or confusing, we attempted to determine whether any one component of the score was a reliable predictor of contralateral involvement. We found that a triradiate score of 1, which means the triradiate cartilage is wide open, was a good predictor for the development of a contralateral slip. Eighty-nine percent of patients who had a triradiate score of 1 went on to develop a contralateral slip ($P < 0.0001$)

We used positive and negative predictive values to determine whether the combined score or the triradiate

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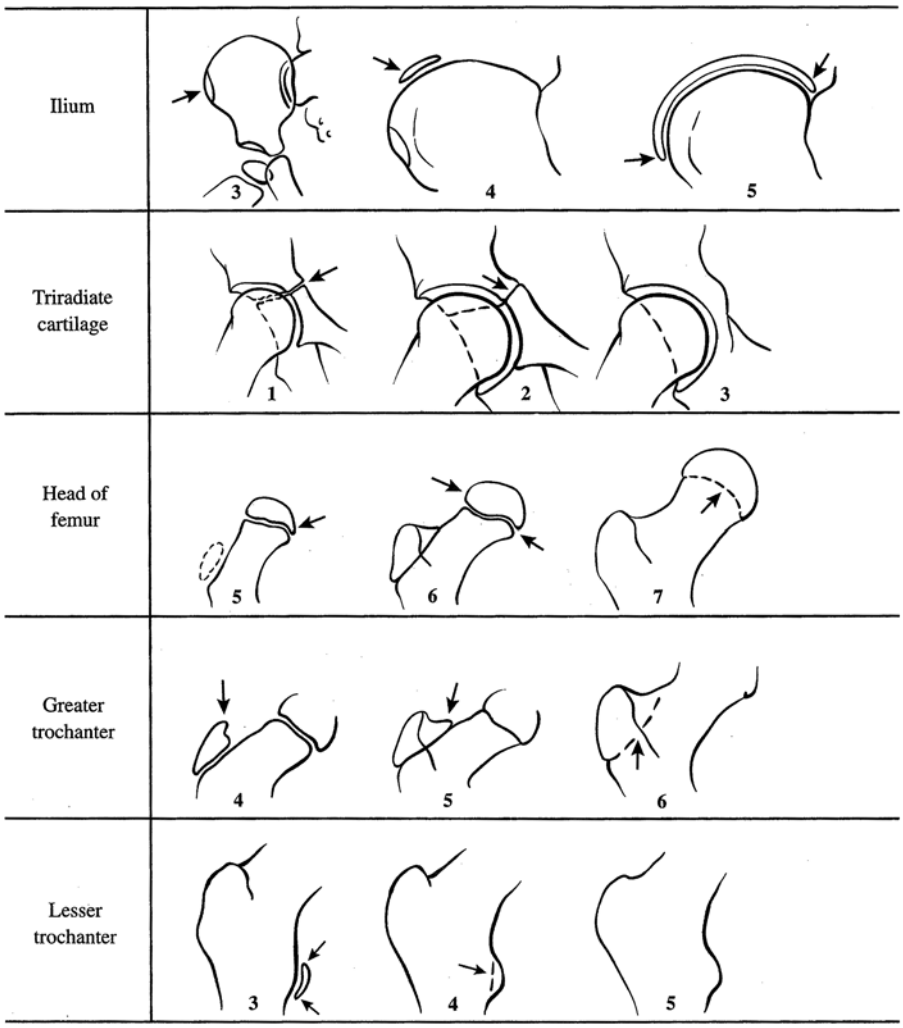


FIGURE 2. The modified Oxford bone score.

score alone was a better tool to predict contralateral involvement. As the clear demarcation for contralateral involvement using the modified Oxford bone score was 18, we determined the positive and negative predictive values by combining the 16 to 18 groups. We found that if a person had a combined modified Oxford bone score of 16, 17, or 18 the positive predictive value of developing a contralateral slip was 96%, and the negative predictive value was 92%. For a triradiate score of 1, the positive predictive value was 89% and NPV was 86%. In other words, if a modified Oxford bone score of 16 to 18 had been used to prophylactically pin a contralateral hip, 4/100 children would have undergone unnecessary surgery, and 8/100 children would have been missed. If a wide open triradiate had been used to prophylactically pin a contralateral hip, 11/100 children would have undergone unnecessary surgery and 14/100 children would have been missed. Therefore, the modified Oxford bone score is the best predictor of future development of a contralateral slip in otherwise normal patients.

