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Original article

A simple method to determine the pelvic inclination angle based on anteroposterior radiographs

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Abstract

Background. The aim of this study was to propose a simple method to determine the pelvic inclination angle using anteroposterior radiographs of the hip.

Methods. The 283 subjects were randomly selected from patients who had undergone hip surgery at our institution from July 2002 to June 2004. Anteroposterior (AP) and lateral radiographs of the pelvis were obtained in the standing position. To assess the pelvic inclination angle from AP radiographs, a formula was determined by a trigonometric function. A significant correlation between the angle calculated by the formula and the measured angle (θ_0) on lateral radiographs was confirmed. The calculated angle (θ_1) was obtained from two measured values: the pelvic foramen height (H) on AP radiographs and the pelvic foramen distance (D) on lateral radiographs. The formula used was as follows: $\sin\theta = H/D$. The calculated angle (θ_2) was obtained from one measured value — the pelvic foramen height on AP radiographs — because the pelvic foramen distance on lateral radiographs substituted for the average of the pelvic foramen distance investigated in 236 patients. The formula was $\sin\theta = H/\text{average}$.

Results. The correlation between the calculated angle (θ_1) and the measured angle (θ_0) was significant, and the correlation between calculated angle θ_1 and calculated angle θ_2 was also significant.

Conclusions. The pelvic inclination angle can be estimated by measuring the height of the pelvic foramen according to our formula. Our formula was shown to have adequate reliability and reproducibility.

Introduction

Pelvic inclination is an important factor that needs to be carefully evaluated during the treatment of hip disease.[1–4] When a patient with hip disease is followed during treatment, anteroposterior (AP) plain radiographs are generally obtained. If it were possible to obtain accurate measurements of the pelvic inclination angle using AP radiographs, such a method would have numerous clinical advantages regarding exposure to radiation and the calculated time in comparison to computed tomographic (CT) reconstruction.[5]

A few methods have been proposed to evaluate the pelvic inclination angle using AP radiographs of the pelvis,[6–8] but those formulas were all rectilinear. Because the movement of pelvic inclination is a rotary motion through the horizontal axis,[9] the relation between the distance on AP radiographs and the pelvic inclination angle should be a trigonometric function.

We measured the pelvic foramen height on AP radiographs and converted the height to the pelvic inclination angle using a theoretical formula based on a trigonometric function. The aim of the present study was to propose a method for measuring the pelvic inclination angle using AP radiographs of the hip.

Materials and methods

The theoretical background is shown in Fig. 1. Once the pelvic foramen distance (D) is determined, we can assess the pelvic inclination angle using the height of the pelvic foramen (H) on AP radiographs. The formula is $H = D\sin\theta$.

The 283 subjects were randomly selected from patients who had undergone hip surgery at our institution from July 2002 to June 2004. The analyzed patients consisted of 236 women and 47 men with a mean age of 57 years (range 32–87 years). AP and lateral radiographs of the pelvis were obtained in the standing position. The superior margin of the pubic symphysis was the target of the central X-ray beam, and the distance between the focus and the film was 120 cm. The height of the pelvic foramen was measured on AP radiographs, and the pelvic foramen distance was measured on lat-

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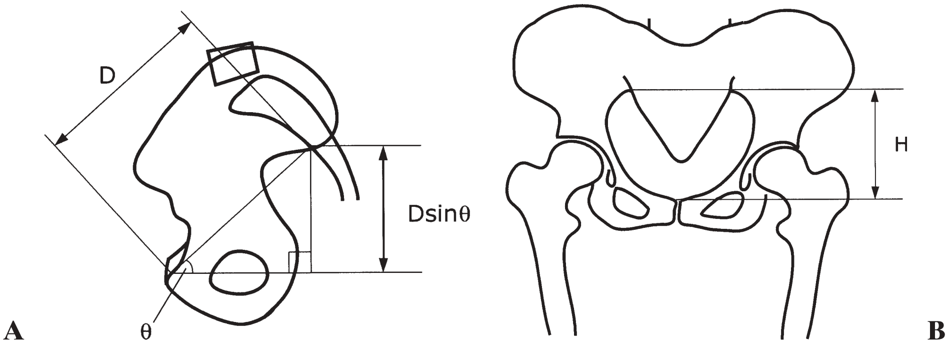


Fig. 1A,B. Calculation method. **A** Lateral radiograph. The pelvic foramen distance (*D*) is defined as the distance between the midpoint of the inferior margins of the bilateral sacroiliac joints and the superior margin of the pubic symphysis on a lateral radiograph. The pelvic inclination angle (θ) is defined as the angle between the horizontal line and line *D* on a lateral radiograph. **B** Anteroposterior (AP) radiograph. The height of the pelvic foramen (*H*) is defined as the distance between the midpoint of the line that connects the inferior margins of the bilateral sacroiliac joints and the superior margin of the pubic symphysis on an AP radiograph. The formula is $H = D \sin\theta$ [$\theta = \arcsin(H/D)$]

eral radiographs. The pelvic inclination angles (θ_0) were also measured on lateral radiographs.

