ORIGINAL ARTICLE

Pelvic Incidence Angle in Standing, Maximal Anterior and Maximal Posterior Pelvic Rotation in a Sample of Healthy Subjects

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Abstract- This study aimed to investigate the differences in pelvic incidence (PI) between three standing, maximal anterior and maximal posterior pelvic rotation. This cross-sectional study was done on 150 healthy subjects. Lateral spine radiography was taken in 3 different positions in the same standard radiographic protocol. Sacral slope (SS) pelvic tilt (PT), lumbar lordosis (LL) and lumbosacral junction angle were measured by two independent, experienced spine surgeons. PI was calculated as sum SS and PT. The mean of PI in standing positions was 52.6±5.1, in anterior position was 52.6±5.5 and in posterior position was 52.3±5.2 degree. The mean of PI, PT, and SS in total and between male and female subjects was not statistically significant in three different positions (P>0.05). PI in 136 subjects (90.7%) is changed when the position was changed from standing to the posterior position, by mean of 2.06 degree. When the position was changed from standing to an anterior position, the change in PI degree was observed in 126 subjects (84%) by mean of 2.12 degree. Despite the none, significant value of PI in three different positions, a large number of subjects with a change in their PI when the position was changed to anterior or posterior (90.1%) position, show that PI can be varied by pelvic rotation in healthy adult subjects.

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Keywords: Pelvic incidence; Sacral slope; Pelvic tilt; Lumbar lordosis

Introduction

Pelvic incidence (PI) as a parameter for pelvic configuration independent from pelvic movement is known as the sum of the sacral slope (SS) and the pelvic tilt (PT), are an individual and unchangeable measure (1-2). The mean of PI in normal healthy populations is reported around fifty degrees, and it was found that PI is a hugely variable parameter in normal adults (28-84 degree) and increasing with advancing age until the end of growth (3-6). To maintain sagittal balance, although PI is static, PT and SS may dynamically change in response to postural changes (7).

The pelvis must be well positioned during the acquisition of the radiograph, to obtain reliable radiographic parameters. Anteroposterior tilting of the pelvis should not change the projected PI, whereas, the position of the spine and pelvis depend directly on PT and rotation during radiograph acquisition. A PI measurement is a likely to change in the rotation of the pelvis around the vertical axis on lateral 2-dimensional spinopelvic radiograph (8).

It is demonstrated that PI has a close and direct association with lumbar lordosis (LL) and lower PI in subjects who had a lower LL in the upright position (1,6). But the data about the effects of pelvic position or movement on PI in healthy population are limited and in only study, Place *et al.*, (9) assessed the differences in pelvic incidence between three pelvic positions in 50 healthy subjects and demonstrated that PI was changed by simply rotating the pelvis from a resting position to maximal anterior pelvic rotation or from a resting position to a maximal posterior pelvic rotation. So, the present study was designed to evaluate and compare the value of PI in three standing, maximal anterior and maximal posterior pelvic rotation in a sample of healthy subjects.

Materials and Methods

In this cross-sectional study, 150 healthy subjects

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among the companions of hospitalized patients, who were a candidate for lumbar fusion surgery, in Al-Zahra hospital in Isfahan Iran. Subjects of both sexes between 18 to 70-year-old were eligible if their BMI was lower than 30 kg/m2, did not have any previous history of the spine, pelvic, or lower extremity pain (continued longer than 48 hours). Pregnant women, subjects who had a history of received medical care for any disorder in the spine, pelvis or lower extremity, and those with a history of radiographic abnormalities such as scoliosis, spondylolisthesis, or Scheuermann's kyphosis did not enter to the study. The protocol of the present study is reviewed and approved by the Ethics Committee of Isfahan University of Medical Sciences, and informed consent was obtained from all subjects before participation.

Data about age, sex and BMI were collected, and lateral spine radiography was taken in 3 different positions for all subjects in the same standard radiographic protocol using Dura Diagnostic Digital radiography system. The standing lateral radiograph was taken after that subjects were instructed to stand in a comfortable position with fists on clavicles, hips, and knees fully extended. Lateral radiograph in anterior and posterior positions was taken when the subjects were instructed to maximally rotate their pelvis on the femoral heads in an anterior direction and then to maximally rotate their pelvis on the femoral heads in a posterior direction. All radiographs were stored in a digital format and examined using validated software (Surgimap; Nemaris, Inc.) to measured spino-pelvic parameters. The measured spino-pelvic parameters included SS, PT, PI, LL, Lumbosacral junction angle (LJA), and TLL. SS (as the angle between the line parallel to the S1 endplate and the reference horizontal line) and PT (as the angle between the line joining the center of the bicoxofemoral axis and the center of the S1 endplate and the vertical line) were measured automatically by the software. PI as the angle between the line joining the center of the bicoxofemoral axis and the center of the S1 endplate and the line orthogonal to the S1 endplate was calculated as follow a formula, PI=SS+PT. LL was measured between T12 and S1. TLL was calculated as the sum of LL and LJA.

