Title:

An assessment of the relationship between pelvic tilt and the sacro-femoral-pubic angle in middle-aged and elderly Japanese individuals

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Abstract

Background : The measurement of pelvic tilt (PT) is important for the diagnosis and treatment of adult spinal deformity (ASD). However, the identification of the femoral heads on sagittal radiographs, which is necessary to determine the PT, is often difficult. The purpose of this study is to evaluate the correlation between the PT and the sacro-femoral-pubic (SFP) angle, which is easier to identify than the PT, in middle-aged and elderly Asian subjects from the general population.

Methods : Standing coronal and sagittal pelvic radiographs of individuals of more than 50 years of age were taken during a local medical examination. The subjects were divided into a female group, a male group and a total group at the time of evaluation. A linear regression analysis was performed to investigate the relationship between the PT and the SFP angle, which were obtained from these X-ray films.

Results : The present study included a total of 291 subjects. There was no statistically significant difference between the left and right SFP angles nor was there a gender difference in the SFP angle. However, a gender difference was observed in PT. The correlation between the PT and the SFP angle was substantiated in each group. The Pearson's correlation coefficients between the PT and the SFP angle in the total group, the female group and the male group were 0.696, 0.853 and 0.619, respectively. In a linear regression analysis, PT was calculated as follows: PT = 60.1－0.77×(SFP angle) in the total group; PT = 62.8－0.80×(SFP angle) in the female group; and PT = 51.5－0.64×(SFP angle) in the male group.

Conclusions : A significant correlation between the PT and the SFP angle was observed in middle-aged and elderly Asian subjects from the general population.

Background

The prevalence of adult spinal deformity (ASD) is expected to increase as the population ages [1-3]. ASD can cause pain and disability and consequently affects the health-related quality of life (HRQOL) [4]. Spinopelvic parameters, including pelvic tilt (PT), are used in the diagnosis and treatment of ASD [5,6]. However, the measurement of PT is often difficult because the femoral heads often become unclear on sagittal radiographs, especially in the case of full spine radiographs. In addition, we may not be able to evaluate the center of the femoral head on the opposite side in patients with bipolar or total hip arthroplasty. Blondel et al. reported the correlation between the PT and the sacro-femoral-pubic (SFP) angle, which is measured from coronal radiographs of the pelvis [7] and concluded that even if the femoral head is blurred in the sagittal radiographs, it is possible to predict the PT from the SFP angle. A correlation between the PT and the SFP angle has been reported in different diseases and in subjects of various ages [8-11]. However, at the time of writing, there have been no studies on the association between the PT and the SFP angle in middle-aged and elderly Asian individuals.

The purpose of the present study is to evaluate the correlation between the PT and the SFP angle in middle-aged and elderly Asian subjects from the general population.

Materials and methods

1. Subjects

Local medical examinations have been conducted in a mountain village in Japan to prevent lifestyle-related diseases. During the local medical examination in 2015, the residents who were older than 50 years of age underwent standing coronal and sagittal pelvic radiographs. The radiographs of patients with advanced hip osteoarthritis were excluded because the exact border between the acetabuli and the center of the femoral head were unclear. Residents with bipolar or total hip arthroplasty were also excluded from the study.

Consent was obtained from all of the participants after informing them that their data would be used in the present study.

This study was approved by the institutional review board of Gunma University.

2. Radiographic measurements

The SFP angle was defined as the angle between the midpoint of the upper sacral endplate (by drawing the midpoint between the lateral borders of the L5-S1 facet joints), the centroid of one acetabulum, and the upper midpoint of the pubic symphysis on a coronal radiograph [7] (Fig. 1). The SFP angle was measured on both the right and left sides.

The PT was defined as the angle between the lines connecting the midpoint of the sacral plate to the point halfway between the two femoral centers and the vertical plane on a sagittal radiograph [11] (Fig.2).

3. Statistical analysis

The data were expressed as the mean ± SD. Gender differences in the SFP angle, the PT, and age,

and differences between the left and right SFP angles were evaluated by Welch's test. A Pearson's correlation analysis and a linear regression analysis were used to assess the relationship between PT and the SFP angle. P values of <0.05 were considered to indicate statistical significance. All of the statistical analyses were performed using the IBM SPSS Statistics software program (version 22, IBM Japan, Tokyo, Japan).

