

# Intra- and inter-observer repeatability of radiographic measurements for previously slipped capital femoral epiphysis at skeletal maturity

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## Abstract

**Background:** Recent studies suggest that even a mild slip of the femoral capital epiphysis may lead to later degenerative changes when undiagnosed. However, little is written on the accuracy of radiographic measurements used to diagnose a slip at skeletal maturity.

**Purpose:** To assess the accuracy of radiographic measurements commonly used for assessment of previously slipped capital femoral epiphysis (SCFE) at skeletal maturity.

**Material and Methods:** All children born at our hospital during 1989 ( $n = 4006$ ) were invited to participate in a follow-up hip trial at age 18–19 years. Erect pelvic anteroposterior and supine frog leg radiographs were obtained in a standardized fashion. For the purpose of this study, we selected a subset of 100 radiographs. To balance the data-set, we added another 28 radiographs from skeletal mature patients diagnosed and operated for a SCFE. Two observers independently measured Southwick's head-shaft angle, Murray's tilt-index, and the femoral head-neck angle. Intra- and inter-observer variation was assessed using the mean difference, with its 95% limits of agreement.

**Results:** A high percentage of the images (40%), particularly for the measurement of the Southwick's head-shaft angle, were judged immeasurable by at least one observer. Mean head-shaft angle was  $11.0^\circ$  (SD = 17.0), head-neck angle was  $8.0^\circ$  (SD = 12.0), and Murray's tilt-index was 1.18 (SD = 0.4). For head-shaft angle, the mean difference between measurements (Observer 2) was  $0.8^\circ$  (SD =  $2.7^\circ$ , 95% limits of agreement  $-4.5^\circ$  to  $6.1^\circ$ ), while the corresponding figure for the Murray's tilt-index was 0.02 (SD = 0.08, 95% limits of agreement  $-0.18$  to 0.14), and for the head-neck angle  $0.9^\circ$  (SD = 4.0, 95% limits of agreement of  $-6.9^\circ$  to  $8.7^\circ$ ). Slightly higher variance was seen for Observer 1 and between the two observers.

**Conclusion:** Common radiographic measurements for the assessment of a previously slipped capital femoral epiphysis are relatively inaccurate in skeletal mature adolescents, in particular between observers (inter-observer), but also for the same observer (intra-observer). Our results underscore the importance of thorough standardization for both image and measurement technique when used in a clinical setting.

**Keywords:** Slipped capital femoral epiphysis, measurement repeatability, intra- and inter-observer, Southwick's head-shaft angle, Murray's tilt-index, head-neck angle

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Slipped capital femoral epiphysis (SCFE) is one of the most common hip disorders in adolescents (1) with a reported annual incidence of approximately 3–5 per 100,000 (2, 3), and up to 60% being bilateral (4). Pathoanatomically, there is a separation of the femoral head from the metaphysis;

the femoral head remaining within the acetabulum and the metaphysis moving superior-anteriorly in relation to the head (5). The etiology is unknown, but both mechanical and endocrinological factors are thought to play a role (6, 7). Patients typically present with insidious onset of thigh or

knee pain with a painful limp. The diagnosis is based on clinical and radiological findings; hip motion will be limited, particularly internal rotation. Commonly used radiological markers for SCFE are Southwick's head-shaft angle (8) as measured on the anteroposterior (AP) (9, 10) or frog-leg views (1, 11, 12), posterior sloping angle of Barrios (13), Klein's tangent (14), Murray's tilt-index (15, 16), displacement of the femoral epiphysis on the metaphysis measured in mm or percentage (17, 18), and the lateral slip angle (19, 20). An extensive literature research, however, revealed only a few studies addressing the repeatability of these measurements (21, 22). Variability in two of the most used methods, namely the lateral head-shaft angle and amount of displacement of the epiphysis on the metaphysis both measured on the frog-leg view, was tested with a conclusion that angular measurements converted into a discrete category (mild, moderate, severe) was the only measurement yielding an acceptable intra- and inter-observer variation (22).

As part of a large clinical and radiological follow-up of a previous randomized hip-trial (23), we aimed at examining intra- and inter-observer repeatability for radiographic measurements commonly used for measurements of a previous slipped capital femoral epiphysis, namely the Southwick's head-shaft angle, the femoral head-neck angle, and Murray's tilt-index.

