

Radiological Assessment of the Sacrofemoral Angle: A Novel Method to Measure the Range of Hip Joint Flexion

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Abstract

Background: A quantitative and accurate measurement of the range of hip joint flexion (RHF) is necessarily required in the evaluation of disordered or artificial hip joint function. This study aimed to assess a novel method to measure RHF more accurately and objectively.

Methods: Lateral radiographs were taken of 31 supine men with hip joints extended or flexed. Relevant angles were measured directly from the radiographs. The change in the sacrofemoral angle (SFA) (the angle formed between the axis of the femur and the line tangent to the upper endplate of S1) from hip joint extension to hip joint flexion, was proposed as the RHF. The validity of this method was assessed via concomitant measurements of changes in the femur-horizontal angle (between the axis of the femur and the horizontal line) and the sacrum-horizontal angle (SHA) (between the line tangent to the upper endplate of S1 and the horizontal line), the difference of which should equal the change in the SFA.

Results: The mean change in the SFA was $112.5 \pm 7.4^\circ$, and was independent of participant age, height, weight, or body mass index. The mean changes in the femur-horizontal and SHAs were $123.0 \pm 6.4^\circ$ and $11.4 \pm 3.0^\circ$, respectively. This confirmed that the change of SFA between hip joint extension and hip joint flexion was equal to the difference between the changes in the femur-horizontal and SHAs.

Conclusions: Using the SFA, to evaluate RHF could prevent compromised measurements due to the movements of pelvis and lumbar spine during hip flexion, and is, therefore, a more accurate and objective method with reasonable reliability and validity.

Key words: Flexion; Hip Joint; Measurement; Sacrofemoral Angle

INTRODUCTION

Quantitative and accurate measurement of the range of hip joint flexion (RHF) is essential for thorough clinical evaluation of the hip function.^[1-3] Several methods have been used to measure RHF, including the Thomas test, the modified Thomas test, and measurement of the pelvifemoral angle.

The Thomas test proposed by Thomas, in 1876, was initially designed to determine hip flexion deformity,^[4] but was gradually adopted by clinicians for the general evaluation of RHF.^[5,6] Specifically, the Thomas measurement involves flexing the hip until the thigh touches the abdomen. However, hip joint flexion is an integrated movement with contributions from the pelvis and lumbar spine, which are not accounted for in Thomas' method.^[7] Bohannon *et al.*^[8] demonstrated this, in 1985, by using a 16-mm motion picture camera to film the active and passive, unilateral and bilateral,

hip flexion of healthy young subjects in the supine position; pelvic rotation contributed from 25% to 35% of hip flexion movement. Therefore, the Thomas test is inaccurate, as it fails to eliminate the motion of the pelvis and lumbar spine.

In 2008, Elson and Aspinall^[9] introduced a modification of Thomas's test that incorporates the straight leg raise test. Yet this test entails visual estimation and palpation of the pelvis, which is not sufficiently sensitive to detect the early onset of posterior pelvic rotation or lumbar flexion.

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Measurement of the pelvifemoral angle, that is, the backward opening angle formed by the axis of the femoral shaft and Nelaton's line,^[10] has also been applied to represent the RHF. Although an objective method, it is relatively difficult to obtain, regardless of whether measured by instrument or through radiological evaluation. This is because the accurate location of four anatomical bony landmarks is required, and the mislocation of any is a source of potential error.^[11] Thus, all the above methods for measuring the RHF have a degree of inaccuracy, and a more adequate and objective method is needed.

The complex movement of the hip joint in the sagittal plane suggests that a fixed anatomical landmark is necessary as a reference point^[12] for accurately measuring the RHF, but no stable and reliable landmark on the pelvis is known. For this purpose, we note that the sacroiliac joint has so small a range of motion, especially in the sagittal plane, that the sacrum and pelvis can be regarded as a single entity. Stuesson *et al.*^[13-15] utilized Roentgen stereophotogrammetric analysis to show that sacroiliac joint motion in various positions is quite limited. Accordingly, the sacroiliac joint may be regarded as an acceptable substitute for a fixed pelvic landmark. In addition, the line tangent to the upper endplate of S1 on a sagittal plain radiograph is easy to determine and can be used as another fixed landmark. Herein, we report a new method to evaluate RHF, based on the radiological assessment of the sacrofemoral angle (SFA).

