

# Radiographic Analysis of the Sacropelvic Parameters of the Spine and Their Correlation in Normal Asymptomatic Subjects

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## Abstract

**Study Design** Cross-sectional study.

**Objective** Sacropelvic parameters in various spine and hip disorders have been published in various studies. We aimed to study the normal sacropelvic parameters and curvatures of the spine and their correlation in asymptomatic Indian adults in relation to variations in sex and age.

**Methods** The study included 101 asymptomatic adults (50 men and 51 women with an average age of 47.16 and 48.59 years, respectively). For each subject, the thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) were measured from standing lateral radiographs. After stratification of the group by sex and age with a cutoff of 50 years, descriptive, correlation, and regression analysis were performed using SPSS software.

**Results** The average PI, SS, PT, LL, and TK values were 55.48 ( $\pm 5.31$ ), 35.99 ( $\pm 7.53$ ), 17.97 ( $\pm 7.16$ ), 48.84 ( $\pm 9.82$ ), and 32.55 ( $\pm 10.92$ ), respectively. No statistically significant difference was observed in these values with regards to sex and age < 50 years and > 50 years but the pelvic incidence was found to be higher in women. A positive correlation between the PI and SS and a negative correlation between the SS and PT was observed. A positive correlation between the TK and LL was found in subjects > 50 years. Simple and multiple regression analyses were also performed for different groups.

**Conclusion** The current study is the first of asymptomatic Indian adults and provides invaluable information to the clinicians about the normal range of sacropelvic and spinopelvic parameters, which is useful to plan spinal deformity corrections and to evaluate pathologic conditions associated with abnormal angular values.

## Keywords

- ▶ sacropelvic parameters
- ▶ lumbar lordosis
- ▶ thoracic kyphosis
- ▶ asymptomatic adults

## Introduction

The influence of sacropelvic balance and morphology in the evaluation and treatment of developmental spondylolisthesis,<sup>1–6</sup> degenerative spondylolisthesis,<sup>7</sup> adolescent idiopathic scoliosis,<sup>8</sup> and adult spinal deformity has been investigated in various studies.<sup>9</sup> The role of sacropelvic morphology and

balance in the pathogenesis and surgical treatment of hip osteoarthritis has been stated in some reports.<sup>10</sup> As a basis for comparison, it is therefore important to document the sacropelvic balance and morphology in the normal population. Few studies in the literature have noted the normal values of these parameters in adults,<sup>11–15</sup> but no study has documented the normal sacropelvic parameters and their

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correlation in the Indian population. Boulay et al did not find any significant difference in the sacral slope (SS), pelvic tilt (PT), or pelvic incidence (PI) between adult women and men.<sup>12</sup> On the contrary, Vialle et al found statistically significant differences in the SS and PI but not the PT between female and male subjects.<sup>14</sup> A weak statistical relationship not likely to be clinically significant was observed between different age groups and the PI, SS, and PT. The SS and PT were not related to age. Hammerberg and Wood evaluated 50 asymptomatic subjects aged 70 to 85 years and did not find any relationship between increasing age and sacropelvic parameters of balance and morphology, with the mean PT and PI higher than those observed previously in younger adults.<sup>15</sup> Mac-Thiong et al documented values for these parameters in their population and did not find any difference in these values between male and female subjects.<sup>16</sup>

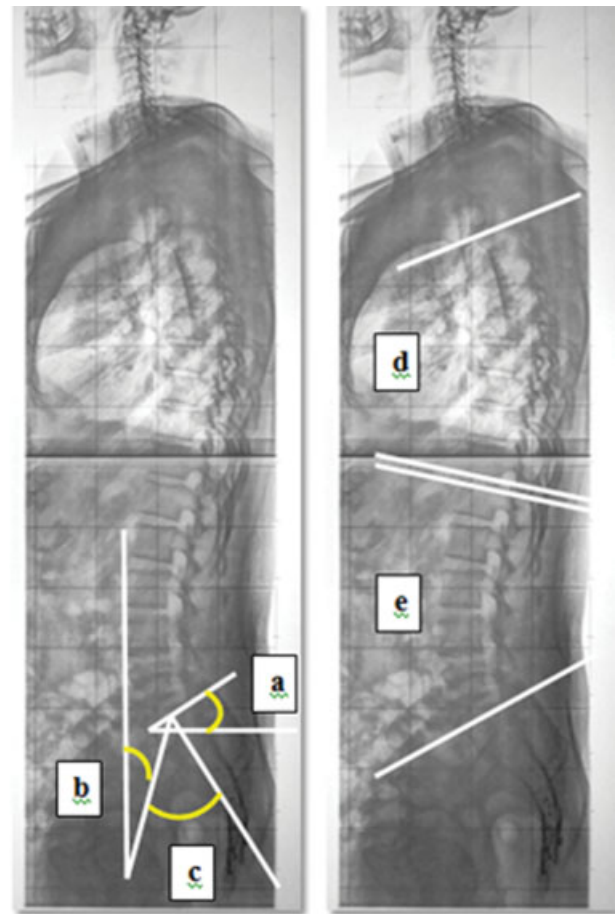
With this background, we aimed to study the various sacropelvic parameters and the sagittal alignment of the spine in a prospective cohort of 101 normal asymptomatic subjects in the Indian population to provide a baseline value of the sacropelvic parameters.