Two independent, experienced spine surgeons measured PT and SS once on each of the lateral radiographs to determine the interobserver reliability. The interobserver reliability of these measurements was 0.98, and so, in the final analyses, measurements taken by one observer were used.

All data were analyzed using SPSS 24 for Windows (SPSS inc., Chicago, IL, USA). Descriptive statistics are presented as means±standard deviations or number (percent) as appropriate. Independent sample t-test and *Chi*-square test were used to compare variables as appropriate. Statistical significance was set at *P* less than 0.05.

Results

The characteristics of the studied subjects are presented in table 1. The mean of age in studied subjects was 45.7 years, 50.7% were male, and 49.3% were females. More than half of the subjects reported low back pain. The mean of LL and lumbosacral junction angle were 38.5 and 19.1 degrees, respectively.

Table 1. Characteristics of studied subjects

Age (year)	**Mean**	45.7 ± 14.3
	Min-Max	20-70
Gender	**Male**	76 (50.7)
	Female	74 (49.3)
Low back pain	**Positive**	89 (59.3)
	Negative	61 (40.7)
VAS score		1.8 ± 1.9
Lumbar Lordosis		38.5 ± 8
Lumbosacral junction angle		19.1 ± 7.7
Total Lumbosacral Lordosis		57.6 ± 5.2

Data are mean ± SD or number (%)

Comparison of pelvic parameters in three different positions is presented in table 2. The mean of PI of all subjects in standing and anterior positions was 52.6, and in posterior position was lower (52.3) but was not statistically significant. Also, PT and SS in all subjects were similar in three different positions. The mean of PI in standing, posterior and anterior positions in male subjects were 51.9, 51.7 and 51.9 degrees, respectively, which was not statistically significant between different positions. Among women, mean of PI was 53.2 in

standing position, 52.9 in posterior position and 53.3 in an anterior position (P>0.05). The mean of PT and SS among male and female subjects were not statistically significant between three different positions. Also, the differences in the mean of PI, PT, and SS between male and female subjects were not statistically significant.

Table 2. Comparison of pelvic parameters in different positions

		Pelvic incidence	Pelvic tilt	Sacral slope
Total	**Standing position**	52.6 ± 5.1	14.4 ± 3.3	38.1 ± 4.4
	Posterior position	52.3 ± 5.2	14.1 ± 3.5	38.2 ± 4.5
	Anterior position	52.6 ± 5.5	14.5 ± 3.5	38.1 ± 4.3
	P*-value	0.242	0.152	0.523
	***P*-value†**	0.764	0.826	0.944
	***P*-value††**	0.101	0.072	0.533
Male	**Standing position**	51.9 ± 5.1	14.4 ± 3.2	37.5 ± 4.3
	Posterior position	51.7 ± 5.1	14 ± 3.5	37.7 ± 4.4
	Anterior position	51.9 ± 5.6	14.3 ± 3.4	37.6 ± 4.4
	P*-value	0.441	0.176	0.239
	***P*-value†**	0.920	0.556	0.349
	***P*-value††**	0.492	0.371	0.576
Female	**Standing position**	53.2 ± 5.1	14.4 ± 3.3	38.8 ± 4.5
	Posterior position	52.9 ± 5.2	14.2 ± 3.5	38.7 ± 4.6
	Anterior position	53.3 ± 5.3	14.6 ± 3.6	38.6 ± 4.3
	P*-value	0.381	0.494	0.891
	***P*-value†**	0.621	0.397	0.449
	***P*-value††**	0.065	0.095	0.698

Data are mean ± SD

P calculated by paired samples *t*-test, *****Comparison between Standing position and Posterior position, †Comparison between Standing position and Anterior position, †† Comparison between Posterior position and Anterior position.

Table 3 shows the changes in PI value from standing position to posterior or anterior positions in all subjects and male and females. The value of PI in 90.1 % of subjects is changed when the position was changed from standing to the posterior position, whereas, the mean of changes in these subjects was 2.06 degree. When the position was changed from standing to an anterior position, the change in PI degree was observed in 84% of subjects and the mean of changes was 2.12 degree. PI was changed nearly in 95% of male subjects whereas 86.5% of female had changed in their PI when moving from a standing to the posterior position, but the mean of changes in females was more than males. However, the difference between male and female subjects was not statistically significant. When the position was changed from standing to anterior, the number of female and male with a change in their PI but the mean of changes in males was more than females; however, this difference was not statistically significant. The number of male subjects who had more than 3 degrees of change was significantly more than female subjects (21.9% versus 9.7%, respectively, P=0.030).