The pelvic inclination angle (θ_1) was calculated by the formula $\theta_1 = \arcsin[H/D]$ (formula 1). Two measured values were substituted in the formula. The difference and the correlation between the measured angle (θ_0) and the calculated angle (θ_1) were examined.

To assess the height from AP radiographs, we used formula 2: $\theta_2 = \arcsin$ [H/average value]; that is, D was substituted for the average of the pelvic foramen distances determined in 236 women and 47 men. The differences and correlations between the measured angle (θ_0) and the calculated angle (θ_2) were examined. The difference and the correlation between calculated angle θ_1 and the calculated angle θ_2 were examined.

The correlations were analyzed using Pearson's correlation coefficient (*R*). The repeatability of the radiographic measurements was determined by having three of the authors measure these values for 283 patients on two occasions at a 3-week interval. The interobserver and intraobserver coefficients of repeatability were then assessed by intraclass correlation coefficients. $P < 0.001$ was considered significant.

Results

The correlation between the calculated pelvic inclination angle θ_1 and the measured angle θ_0 is shown in Fig. 2. The mean ± SD of the calculated angle θ_1 was 27.4° ± 10.8°, and the mean ± SD of the measured angle θ_0 was 27.7° ± 11.1°. The difference was –0.3° ± 4.1°. The *R* value between the calculated angle θ_1 and the measured angle θ_0 was 0.931 ($P < 0.001$).

On plain lateral radiographs of the 236 patients, the average pelvic foramen distance in women was 165 ± 12 mm, and in the 47 men it was 157 ± 13 mm (Fig. 3). D was substituted for the average (165 or 157 mm) pelvic foramen distance. The correlation between the calculated pelvic inclination angle θ_2 as determined by formula 2 and the measured angle θ_0 is shown in Fig. 4. The mean ± SD of calculated angle θ_2 was 27.9° ± 10.9°. The difference between calculated angle θ_2 and measured angle θ_0 was 0.2° ± 4.9°. The *R* value was 0.904 ($P < 0.001$).

The correlation coefficient between formula 1 (θ_1) and formula 2 (θ_2) was 0.973 ($P < 0.001$) (Fig. 5). The difference was within 1° below 20° and within 5° above 20°.

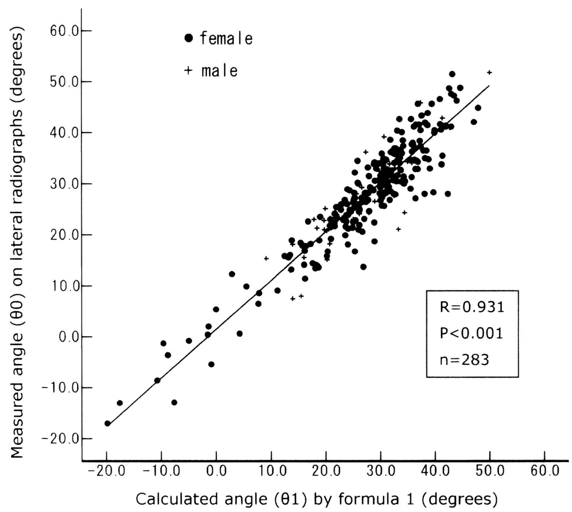


Fig. 2. Correlation between the calculated angles (θ_1) from formula 1 and the measured angles (θ_0). Formula 1 is $\theta_1 = \arcsin(H/D)$. D was measured on radiographs obtained from each patient