## Materials and Methods

A prospective cohort of 101 normal asymptomatic adults who attended the outpatient department of Sir Gangaram hospital from March 2013 to June 2013 with no complaints related to spine were included in the study after obtaining clearance from the Institute's ethical committee. Subjects included 50 men and 51 women with an average age of 47.16 and 48.59 years, respectively. A standing left lateral radiograph exposing C7 to S1 and both the hips with a long 36-inch cassette placed at 72 cm from the X-ray tube was performed by a single radiographer to avoid bias. The subjects were instructed to stand in a comfortable position with the hips and knees fully extended.<sup>17</sup> The sacropelvic parameters were then measured by a single observer using the KEOPS software (Images Viewer v.3.2.1.0). For each subject, the thoracic kyphosis (TK), lumbar lordosis (LL), PI, PT, and SS were measured (►Fig. 1).

The TK was measured from the superior end plate of T3 to the inferior end plate of T12. The LL was measured from the superior end plate of L1 to the superior end plate of S1 in standing lateral views. The PI was measured as the angle between two lines: the first line is from the middle of a line connecting the center of each femoral heads to the midpoint of the superior sacral end plate and the second line is perpendicular to the superior sacral end plate. The angle between the vertical and a line drawn from center of a line connecting the center of each femoral head to the midpoint of the superior sacral end plate was measured for obtaining the PT, and the angle between the horizontal line and the superior sacral end plate was used for SS (►Fig. 1).

Statistical analyses were performed using the SPSS version 17.0 program for Windows. We conducted a Shapiro-Wilk test to verify the distribution of the data. All data was summarized as the mean  $\pm$  standard deviation (SD). The chi-square test was used to compare the differences in variables between the



**Fig. 1** Angular parameters measured in standing whole-spine lateral view X-ray. (a) Sacral slope; (b) pelvic tilt; (c) pelvic incidence; (d) thoracic kyphosis; (e) lumbar lordosis.

two groups. The Student *t* test was used for continuous, normal variables. Pearson correlation analyses were used to assess the correlations among parameters. The variables were entered into a multiple linear regression analysis if their *p* value was less than 0.05 in the univariate analysis to assess independent association. The assumptions of regression model was also met; error terms were constant (homoscedasticity) and were normally distributed.

## Results

The average PI was 55.48 ( $\pm 5.31$ ), SS was 35.99 ( $\pm 7.53$ ), PT was 17.97 ( $\pm 7.16$ ), LL was 48.84 ( $\pm 9.82$ ), and TK was 32.55 ( $\pm 10.92$ ; ►Table 1). The results revealed a statistically significant difference in PI between men and women with women having a higher PI. The PT, SS, LL, and TK did not show any statistically significant difference between sex and age (►Tables 2 to 5). The average difference between LL and TK was  $-16$  degrees. The SS was greater than half of PI.

Irrespective of age and sex, there was a positive correlation between the PI and SS (►Tables 6 to 9). Regardless of age and sex, there was a statistically significant negative correlation between the SS and PT (►Tables 6 to 9). There was no correlation between the PT and LL or TK. A statistically

**Table 1** Values of various parameters

	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Age	101	18	79	44.91	15.811
Sacral slope (degrees)	101	10	50	35.99	7.531
Pelvic tilt (degrees)	101	9	43	17.97	7.167
Pelvic incidence (degrees)	101	43	62	55.48	5.311
Lumbar lordosis (degrees)	101	27	78	48.84	9.827
Thoracic kyphosis (degrees)	101	10	59	32.55	10.927

**Table 2** Values of the parameters in women

	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Age	51	18	73	48.59	13.234
Sacral slope (degrees)	51	13	48	35.87	7.786
Pelvic tilt (degrees)	51	9	43	19.06	7.587
Pelvic incidence (degrees)	51	44	62	57.93	3.993
Lumbar lordosis (degrees)	51	29	78	50.53	9.301
Thoracic kyphosis (degrees)	51	12	59	33.91	11.264

**Table 3** Values of the parameters in men

	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Age	50	18	79	41.16	17.408
Sacral slope (degrees)	50	10	50	36.12	7.338
Pelvic tilt (degrees)	50	10	41	16.86	6.602
Pelvic incidence (degrees)	50	43	60	53.03	4.646
Lumbar lordosis (degrees)	50	27	71	47.12	10.140
Thoracic kyphosis (degrees)	50	10	55	31.17	10.504

significant positive correlation was observed in our study between the LL and TK in subjects > 50 years of age (► **Tables 6 to 9**). We did not find a significant correlation between the PI and LL. A regression analysis was performed using multiple variables to predict the SS, PT, and LL based on

PI. A regression analysis was also performed to predict the LL based on age (► **Table 10**). Equations were also calculated for predicting the PI based on the SS and the LL based on the TK for men, women, and subjects < 50 years and > 50 years of age (► **Tables 11 and 12**).