METHODS

Definitions of the relevant angles

The SFA was measured from the lateral radiographs of the participant, which was formed between the axis of the femur and the line tangent to the upper endplate of S1 [Figure 1]. Changes in the SFA reflect the range of hip joint flexion. Although it is difficult to measure change of the SFA at the body surface, it is easy to do in a sagittal radiograph. Two other angles pertinent to this discussion are the femur-horizontal angle (FHA, between the axis of the femur and a horizontal line) and the sacrum-horizontal angle (SHA, between the line tangent to the upper endplate of S1 and the horizontal line). Changes in the SHA reflect tilting of the pelvis in the sagittal position, and it is directly influenced by the mechanics of the lumbosacral junction).

Participants

Thirty-one healthy young men were recruited as volunteers for this study, with mean age 22.2 ± 0.7 years, height 175.6 ± 4.1 cm, weight 67.7 ± 7.9 kg, and body mass index 21.9 ± 2.3 kg/m². The participants were screened to exclude those with any identifiable movement dysfunction, a history of significant pathology, or pain in the hip, knee, or spine that might compromise their well-being or the study results. Each subject provided written informed consent. The Human Research Ethics Committee of the Second Military Medical University approved the study.

Measurement protocol

The measurements of the SFA, FHA, and SHA of each participant were performed in accordance with a

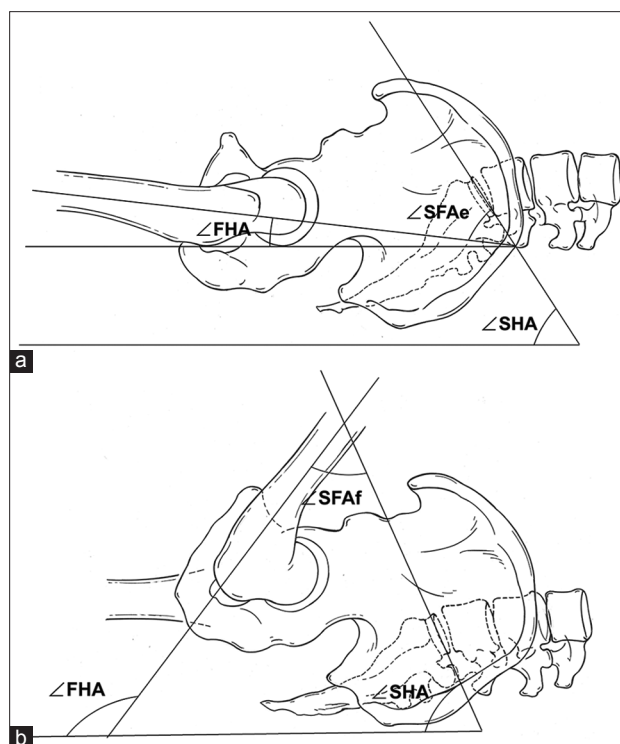


Figure 1: Definition of the sacrofemoral angle formed between the axis of the femur and the line tangent to the upper endplate of S1: (a) SFAe indicates the sacrofemoral angle in extension and (b) SFAf indicates the sacrofemoral angle in flexion. Femur-horizontal angle represents the angle formed between the axis of the femur and the horizontal line, and sacrum-horizontal angle represents the angle formed between the line tangent to the upper endplate of S1 and the horizontal line.

standardized protocol. Each participant was positioned supine on a flat examining table, with both lower extremities in natural extension and the arms folded across the chest to minimize variations due to the effects of trunk posture on the lumbosacral junction [Figure 2a]. The first lateral X-ray radiograph was taken with the X-ray beam approximately 1.2 m away from and perpendicular to the cassette in the sagittal plane. The range of the radiograph included the full sacrum, upper half of the femur, and the entire pelvis. The second lateral X-ray radiograph was taken with the subject flexing the left hip actively until the thigh touched the abdomen and the chest [Figure 2b].

All the radiographs were taken by a single experienced radiographic operator. The values of the SFA, FHA, and SHA were measured from the radiographs using digital software (Centricity DICOM Viewer, GE Medical Systems, Shanghai, China) independently by two orthopedists (Wei and Wang). The measurement of these angles was repeated 3 times by each orthopedist. The RHF was assessed as the change of SFA (CSFA), equal to the sum of the SFA in extension (SFAe; Figure 1a) and the SFA in flexion (SFAf; Figure 1b): $RHF = CSFA = SFAe + SFAf$.