DISCUSSION

The decision of whether or not to prophylactically pin a normal hip in a child who presents with a unilateral idiopathic slip is controversial. The controversy exists because of uncertainty in the prediction of who ultimately will develop a subsequent slip and the iatrogenic risk associated with treating an otherwise normal joint. Despite the identification of a correlation between younger patient age and increased body mass index at the onset of the first slip to subsequent development of a contralateral slip,[5] prediction of the need to pin the opposite hip cannot be made using these parameters.

Stasikelis et al[12] reviewed 50 patients who subsequently developed a contralateral slip and determined that there was a linear distribution between the modified Oxford bone score and the risk of development of a contralateral slip. The data presented in their study do not seem to have affected clinical decision making with regard to prophylactic pinning. We hypothesize that this is because of the fact that their study had a small number

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TABLE 1. Probability of Developing a Contralateral Slip Based on the Modified Oxford Bone Score Using a Linear Regression Model

Modified Oxford Bone Score	Developed Contralateral Slip	Remained Unilateral	Probability of Developing Contralateral Slip (%)
16	9	0	100
17	23	0	97
18	16	2	85
19	9	27	44
20	6	58	5
21	1	64	1
22	0	32	1
23	0	11	0
24	0	2	0
25	0	0	0
26	0	0	0
Total	64	196	

of patients, because of the perceived difficulty of determining the modified Oxford bone score, and because of the lack of stratification of their data. They determined that the risk of developing a contralateral slip with a modified Oxford bone age of 16 was 85%, and the risk with a score of 22 was 0%. These data still leave the dilemma of whether the risk-benefit ratio favors prophylactic pinning in those who have scores of 17 to 21.

Puylaert et al[15] previously reported on the importance of the triradiate cartilage in staging puberty. They state that SCFE occurs during a very narrow window of puberty. Once the triradiate cartilage is completely closed, children are no longer in a phase of puberty that is conducive to developing an SCFE. In their study, there were 68 patients who presented with unilateral slips. Only 6 went on to develop a contralateral slip. Puylaert and colleagues determined from these data that once the triradiate was completely closed there was only a 4% chance of developing a contralateral slip.

Many surgeons have based their decision for prophylactic pinning on the patient's age and the perceived reliability of the family. Unfortunately, despite proper education about the disease, many families do not seek medical treatment at the onset of pain in the contralateral limb. In our patient population, many of our subsequent slips had symptoms for >1-month duration before seeking treatment. Stasikelis et al[12] reported that only 35% of their subsequent slips had been seen in follow-up at the time intervals specified.

Natural history studies have shown that the long-term outcome after SCFE is related to the severity of the slip.[3,16–22] Several total joint surgeons have reported that SCFE is the most common cause of degenerative joint disease in those seeking hip replacement surgery.[19,23] Carney and Weinstein[17] published a natural history study of untreated SCFE followed up for an average of 41 years. They studied 31 hips in 28 patients. The hips with a mild slip had an Iowa hip-rating score of >80 points, compared with only 64% with a moderate or severe slip. Thirty-six percent of the hips with a mild slip at presentation had no degenerative changes at 41-year follow-up versus none in the moderate-to-severe group.

Oram[21] followed up 22 hips with untreated SCFE, half of which were observed for >15 years. The hips with moderate displacement faired decently. The hips with severe slips had poor function and developed degenerative arthritis within 15 years. Hagglund et al[24] found that 25% of subsequent slips diagnosed at late follow-up had degenerative arthritis. Therefore, they recommended prophylactic pinning of all normal hips. Jensen et al[25] reported a 20% arthritis rate in subsequent slips diagnosed during delayed follow-up.

Kocher et al[26] determined by a sensitivity analysis that, if the risk for developing a contralateral slip was >27%, then prophylactic pinning should be performed. In most studies, this percentage of children do go on to develop a subsequent slip, and the treating physician is still left with the dilemma of performing potentially unnecessary surgery on a large percentage of children.

Subsequent slips are not necessarily detected when they are mild and therefore do not have a benign natural history. Loder et al[5] found that subsequent slips did not differ in their severity compared with the index slip. Stasikelis et al[12] also found no difference in the severity of subsequent slips in children who returned for regular follow-up and those who did not. Jerre et al[27] reported that 25% of those having a subsequent SCFE went on to develop degenerative arthritis in that hip.