Change direction, in PI from standing position to posterior and anterior positions by gender are shown in figure 1. There were no significant differences between male and female subjects in the frequency of increased or decreased PI for change position from standing to posterior position (P=0.215) or to an anterior position (P=0.642).

Table 3. Change in Pelvic Incidence from standing position

		Standing to Posterior position	Standing to Anterior position
Total	**No Change**	14 (9.3)	24 (16)
	Change, n(%) / mean ± SD	136 (90.7) / 2.06 ± 1.05	126 (84) / 2.12 ± 1.01
	Change = 1°	47 (34.6)	43 (34.1)
	Change = 2°	40 (29.4)	46 (36.5)
	Change = 3°	34 (25)	17 (13.5)
	Change > 3°	15 (11)	20 (15.9)
Male	**No Change**	4 (5.3)	12 (15.8)
	Change, n(%) / mean ± SD	72 (94.7) / 2.03 ± 0.98	64 (84.2) / 2.19 ± 1.11
	Change = 1°	27 (37.5)	20 (31.2)
	Change = 2°	22 (30.6)	26 (40.6)
	Change = 3°	17 (23.6)	4 (6.2)
	Change > 3°	6 (8.3)	14 (21.9)
Female	**No Change**	10 (13.5)	12 (16.2)
	Change, n(%) / mean ± SD	64 (86.5) / 2.23 ± 1.05	62 (83.8) / 2.03 ± 0.99
	Change = 1°	20 (31.2)	23 (37)
	Change = 2°	18 (28.1)	20 (32.3)
	Change = 3°	17 (26.6)	13 (31)
	Change > 3°	9 (14.1)	6 (9.7)
	P-value*	0.082	0.943
	P-value†	0.665	0.030

Data are number (%)
P-values calculated by *Chi*-square test, *Comparison between male and female subjects in regard to the presence of change, †Comparison between male and female subjects in regard to the degree of change

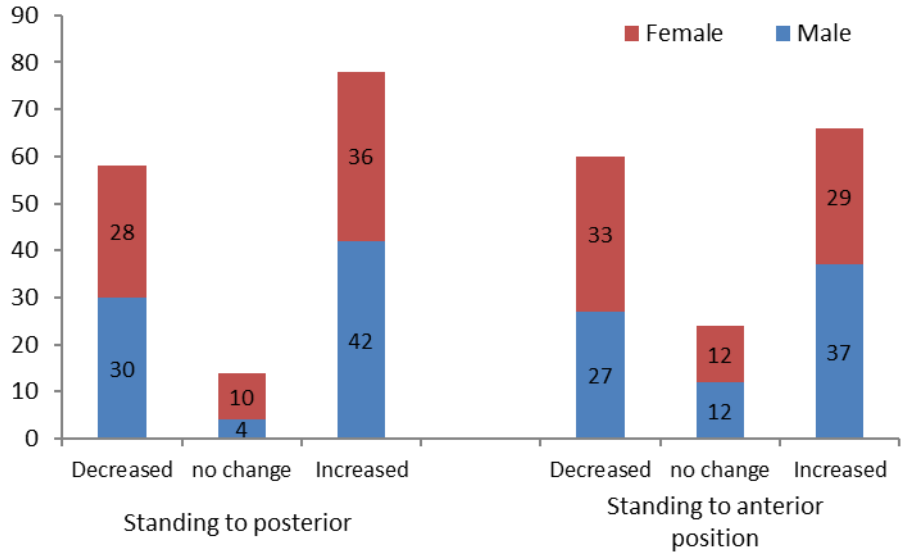

Figure 1. Change direction in Pelvic Incidence from standing position by gender (*P* for Standing, to posterior position = 0.215 and to anterior position = 0.642)

Correlation between PI change value and other variables was evaluated, and results showed that a direct weak positive correlation was observed between PI with age, low back pain, lumbosacral junction angle and total lumbosacral lordosis and a negative correlation was observed between PI with LL. However, the correlation between PI change value and these variables were not statistically significant (Table 4). The mean of age, LL and total lumbosacral lordosis in subjects who had changed in their PI when moving from a standing to the posterior position were significantly higher than subjects without a change in their PI, subjects with change were older than the other subjects. On the other hand, subjects who had changed in their PI when moving from a standing to the anterior position were significantly younger than the other subjects (Table 5).