Statistical analysis

The results are reported as mean \pm standard deviation (SD). The descriptive statistics were obtained using Microsoft Excel 2003,

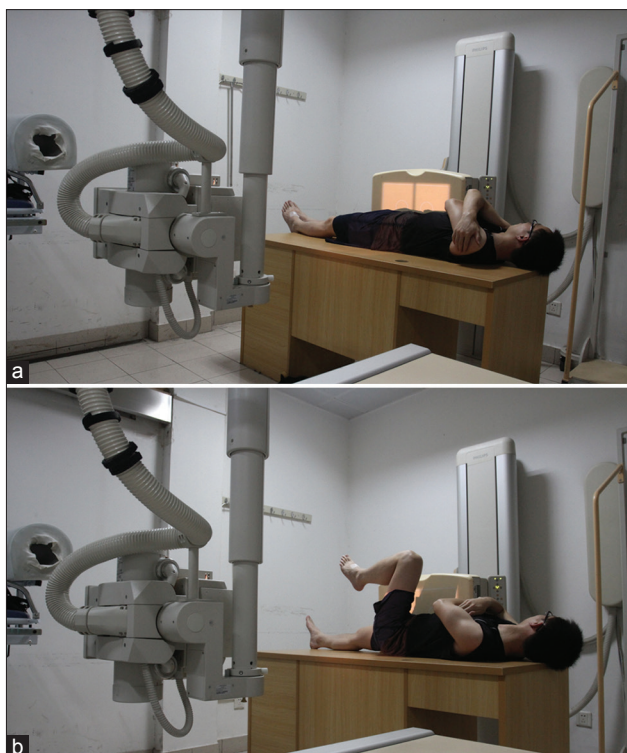


Figure 2: Representative images showing how the two lateral X-ray radiographs were taken: (a) Subjects were positioned supine on a flat examining table, with both lower extremities in natural extension and the arms folded across the chest; (b) The subject flexes the left hip actively until the thigh touches the abdomen and the chest.

and the inter-observer reliability of radiographic measurements was evaluated by inter-class coefficient using Statistical Package for the Social Sciences version 18.0 (SPSS, Chicago, IL, USA). A $P < 0.05$ was considered statistically significant.

RESULTS

Representative lateral radiographs taken with subjects in the extension and flexion positions of the hip are shown in Figure 3a and b, respectively. The measured angles are shown in Tables 1 and 2, and they were independent of patient age, height, weight, and body mass index.

The inter-class coefficient calculated to assess inter-observer reliability of radiographic measurements is 0.946, and thus the radiological assessment of the SFA, FHA, and SHA is reliable. From Tables 1 and 2, the mean SFAe and SFAf were $52.4 \pm 3.8^\circ$ and $60.1 \pm 8.1^\circ$, respectively, and the mean CSFA was $112.5 \pm 7.4^\circ$. The mean FHAs in extension and flexion were $6.4 \pm 1.4^\circ$ and $129.4 \pm 6.4^\circ$, and the mean change of FHA (CFHA) was $123.0 \pm 6.4^\circ$. The mean SHAE and SHAF were $58.8 \pm 4.0^\circ$ and $70.2 \pm 4.2^\circ$, and the mean change of SHA (CSHA) was $11.1 \pm 3.0^\circ$. There is no significant difference between the mean value of CSFA ($112.5 \pm 7.4^\circ$) and the calculation CFHA – CSHA ($111.8 \pm 6.3^\circ$) ($P = 0.27$).

DISCUSSION

Hip movement and flexion in particular, is a combination of

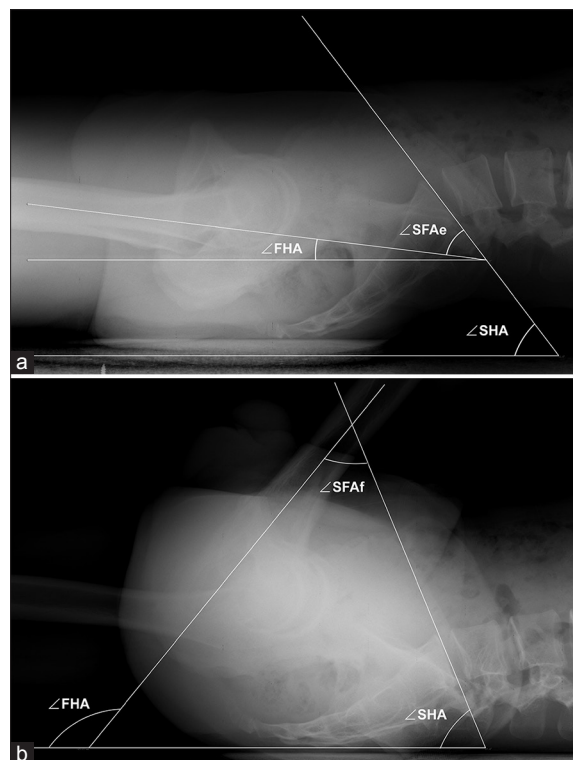


Figure 3: Representative lateral radiographs of a subject in the supine position when (a) both lower extremities are in extension, and (b) with the left hip in flexion.