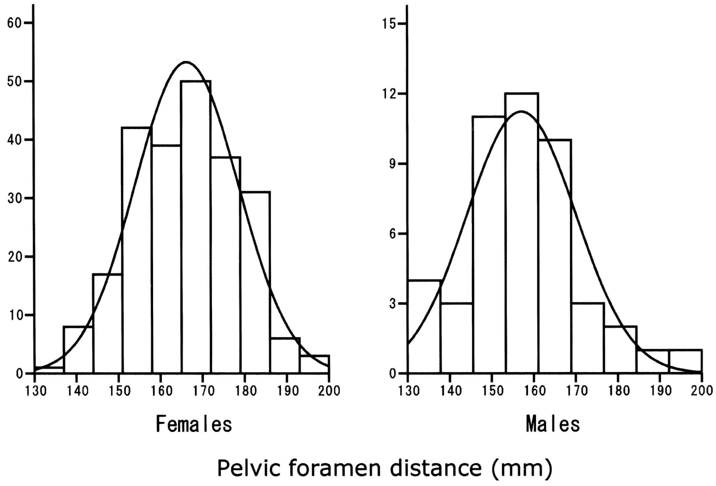


Fig. 3. Histogram of the pelvic foramen (*D*) distance on lateral radiographs of 236 women and 47 men. The pelvic foramen distance showed a normal distribution. The mean ± SD for the women was 165 ± 12 mm, and the mean ± SD for the men was 157 ± 13 mm. The difference was 8 mm

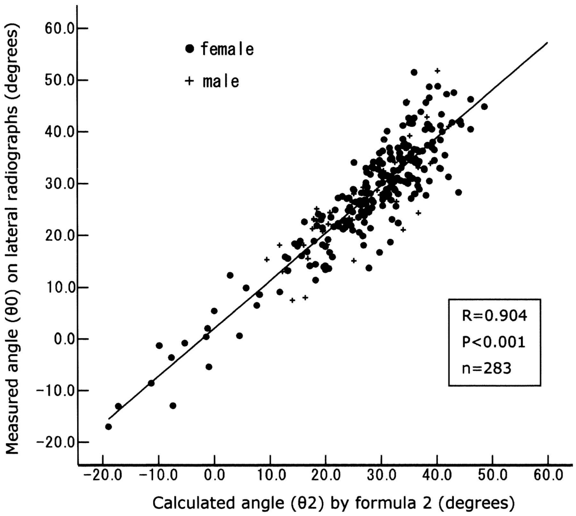


Fig. 4. Correlation between the calculated angles (θ_2) from formula 2 and the measured angles (θ_0). *D* was substituted for the average of the pelvic foramen distance (165 mm or 157 mm). For women, the results as calculated by formula 2 are θ_2 = arcsin (H/165); for men the same result is θ_2 = arcsin (H/157)

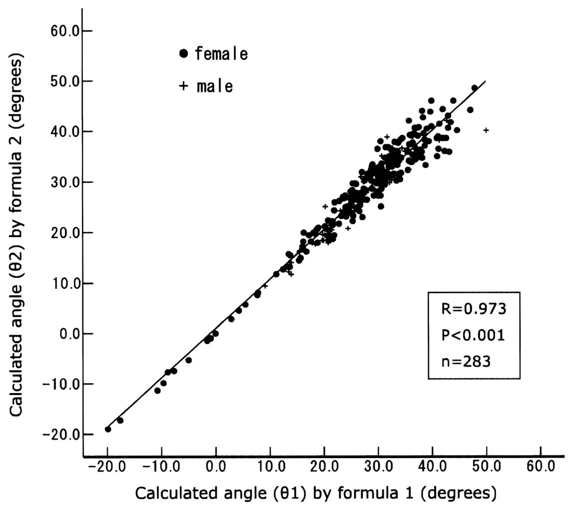


Fig. 5. Correlation between the findings for formula 1 and formula 2 in 283 patients. Formula 1 is θ_1 = arcsin (H/D). Formula 2 is θ_2 = arcsin (H/165 or H/157)

The interobserver and intraobserver reliability of the measured values and the calculated angle is shown in Table 1. The inter- and intraobserver reliability for the calculated angle by formula 1 and formula 2 was high. The intra- and intra-observer reliability of formula 2 was higher than that of formula 1 because D was substituted for the average pelvic foramen distances determined in the 283 patients.