A recent study by Yildirim et al[28] evaluated the rate of chondrolysis, avascular necrosis, and slip severity in patients with a subsequent contralateral slip. They found that 18 of 82 subsequent slips were moderate or severe. Five of the 82 patients developed avascular necrosis or chondrolysis. Overall, they reported a poor outcome in 23% of the contralateral hips with a subsequent slip. We did not record the severity of our subsequent slips. However, 2 of the patients in our study who developed a contralateral slip had unstable slips, 1 of whom went on to develop avascular necrosis, which carries a poor long-term prognosis. Yildirim and colleagues concluded that prophylactic pinning of all normal contralateral hips is safer than observation and symptomatic treatment. Their study still does not resolve the issue of having a high rate of unnecessary surgery if all normal hips are prophylactically pinned.

Opponents of prophylactic pinning of all normal contralateral hips argue that most children do not subsequently go on to develop a contralateral slip and that the procedure is not risk free. Although there are no reported cases of avascular necrosis or chondrolysis in the literature from prophylactic pinning, these are potential complications. Although we could not find any case reports of subtrochanteric femur fracture from placement of a prophylactic screw, we have had several such cases reported to us anecdotally. There is also the risk of infection with any operation. A study conducted by Dewnany and Radford[7] reported 1 case of a superficial wound infection treated with oral antibiotics after prophylactic pinning. Bertani et al[6] reported a case of a septic

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hip that subsequently developed avascular necrosis and necessitated total hip arthroplasty after prophylactic pinning of a normal hip.

Despite the association of younger age at presentation and higher body mass index with a higher risk of developing a contralateral slip,[5] many surgeons still face the quandary of which patients should have their normal hip prophylactically pinned. This dilemma stems from prior inability to better quantify who truly is at risk for a contralateral slip. Our study shows that children with a modified Oxford bone score of 16, 17, or 18 have a 96% probability of developing a contralateral slip. Given the plethora of data that exist suggesting that deformity of the proximal femur leads to subsequent development of arthritis, we have now made it our clinical practice to prophylactically pin all patients with a unilateral slip who have a modified Oxford bone score of 16, 17, or 18.

We recognize that the modified Oxford bone score is difficult for physicians to recollect and in an acute setting may not be readily available for reference. We therefore looked to see whether any one component of the score was a reliable predictor of contralateral involvement. We found that a triradiate score of 1, which means the triradiate cartilage is wide open, was also a good predictor, but was not as good a predictor as the modified Oxford bone age. Eighty-nine percent of patients who had a triradiate score of 1 went on to develop a contralateral slip ($P < 0.0001$). We feel prophylactic pinning in this group is also indicated.

Until now, surgeons have not been able to present probability data to families when discussing the risk of developing a contralateral slip. Clearly, close follow-up is not sufficient to prevent development of a contralateral slip. The benefits of prophylactic pinning must outweigh the risks associated with the procedure. This study provides probability data that can be shared with families and allows physicians to decide what their threshold is for prophylactically pinning a normal contralateral hip.