movements of the thigh, pelvis, and lumbar spine. A decrease in the range of hip flexion is not only correlated with loss of hip function but is also a consistent and diagnostic feature of hip osteoarthritis.^[16-18] While the accurate measurement of the range of hip flexion is very important, there are reasons to question the reliability of the current methods, like the Thomas test. The replicability of the Thomas test in particular was challenged by a study performed by Peeler and Anderson,^[19] who found that it was almost impossible for different examiners to agree on the extent to which the opposite leg should be flexed adequately to obliterate the lumbar curve.

In the present study, we introduce a more accurate and objective method for determining the RHF, by considering it equal to the CSFA. Our results from lateral X-ray radiographs show that the CSFA equaled the difference between the CFHA and the CSHA. As a matter of fact, the CFHA corresponds to the angle measured using the traditional Thomas test, and the CSHA is that portion of hip flexion, that is, due to movement of the pelvis and lumbar spine. Therefore, this contributory motion could be eliminated when using CSFA as the method for evaluation.

The Thomas test is inaccurate for lack of a standard reference from which the leg will flex. Knowledge of the hip flexion pattern and determination of a fixed anatomical landmark are necessary for accurate and objective evaluation of RHF. Wilke *et al.*^[20] reported that in the supine position, the motion of the sacroiliac joint in the sagittal plane during

Table 1: Measurement of the SFA, the FHA, and the SHA before and after hip joint flexion (n=31)

Items	SFA (°)		FHA (°)		SHA (°)	
	Extension	Flexion	Extension	Flexion	Extension	Flexion
Examiner 1	52.6 ± 4.2	60.0 ± 8.0	6.0 ± 1.4	129.5 ± 6.6	58.8 ± 4.5	70.5 ± 4.2
Examiner 2	52.0 ± 3.6	60.2 ± 8.4	6.7 ± 1.5	129.3 ± 6.2	58.8 ± 3.8	70.0 ± 4.4
Mean	52.4 ± 3.8	60.1 ± 8.1	6.4 ± 1.4	129.4 ± 6.4	58.8 ± 4.0	70.2 ± 4.2

SFA: Sacrofemoral angle; FHA: Femur-horizontal angle; SHA: Sacrum-horizontal angle.

Table 2: CSFA, CFHA, and CSHA from hip joint extension to hip joint flexion (n=31)

Items	CSFA (°)	CFHA (°)	CSHA (°)
Examiner 1	112.9 ± 7.4	123.5 ± 6.6	11.7 ± 3.4
Examiner 2	112.2 ± 7.7	122.5 ± 6.2	11.1 ± 4.4
Mean	112.5 ± 7.4	123.0 ± 6.4	11.4 ± 3.0

CSFA: Change of sacrofemoral angle; CFHA: Change of femur-horizontal angle; CSHA: Change of sacrum-horizontal angle; ROM: Range of motion.

right hip flexion, with left hip extension, is only about 0.3°, and *in vivo* the largest distance was only 0.3 mm relative to the pelvis from the horizontal measured by goniometer. The extremely small range of motion of the sacroiliac joint in the sagittal plane was further reported by Goode *et al.*^[21] The introduction of the SFA in the present study is based on the supposition that the sacrum and pelvis can be regarded as a single and united entity for the purpose of measuring the RHA. Our results indicate that taking the sacrum as a reference point is effective and viable.

One major limitation of the present study is that the number of participants is relatively small, and only young healthy males were included. Further research is required to investigate whether this method can be used to evaluate the RHF for females and also the range of flexion for prosthetic joints in total hip replacement. In addition, the risks of exposing the patient to radiation and the extra expenditure involved in the new method should be considered.

In conclusion, we introduced in the present study, a novel method to evaluate the RHF using the SFA, which can be obtained via lateral X-ray radiographs. It is a simple but more accurate and objective method with reasonable reliability, which eliminates the contributory motion of the pelvic and lumbar spine during hip flexion. By shedding new light on the relationship between the femur, the pelvis, and the spine, this proposed method may be useful to gain a better understanding of the complicated movement in hip flexion.

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Conflicts of interest

There are no conflicts of interest.

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