Results

1. Demographics

The present study included a total of 291 subjects (female, n=193; male, n=98). The average ages of the total, female, and male groups were 69.0 ± 9.6 years, 68.5 ±9.9 years and 70.0 ±9.1 years, respectively; the age of the male and female subjects did not differ to a statistically significant extent (Table 1).

2. Radiographic results

The PT and SFP angle of the subjects are shown in Table 2. In the total group, the average PT, right-side SFP angle and left-side SFP angle were 18.8 ± 9.7 degrees, 53.3 ± 10.2 degrees and 52.9 ± 10.4 degrees, respectively. In the female group, the average PT, right-side SFP angle and left-side SFP angle were 20.0 ± 10.7 degrees, 53.6 ± 11.5 degrees and 53.2 ± 11.6 degrees, respectively. In the male group, the average right-side SFP angle and left-side SFP angle were 16.4 ± 6.9 degrees, 52.6 ± 7.1 degrees and 52.3 ± 7.4 degrees, respectively. No statistically significant differences were observed in the SFP angles on the left and right sides ($p>0.05$); moreover, there no gender differences regarding the SFP angle. However, a gender difference was observed regarding the PT.

3. The correlation analysis and the linear models

According to the results of the Pearson's correlation analysis, there was a strong correlation between the PT and the SFP angle. The Pearson's correlation coefficients of the total group, the female group and the male group were 0.696, 0.853 and 0.619, respectively (Table 3). A linear regression analysis was performed in which PT was calculated as: PT = 60.1－0.77×(SFP angle)

in the total group; PT = 62.8－0.80×(SFP angle) in the female group; and PT = 51.5－0.64×(SFP angle) in the male group (Fig. 3).

Discussion

ASD is likely to cause pain, disability and a reduction in the HRQOL [4]. Recent studies have used the Scoliosis Research Society (SRS)-Schwab Adult Spinal Deformity classification for the diagnosis and treatment of ASD [4,12]. PT is included as one of the 3 sagittal modifiers in this classification system. PT is correlated with the HRQOL in ASD, and is one of the critical goals when planning realignment surgery for ASD [6]. The measurement of the PT is therefore very important. However, the profile of the femoral heads is often blurred in sagittal radiographs of the full spine, which makes it difficult to measure the PT.

Blondel et al. showed that the SFP angle obtained from coronal radiographs of the pelvis was correlated with the PT, and suggested the formula PT=74.6－0.942×(SFP angle) [7]. Following the report by Blondel et al., some other authors demonstrated a correlation between the PT and the SFP angle, although the studies focused on different diseases and patients of different ages [8-11]. The formulas that have been reported to date and our own formula differed in regard to their intercept and slope. These factors might be affected by a difference in the spine disease, race or age. In almost all of the reported studies the subjects had no spinal disease or a spinal disease such as adolescent idiopathic scoliosis, ankylosing spondylitis or congenital scoliosis. On the other hand, because we only performed pelvic radiographs in local medical examinations, it wasn't possible to confirm the presence or absence of the spinal diseases. Hu et al. derived their formula in a study of patients with ankylosing spondylitis and showed fewer errors in comparison to the formula reported by Blondel et al. when two formula were applied to the patients with ankylosing spondylitis [9]. Consequently, the formulae that are appropriate for calculating the relationship between the PT and the SFP angle may differ in other diseases. Additionally, some authors have noted that racial differences influence the parameters of the

spine and/or pelvis [13-17]. Mac-Thiong reported that weak correlations existed between the PT and the sacral slope (SS) with respect to age [17]. As the average age of our subjects was the oldest among the studies that investigated the relationship between the PT and the SFP angle, it is possible that the differences between the formulae of the present and previous studies are explained, not only by racial difference but also by age differences.

In the present study, a gender difference was observed regarding PT. It is possible that the gender difference affected the intercept and the slope of the formula. Consequently, it is necessary to derive the PT separately for each gender.