**Table 4** Values of the parameters in subjects < 50 years of age

	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Age	52	18	48	32.17	10.401
Sacral slope (degrees)	52	16	50	36.02	7.324
Pelvic tilt (degrees)	52	9	41	17.55	6.767
Pelvic incidence (degrees)	52	45	60	53.57	4.365
Lumbar lordosis (degrees)	52	27	78	46.87	9.479
Thoracic kyphosis (degrees)	52	12	52	30.24	9.644

**Table 5** Values of the parameters in subjects > 50 years of age

	<i>n</i>	Minimum	Maximum	Mean	Standard deviation
Age	49	50	79	58.43	6.599
Sacral slope (degrees)	49	10	46	35.97	7.821
Pelvic tilt (degrees)	49	10	43	18.42	7.613
Pelvic incidence (degrees)	49	43	62	54.43	4.463
Lumbar lordosis (degrees)	49	29	76	50.94	9.848
Thoracic kyphosis (degrees)	49	10	59	35.00	11.747

**Table 6** Correlation between the parameters in men

	PI	SS	PT	LL	TK
PI	1	0.474 <sup>a</sup>	0.178	0.222	0.086
SS		1	-0.781 <sup>a</sup>	0.141	-0.132
PT			1	0.000	0.096
LL				1	0.232
TK					1

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis.

<sup>a</sup> $p < 0.01$ .

**Table 7** Correlation between the parameters in women

	PI	SS	PT	LL	TK
PI	1	0.306 <sup>a</sup>	0.213	0.165	0.016
SS		1	-0.865 <sup>b</sup>	0.099	-0.072
PT			1	0.015	0.082
LL				1	0.257
TK					1

Abbreviations: PI, pelvic incidence; LL, lumbar lordosis; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis.

<sup>a</sup> $p < 0.05$ .

<sup>b</sup> $p < 0.01$ .

## Discussion

The spinopelvic and sacropelvic parameters of the spine and pelvis have been emphasized in various studies in the literature. They play a vital role not only in the spinal pathology but

also in the hip pathology. The normal values of these parameters have been described by several authors in their respective populations, but the current study presents the largest cohort of normal asymptomatic Indian adults for the evaluation of the spinopelvic and sacropelvic parameters. According

**Table 8** Correlation between the parameters in subjects with age < 50 years

	PI	SS	PT	LL	TK
PI	1	0.421 <sup>a</sup>	0.190	0.246	0.044
SS		1	-0.811 <sup>a</sup>	0.250	-0.071
PT			1	0.112	0.049
LL				1	0.115
TK					1

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis.

<sup>a</sup> $p < 0.01$ .

**Table 9** Correlation between the parameters in subjects with age > 50 years

	PI	SS	PT	LL	TK
PI	1	0.340 <sup>a</sup>	0.239	0.178	0.144
SS		1	-0.831 <sup>a</sup>	0.009	0.097
PT			1	0.116	0.021
LL				1	0.318 <sup>b</sup>
TK					1

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis.

<sup>a</sup>*p* < 0.01.

<sup>b</sup>*p* < 0.05.

**Table 10** Simple and multivariate linear correlations between various spinopelvic and sacropelvic parameters in entire study group

Linear regression models	Variable	R <sup>2</sup>
SS = 1.804 + 0.634 PI	PI	0.145
PT = - 0.739 + 0.347 PI	PI	0.048
LL = - 21.751 + 0.347 PI	PI	0.051
LL = - 42.926 - 0.127 age	Age	0.042

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, Thoracic kyphosis.

**Table 11** Simple and multivariate linear correlations between various spinopelvic and sacropelvic parameters in men and women

Linear regression models	Variable	R <sup>2</sup>	Beta coefficient standard error
Men			
PI = 42.183 + 0.300 SS	SS	0.225	0.08
LL = 40.154 + 0.224 TK	TK	0.054	0.136
Women			
PI = 47.854 + 0.184 SS	SS	0.06	0.104
LL = 43.332 + 0.212 TK	TK	0.066	0.114

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, thoracic kyphosis.

to our study, there is no difference in the SS, PT, LL, and TK between men and women but the PI is higher in women compared with men. Similarly, we found no difference in the PI, PT, SS, LL, and TK between subjects < 50 years and subjects > 50 years of age.