Discussion

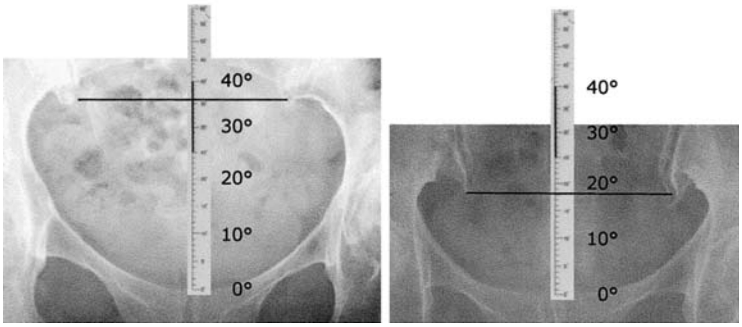
This article presents a simple technique for assessing the pelvic inclination angle using an AP radiograph. The pelvic inclination angle should be determined using a formula based on a trigonometric function because the movement of the pelvic inclination demonstrates a rotary motion.[9] Other methods have been proposed to evaluate the pelvic inclination angle by AP radiographs of the pelvis,[4,6,7] but their formulas were all straight-line formulas without a trigonometric function. The mean and standard deviation of error by our formulas were smaller than by those formulas.

The theoretical background of our formula is shown in Fig. 1. Briefly, the pelvic inclination angle could be accurately predicted by formula 1. A single lateral radiograph should be obtained to measure the distance of the pelvic foramen (D) because the D value is constant

Table 1. Intraobserver and interobserver reliability of the measured values and calculated angle

	Intrareliability			Interreliability		
Parameter	At1At2	Bt1Bt2	Ct1Ct2	At1Bt1	At1Ct1	Bt1Ct1
Height of the pelvic foramen	0.98	0.99	0.98	0.98	0.97	0.96
Distance of the pelvic foramen	0.92	0.86	0.85	0.67	0.66	0.62
Measured angle	0.95	0.89	0.94	0.68	0.80	0.78
Calculated angle by formula 1	0.95	0.94	0.95	0.91	0.90	0.92
Calculated angle by formula 2	0.98	0.99	0.98	0.98	0.97	0.97

The intrareliability was calculated by two readings (t1, t2) by three observers: A, B, and C. The interreliability was calculated for three pairs of readers at time t1



A B

Fig. 6A,B. Scale of the pelvic inclination angle according to the results of formula 2 for women. This method needs no calculations. **A** The height of the pelvic foramen in the supine position was 96.2 mm. The measured angle is 36.0° from the scale of the pelvic inclination angle. The angle calculated from formula 2 was 35.6°. **B** The height of the pelvic foramen in the standing position was 51.3 mm. The measured angle is 18° from the scale of the pelvic inclination angle. The calculated angle of pelvic inclination was 18.1°

individually. The height of the pelvic foramen (H) on AP radiographs changes when the pelvis inclines either anteriorly or posteriorly. Therefore, the pelvic inclination angle is connected with the H value. If a lateral radiograph is not available, the pelvic inclination angle can be predicted by formula 2, where D is replaced by the average pelvic foramen distance.

In this study, the average pelvic foramen distance in 236 women was 165 mm, and the average for 47 men was 157 mm on sagittal radiographs. Provided the magnification was corrected for, this average value is similar to the sagittal diameter of the midpelvis previously reported in the field of obstetrics.[10–13] Therefore, it is reasonable to use the average value in formula 2.

The difference between formula 1 and formula 2 was within 5° in our study. The accepted standard for a measured change representing true change usually has been thought to be 5°.[14] Using a trigonometric function, the difference is smaller if the D value approaches the average whereas it is larger if the D value moves away from the average. In addition, the pelvic inclination angle influences the difference. When the pelvis is inclined anteriorly and the D value exceeds twice the standard deviation, formula 2 might give provide an inaccurate value with a difference of >10°. If the pelvic inclination angle is >40°, formula 1 is better applied than formula 2, where a lateral radiograph is needed.

Clinically, assessment of the pelvic inclination is known to be an important factor for follow-up evaluations of hip disease. The pelvis is reported to incline posteriorly with aging,[15] and significant changes occur in the orientation of the pelvis during the activities of daily living, such as those that involve the supine, standing, and sitting positions.[16] The functional pelvic position influences the anteroposterior ratio of acetabular coverage in the development of coxarthrosis[1,2,5,16–18] and the orientation of the acetabular component in total hip arthroplasty.[3,19] When the yearly and positional changes of the pelvis must be investigated quickly, such as during regular consultations, our method is useful because it is easy to perform and economical. Provided an appropriate scale is made, the pelvic inclination angle can thus be assessed quickly without time-consuming calculations (Fig. 6).

Conclusions

Our formulas are appropriate methods for determining the pelvic inclination angle. Clinically, formula 2 is more convenient than formula 1 because the pelvic inclination angle is only predicted by the height of the pelvic foramen on AP radiographs.

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