Various parameters by which the PT can be estimated have been reported [18-22]. Tannast et al. verified the reliability of these parameters. In both females and males, the vertical distance between the upper edge of the pubic symphysis and the mid-point of the sacrococcygeal joint showed the strongest correlation among all of the other parameters (Pearson's correlation coefficient: 0.63 in females; 0.68 in males)[23]. However numerous studies have examined the relationship between the PT and the SFP angle [8-11,24]. Our results, also support the use of the SFP angle in the prediction of PT.

The sagittal modifiers in the SRS-Schwab Adult Spinal Deformity classification include: "pelvic incidence (PI) minus lumbar lordosis (LL)", "sagittal vertical axis (SVA)" and "PT". Because the upper sacral endplate is visible in the sagittal radiographs of the full spine, the LL, SVA and SS can be measured. If the PT can be predicted from the SFP angle, then it is possible to estimate the PI with the following formula: PI = PT + SS.

The PT is known to change in the supine and standing positions [25]. Dislocation in cases of total hip arthroplasty depends on the anteversion of the cup. The measurement of the change in the PT (using the formula) can help in planning the insertion of the implant during surgery. As a result, it may reduce the risk of dislocation. However, in such cases, it is necessary for the other

side of the hip joint to be normal.

This study is associated with some limitations. First, the male cohort was relatively small. It is conceivable that the accuracy could have been improved by taking pelvic radiographs of other regions. Second, although it would have allowed us to obtain useful information regarding the PT and the SFP angle we were not able to perform a radiographic examination of the spine. Consequently, we could not investigate the relationship of other spinal parameters, including the LL and the sagittal SVA, with the SFP angle. However, to our knowledge, this is the first report to show a correlation between the PT and the SFP angle in middle-aged and elderly Asian subjects from the general population. Moreover, the number of subjects in the present study is the largest to date. Consequently, it is considered that our formula is significant for decision-making in the treatment of ASD and hip disorders.

Conclusions

A significant correlation was observed between the PT and the SFP angle in middle-aged and elderly Asian subjects from the general population.

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Fig. 1.

The SFP angle was defined as the angle between the midpoint of the upper sacral endplate (by drawing the midpoint between the lateral borders of the L5-S1 facet joints), the centroid of one acetabulum and the upper midpoint of the pubic symphysis on a coronal radiograph.

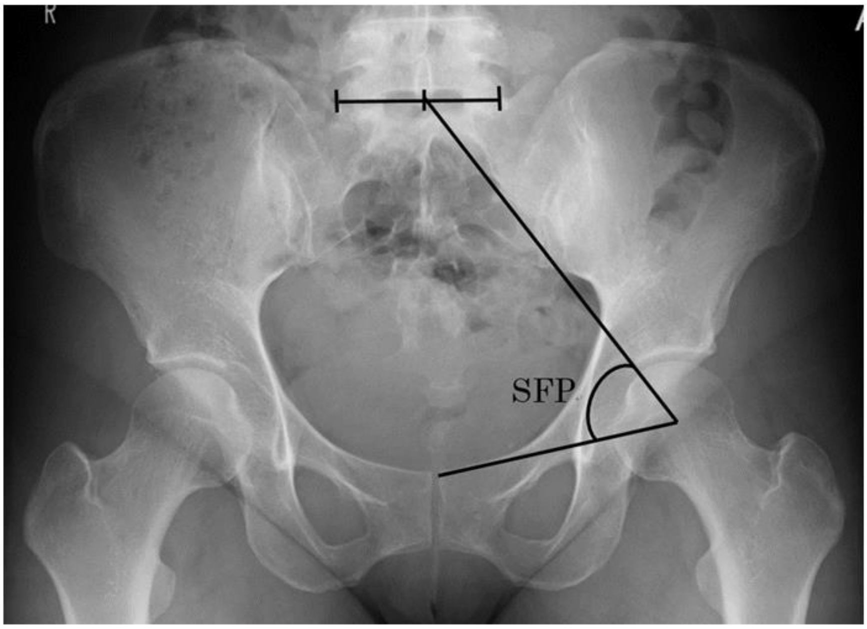

Fig. 2.