Mac-Thiong et al and Zhu et al reported no difference in the PI, PT, or SS between men and women, revealing no relationship between sex and spinopelvic parameters.<sup>16,18</sup> In contrast to these studies, we found that Indian women have a higher PI compared with men. According to Mac-Thiong et al, the

**Table 12** Simple and multivariate linear correlations between various spinopelvic and sacropelvic parameters in subjects < 50 years and subjects > 50 years of age

Linear regression models	Variable	R <sup>2</sup>	Beta coefficient standard error
<50 y			
PI = 42.913 +0.283 SS	SS	0.120	0.108
LL = 43.438 + 0.113 TK	TK	0.013	0.138
>50 y			
PI = 47.450 + 0.194 SS	SS	0.116	0.078
LL = 41.626 + 0.266 TK	TK	0.101	0.116

Abbreviations: LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK, Thoracic kyphosis.

mean  $\pm$  2 SD range was  $52.6 \pm 10.4$  degrees,  $13.0 \pm 6.8$  degrees, and  $39.6 \pm 7.9$  degrees for the PI, PT, and SS, respectively,<sup>16</sup> whereas the values given by Zhu et al were  $44.6 \pm 11.2$  degrees for the PI,  $11.2 \pm 7.8$  degrees for the PT, and  $32.5 \pm 6.5$  degrees for the SS, respectively.<sup>18</sup> Vialle et al postulated mean values  $\pm$  2 standard deviations as  $60 \pm 10$  degrees for LL,  $41 \pm 8.4$  degrees for the SS,  $13 \pm 6$  degrees for the PT,  $55 \pm 10.6$  degrees for the PI.<sup>14</sup> A strong correlation was found between the SS and the PI ( $r = 0.8$ ), between the maximum LL and SS ( $r = 0.86$ ), between the PI and PT ( $r = 0.66$ ), and between the LL and PI, PT, and TK ( $r = 0.9$ ) in their study. However, comparison of these values between sex and different age groups were not formulated in these studies. Kim et al compared these parameters between the young and elderly and found that the TK and PI were higher in the elderly subjects.<sup>19</sup> Our study showed a statistically significant positive correlation between the PI and SS, a negative correlation between the SS and PT irrespective of the age and sex, and a positive correlation between the LL and TK in subjects greater than 50 years of age. However, in contrast to other studies, our study did not show a statistically significant correlation between the LL and PI. As age advances, disk degeneration increases, resulting in loss of disk height and thus a loss of lordosis. To compensate, the TK also decreases to maintain the sagittal balance. This fact is clinically important when planning long segment fixations and fusions in elderly patients, so that adequate LL can be achieved along with an increased TK to prevent proximal junctional failures, which is a potential complication in these patients.

Lafage et al emphasized the importance of the spinopelvic parameters in the treatment of patients with deformities and also their influence in osteotomies in these patients.<sup>20</sup> Glattes et al showed that patients who were slightly kyphotic at the proposed proximal junction compared with the average sagittal alignment in a normal population were not at a higher risk for developing a junctional kyphosis.<sup>21</sup>

Surgeries to correct the spinal deformities ideally should aim at a proper relationship between the sacropelvic parameters and the TK and LL, but a pronounced breach in this relationship can result in a less favorable clinical outcome. No studies in the literature have given the correlation between these parameters and the spinal curvatures, especially in asymptomatic subjects. This study is the first to correlate these parameters, which will give an insight about the amount of osteotomy required to correct deformities and in cases requiring long segment instrumentation and fusions. A positive correlation between the PI and SS was found in our study, which indicates that subjects with a high PI tend to have higher values of SS. Similarly, a negative correlation between the SS and PT implies that as the SS increases, the PT decreases and vice versa to maintain a constant PI. Hence, while planning for fixation and fusion in patients with a high PI, an adequate SS should be attained intraoperatively by maintaining adequate lordosis, failure of which will result in pelvic retroversion as a result of compensatory increase in the PT. There was a significant positive correlation between the LL and the TK in subjects  $>$  50 years of age. Hence, while planning for long segment fixations in the elderly

population, an adequate LL corresponding to the TK should be achieved to avoid proximal junctional failures and other complications.

## Conclusion

The current study presents the largest cohort of normal asymptomatic subjects for the evaluation of the sacropelvic and spinopelvic parameters in the Indian population. The range of values of the PI, PT, and SS corresponding to the mean  $\pm$  2 SD can provide invaluable information to clinicians about the normal range of values expected in 95% of the population, thus serving as a baseline in the evaluation and management of spinal disorders. The correlations between these parameters is of profound importance in calculating the corrections required in spinal deformities.

## Disclosures

G. Sudhir, none  
Shankar Acharya, none  
Kalra K.L., none  
Rupinder Chahal, none

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