## Material and Methods

The Regional Ethical Committee for Medical and Health Research approved this study (No. 3,2006,144), and written informed consent was obtained from all the participants.

A sample of 100 pelvic radiographs from 19-year-olds (67 women) participating in a longitudinal, population-based study on hip-disorders in childhood (23) were included. These radiographs were drawn from a total of 1200 examinations (the 1200 initial participants from a total of 2082, attendance rate of 52%), which had been scored *a priori* with respect to acetabular shape, "pistol grip deformity", femoral neck irregularities, among others. Both subjectively normal hips and hips with subjective findings of pistol grip and different acetabular shape were included. None of these subjects had been treated for SCFE. To obtain a data-set including both presumptive normal as well as SCFE hips, we added 28 hip examinations from skeletal mature patients previously operated for SCFE (24).

All examinations were performed at the Department of Radiology at our hospital, using a low-dose technique (Direct Digital Radiography, Digital Diagnost System, version 1.5, Philips Medical Systems, Best, The Netherlands). Two views were obtained, an erect anteroposterior (AP) view (feet pointing forward, neutral ab-adduction position of the hips) (25) and a supine frog-leg view, using a film/focus distance of 1.2 m and centered at 2 cm proximal to the pubic bone.

Technical image criteria for inclusion were an obturator index between 0.7 and 1.8 according to Tönnis (1976) (26), and for measurement of the head-shaft angle, 2 cm of the

proximal femoral metaphysis had to be included in the frog-leg view. Further, the observers were instructed to omit measurements if the measurement points could not be accurately set. The radiographs were analyzed on an Agfa PACS system (Agfa IMPAX Web1000 v.5.0, Agfa Gevaert, Mortsel, Belgium). Two different observers, one consultant radiologist with more than 20 years of experience in musculoskeletal radiology (Observer 1) and one consultant radiologist with 5 years of experience in musculoskeletal readings (Observer 2), performed the following measurements, using the mean of two measurements (27): Southwick's head-shaft angle (frog-leg view), head-neck angle (frog-leg view), and Murray's tilt-index (AP view) (Fig. 1a-c). The readers were masked to the other findings, and were allowed to use the preferred screen settings. Standardization of the measurements was performed prior to the study by thorough discussions and measurements of 20 different pelvic radiographs. Both observers reread all radiographs after a period of 3 months, masked to the previous measurements.

Intra- and inter-observer variation for each of the measurements was assessed using the mean difference, with its 95% limits of agreement (27, 28). For the purpose of graphic presentation we plotted the differences against the mean measurements (Bland-Altman plots). All results are given for left hip. The statistical package PASW Statistics 18<sup>®</sup> (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses.

## Results

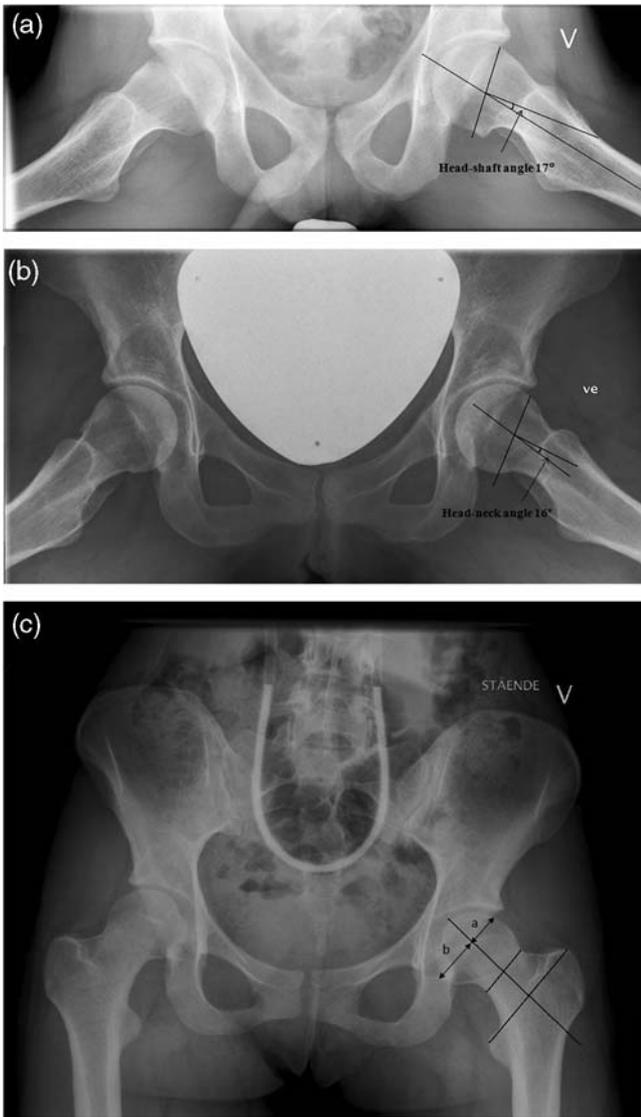
For measurements of Southwick's head-shaft angle, Murray's tilt-index, and the head-neck angle, 75, 119, and 109 of the cases, respectively, were judged measurable by both observers (Table 1). Mean head-shaft angle was 11° (SD = 17.0), mean tilt-index was 1.18 (SD = 0.4), and mean head-neck angle was 8.0° (SD = 12.0).