The PT was defined as the angle between the lines connecting the midpoint of the sacral plate to the point halfway between the two femoral centers and the vertical plane on a sagittal radiograph.

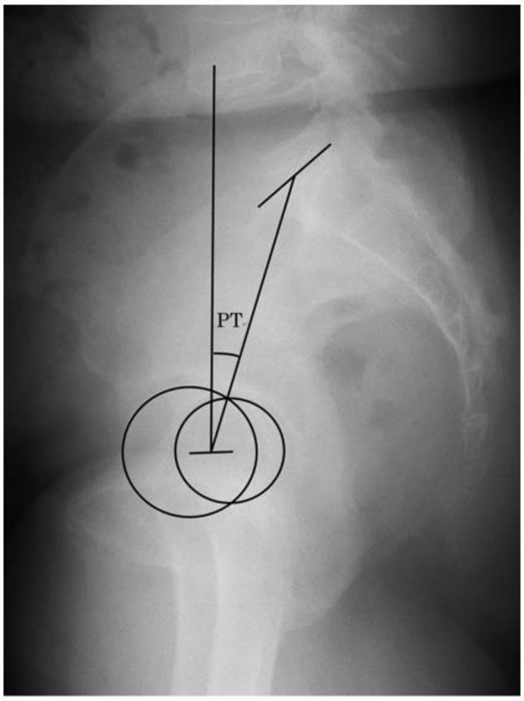

Fig. 3.

(A) A linear regression model showing the correlation between the PT and the SFP angle in the total group. (B) A linear regression model showing the correlation between the PT and the SFP angle in the female group. (C) A linear regression model showing the correlation between the PT and the SFP angle in the male group.

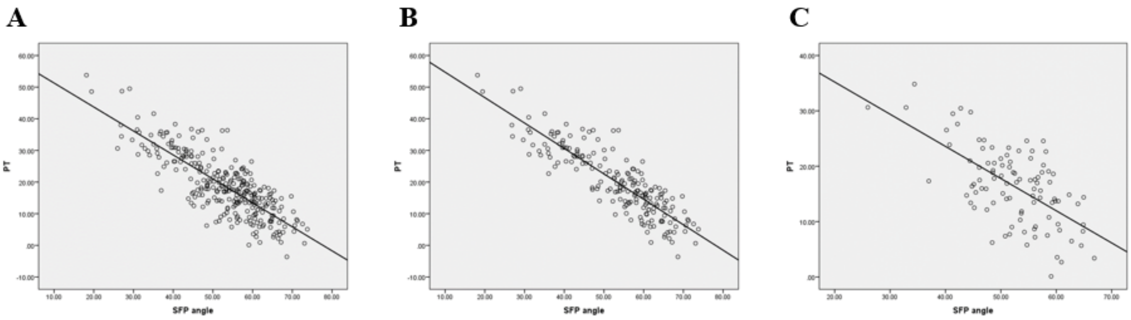

Table 1. Summary of the patients' characteristics

	Number	Age (years)
Females	193	68.5 ± 9.9
Males	98	70.0 ± 9.1
Total	291	69.0 ± 9.6

The age of the male and female subjects did not differ to a statistically significant extent ($P>0.05$, Welch test).

Table 2. The average PT and SFP angle of each group

	PT (º)	SFP angle (º)	
		right	left
Females	**20.0 ± 10.7**	**53.6 ± 11.5**	**53.2 ± 11.6**
Males	**16.4 ± 6.9**	**52.6 ± 7.1**	**52.3 ± 7.4**
Total	**18.8 ± 9.7**	**53.3 ± 10.2**	**52.9 ± 10.4**

No statistically significant difference was observed between the left and right SFP angles ($P>0.05$, Welch test). No gender difference was observed in the SFP angle ($P>0.05$, Welch test). A gender difference was observed in the PT ($P<0.05$, Welch test).

Table 3. A summary of the Pearson's correlation coefficients of each group

	Pearson coefficient
Females	**0.853**
Males	**0.619**
Total	**0.696**