REFERENCES

1. Loder RT. The demographics of slipped capital femoral epiphysis. An international multicenter study. *Clin Orthop Relat Res*. 1996;322: 8–27.
2. Hagglund G, Hansson LI, Ordeberg G, et al. Bilaterality in slipped upper femoral epiphysis. *J Bone Joint Surg Br*. 1988;70:179–181.
3. Jerre R, Billing L, Hansson G, et al. The contralateral hip in patients primarily treated for unilateral slipped upper femoral epiphysis. Long-term follow-up of 61 hips. *J Bone Joint Surg Br*. 1994;76: 563–567.
4. Hurley JM, Betz RR, Loder RT, et al. Slipped capital femoral epiphysis. The prevalence of late contralateral slip. *J Bone Joint Surg Am*. 1996;78:226–230.
5. Loder RT, Aronson DD, Greenfield ML. The epidemiology of bilateral slipped capital femoral epiphysis. A study of children in Michigan. *J Bone Joint Surg Am*. 1993;75:1141–1147.
6. Bertani A, Launay F, Glard Y, et al. Severe hip infection after a prophylactic contralateral fixation in slipped upper femoral epiphysis: a case report. *J Pediatr Orthop B*. 2009;18:238–241.
7. Dewnany G, Radford P. Prophylactic contralateral fixation in slipped upper femoral epiphysis: is it safe? *J Pediatr Orthop B*. 2005;14:429–433.
8. Emery RJ, Todd RC, Dunn DM. Prophylactic pinning in slipped upper femoral epiphysis. Prevention of complications. *J Bone Joint Surg Br*. 1990;72:217–219.
9. Plotz GM, Prymka M, Hassenpflug J. The role of prophylactic pinning in the treatment of slipped capital femoral epiphysis—a case report. *Acta Orthop Scand*. 1999;70:631–634.
10. Schultz WR, Weinstein JN, Weinstein SL, et al. Prophylactic pinning of the contralateral hip in slipped capital femoral epiphysis: evaluation of long-term outcome for the contralateral hip with use of decision analysis. *J Bone Joint Surg Am*. 2002;84-A:1305–1314.
11. Seller K, Raab P, Wild A, et al. Risk-benefit analysis of prophylactic pinning in slipped capital femoral epiphysis. *J Pediatr Orthop B*. 2001;10:192–196.
12. Stasikelis PJ, Sullivan CM, Phillips WA, et al. Slipped capital femoral epiphysis. Prediction of contralateral involvement. *J Bone Joint Surg Am*. 1996;78:1149–1155.
13. Loder RT, Richards BS, Shapiro PS, et al. Acute slipped capital femoral epiphysis: the importance of physeal stability. *J Bone Joint Surg Am*. 1993;75:1134–1140.
14. Acheson RM. The Oxford method of assessing skeletal maturity. *Clin Orthop*. 1957;10:19–39.
15. Puylaert D, Dimeglio A, Bentahar T. Staging puberty in slipped capital femoral epiphysis: importance of the triradiate cartilage. *J Pediatr Orthop*. 2004;24:144–147.
16. Boyer DW, Mickelson MR, Ponseti IV. Slipped capital femoral epiphysis. Long-term follow-up study of one hundred and twenty-one patients. *J Bone Joint Surg Am*. 1981;63:85–95.
17. Carney BT, Weinstein SL. Natural history of untreated chronic slipped capital femoral epiphysis. *Clin Orthop Relat Res*. 1996; 43–47.
18. Carney BT, Weinstein SL, Noble J. Long-term follow-up of slipped capital femoral epiphysis. *J Bone Joint Surg Am*. 1991;73:667–674.
19. Howorth B. Slipping of the capital femoral epiphysis. Pathology. *Clin Orthop Relat Res*. 1966;48:33–48.
20. Jerre T. Early complications after osteosynthesis with a three flanged nail in situ for slipped epiphysis. *Acta Orthop Scand*. 1957;27:126–134.
21. Oram V. Epiphysiolysis of the head of the femur; a follow-up examination with special reference to end results and the social prognosis. *Acta Orthop Scand*. 1953;23:100–120.
22. Ross PM, Lyne ED, Morawa LG. Slipped capital femoral epiphysis long-term results after 10–38 years. *Clin Orthop Relat Res*. 1979; 176–180.
23. Murray RO. The aetiology of primary osteoarthritis of the hip. *Br J Radiol*. 1965;38:810–824.
24. Hagglund G. The contralateral hip in slipped capital femoral epiphysis. *J Pediatr Orthop B*. 1996;5:158–161.
25. Jensen HP, Steinke MS, Mikkelsen SS, et al. Hip physiolysis. Bilaterality in 62 cases followed for 20 years. *Acta Orthop Scand*. 1990;61:419–420.
26. Kocher MS, Bishop JA, Hresko MT, et al. Prophylactic pinning of the contralateral hip after unilateral slipped capital femoral epiphysis. *J Bone Joint Surg Am*. 2004;86-A:2658–2665.
27. Jerre R, Billing L, Hansson G, et al. Bilaterality in slipped capital femoral epiphysis: importance of a reliable radiographic method. *J Pediatr Orthop B*. 1996;5:80–84.
28. Yildirim Y, Bautista S, Davidson RS. Chondrolysis, osteonecrosis, and slip severity in patients with subsequent contralateral slipped capital femoral epiphysis. *J Bone Joint Surg Am*. 2008;90:485–492.

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