For observer two, the mean difference in head-shaft angle between two measurements was 0.8° (SD = 2.7°, 95% limits of agreement -4.5° to 6.1°) (Table 1, Fig. 2). For the head-neck angle, there was a mean difference between measurements of 0.9° (SD = 4.0) and 95% limit of agreement of -6.9° to 8.7°. The mean difference for the tilt-index was 0.02 (SD = 0.08) and the 95% limits of agreement was -0.18 to 0.14. Slightly higher variation was seen for Observer 1 (Table 1, Fig. 2).

The mean difference in head-shaft angle between the two observers was 1.3° (SD = 3.9) however the 95% limit of agreement ranged from -6.3° to 8.9° (Table 1, Fig. 2).

## Discussion

We have shown that commonly used, radiographic measurements for the assessment of a previous SCFE are relatively inaccurate, in particular inter-observer, but also for intra-observer. Further, a high percentage of the images, particularly for the measurement of the Southwick's head-shaft angle, were judged immeasurable



**Fig. 1** (a) Frog-leg view in an 18-year-old man. Southwick's head-shaft angle, measured to be 17° in left hip. The angle is measured between a line perpendicular to the line through the physis and a line parallel to the femoral shaft. (b) Frog leg view in an 18-year-old woman. The angle between the femoral head and femoral neck, head-neck angle, measured to be 16° in left hip. The angle is measured between a line perpendicular to the line through the physis and a line parallel to the femoral neck. (c) Anteroposterior view of the pelvis in an 18-year-old woman. The Murray's tilt-index is defined as the ratio b/a, where a ratio higher than 1.35 is believed to be pathological. Tilt-index is 1.28 in this radiograph, a = 19.5 mm, b = 25 mm. A line is drawn through the mid-point between the superior-lateral margin of the greater trochanter and the most prominent edge of the lesser trochanter and the mid-point in the narrowest portion of the femoral neck and extended to divide the femoral head. In the femoral head the vertical distance to the line was measured both medially (b) and laterally (a) and the ratio calculated (Murray 1965)

by both observers. Our results underscore the importance of thorough standardization of measurement techniques.

One limitation to our study is an unbalanced data-set with regard to slips, despite efforts being made to include hips with different shape of the femoral head and of the acetabulum. Second, the frog-leg view posed problems in large subjects as even the largest field of view available did not cover enough of the proximal femur for the Southwick's angle to be measured. Further, the physal line was partly fused in a proportion of the subjects, or too little of the femoral shaft was visible, hindering measurement of the head-shaft angle for at least one of the observers (53/128). Although the study was not designed to perform subgroup analysis, no differences in repeatability/reproducibility were seen between those treated for a previous SCFE and those not treated.

The strengths of this study include the standardized examinations, one particularly trained radiographer performing all the radiographs according to a well-defined protocol and the high numbers and relatively thorough standardization of the measurements performed.

Overall the degree of inter-observer variation was higher than the intra-observer variation for all three markers. In addition the Bland-Altman analysis demonstrated that although the mean difference between the two readers was small the standard deviation was large, with a relatively wide 95% limit of agreement. The increased variability in the measurements generated between the two observers when compared to that seen for each of the two observers is intuitive. However, this difference also indicates that the standardization between the two observers might have been even better.

Of the angular measurements under investigation, the Southwick's head-shaft angle appeared to be the more consistent, with relatively low variability both within and between observers as compared to the measurement of the femoral head-neck angle.

Our results compare well with a previous study on slip angle in 38 children diagnosed with SCFE (22). Head-shaft angle of 12° was used as a limit where bilateral SCFE was diagnosed. They found that Southwick's angle based on a frog-leg view was the more accurate measurement, however, with 95% limits of agreement of ±12° for both intra- and inter-observer variability. They recommended converting into discrete categories to achieve better variability. Another study of 108 hips, showed a ±5.9° intra-observer variability for the lateral head-shaft angle (29).

To our knowledge, the reliability of the Murray's tilt-index or that of the femoral head-neck angle has not been addressed in previous studies. An extensive literature

**Table 1** Intra- and inter-observer variation for measurements used in the assessment of SCFE, with mean differences (SD) and 95% limits of agreement

Measurement	Subjects	Observer 1		Observer 2		Observer 1 and 2	
		Mean difference (SD)	95% limits of agreement	Mean difference (SD)	95% limits of agreement	Mean difference (SD)	95% limits of agreement
Head-shaft angle, degrees	75	-0.2 (3.9)	-7.8 to 7.4	0.8 (2.7)	-4.5 to 6.1	1.3 (3.9)	-6.3 to 8.9
Murrays tilt-index	119	0.03 (0.16)	-0.28 to 0.34	-0.02 (0.08)	-0.18 to 0.14	-0.02 (0.15)	-0.31 to 0.27
Head-neck angle, degrees	109	0.2 (5.4)	-10.4 to 10.7	0.9 (4.0)	-6.9 to 8.7	-0.7 (6.5)	-13.4 to 12.0

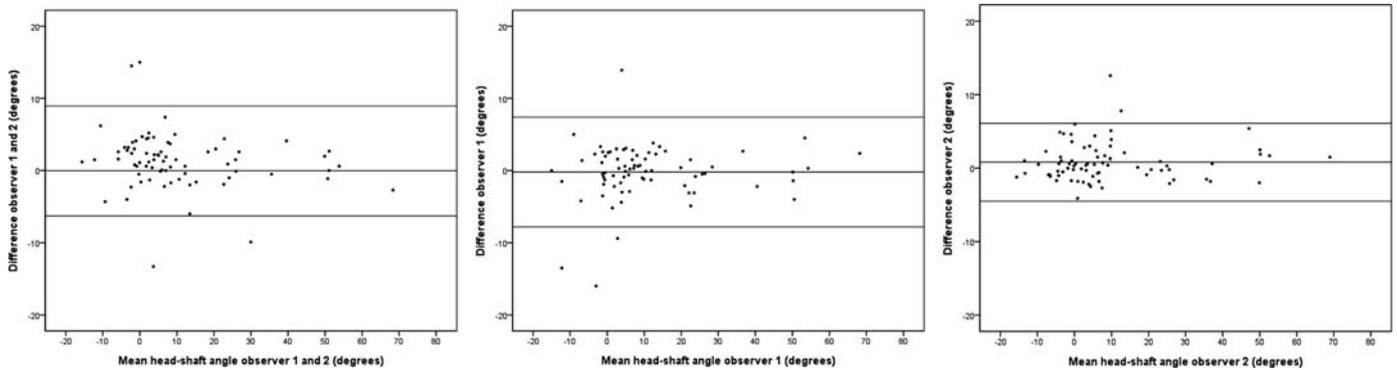


Fig. 2 Differences in measurements with  $\pm 1.96$  SD (95% limits of agreement), plotted against the mean measurements between observer 1 and 2, observer 1 and observer 2 for Southwick's head-shaft angle

search revealed that the Murray's tilt-index has been used as a marker for previous slips at late follow-up only, but not for the assessment of actual slips (15, 16).

In conclusion, radiographic measurements for the assessment of slipped capital femoral epiphysis (SCFE) are relatively inaccurate, in particular between observers, but also for the same observer. We feel that a more rigorous standardization process between observers would have produced smaller observer variation for all measurements, in particular for the head-shaft and head-neck angles. If the measurements are to be used in clinical practice, then we would advise that individuals using the measurements would need thorough training on how to measure, or alternatively the measurements to be done by a single, experienced observer.

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**Conflict of interest:** None.

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