Table 4. Correlation between Pelvic Incidence change value and studied variables

		Pelvic Incidence change
Age	**Pearson correlation coefficients**	0.058
	P	0.484
Low back pain	**Spearman coefficients**	0.088
	P	0.284
Lumbar Lordosis	**Pearson correlation coefficients**	-0.026
	P	0.755
Lumbosacral junction angle	**Pearson correlation coefficients**	0.054
	P	0.511
Total Lumbosacral Lordosis	**Pearson correlation coefficients**	0.041
	P	0.618

Table 5. Comparison of the studied variable in regard to change direction in Pelvic Incidence from standing position

		With change	Without change	*P*
Standing to Posterior position	**Age**	46.7 ± 13.9	36 ± 14.7	0.007
	Low back pain	1.9 ± 1.9	0.9 ± 1.4	0.065
	Lumbar Lordosis	-38.1 ± 8	-42.6 ± 6.9	0.047
	Lumbosacral junction angle	-19.2 ± 8	-17.7 ± 4.4	0.494
	Total Lumbosacral Lordosis	-57.3 ± 5.2	-60.3 ± 4.4	0.040
Standing to Anterior position	**Age**	44.5 ± 14.1	51.7 ± 14.2	0.025
	Low back pain	1.7 ± 1.9	2.4 ± 1.9	0.072
	Lumbar Lordosis	-38.9 ± 8.4	-36.3 ± 4.7	0.145
	Lumbosacral junction angle	-19.1 ± 8.1	-18.9 ± 5.3	0.918
	Total Lumbosacral Lordosis	-58 ± 4.7	-55.2 ± 6.7	0.063

Data are mean ± SD
P calculated by Independent samples *t*-test

Discussion

The PI becomes an increasingly used tool to evaluate sagittal balance in spine pathologies, recognizing the differences that exist between and among individuals is of paramount importance. The results of the present study on radiographic measurements of 150 healthy volunteers revealed that there was no significant difference in PI in three positions and the value of PI standing positions was similar to PI value in anterior and posterior positions. PI in 90.1% of subjects changed by a mean of 2.06 degree when standing position changed to the posterior position, and in 84% of subjects changed by a mean of 2.12 degree when standing position changed to an anterior position. These findings show that, although the changes in different position in our study were not statistically significant and a large number of studied subjects had changed in their PI in a different position, rotation during acquisition of the radiograph must be distinguished because it can change the value of PI.

The average of PI value in normal individuals is

reported between 44-60 degree (10), in our study the average PI value was 52.6 degree which is similar to some studies and more than those reported in previous studies by Weinberg *et al*., (11), Mac-Thiong *et al*., (12), and Barrey *et al*., (13), the differences between results can be explained by samples whereas, Weinberg *et al*., is done on cadaveric specimens, Mac-Thiong *et al*., assessed normal children and adolescents, and studied samples in Barrey *et al*., were patients lumbar degenerative diseases. In a similar study by Place *et al*., (9), 50 healthy subjects were assessed, and their finding shows that changes in PI value were observed in 88% of subjects when the position from relaxed resting was changed to the maximal anterior pelvic rotation (mean of change was 2.86 degree). Similarly, in our study, 84% of subjects had a change in PI value with a mean change of 2.12 degree. When the position changed from relaxed resting to maximal posterior pelvic rotation, 80 subjects in Place *et al*., study, changed their PI by a mean of 2.76 degree which is similar to 90% of subjects by a mean of 2.76 degrees in our study. The results of Place *et al*., study, shows the change of PI in a sample of healthy subjects in both gender and with mean age around 26 years old, in contrast, our results show similar findings in older healthy subjects in both genders with mean age around 45-year-old. So, these findings demonstrate the radiographical change in more than 80% of studied subjects by rotating of the pelvis to the anterior or posterior position. Therefore, the PI may be not a constant value in the adult in a different age. However, further studies are necessary to ultimate the significance of this finding.

In the previous studies, there exists considerable controversy about the relation between PI with age and gender (10). In our study, age was not related to PI change value which is similar to other studied and general ideas that accept the constant value of pelvic incidence throughout adult life (14). On the other hand, subjects with a change in their PI were significantly older than those subjects who did have a change in their PI. Also, female subjects in our study had a little higher PI in compare to male subjects, which was not statistically significant, and is similar to previous reports (6,15-16). However, in one study, higher PI was reported in females (17). The differences between findings can be explained by different sample and measurements method.

In conclusion, although, the PI in standing, posterior, and anterior positions in our study is not statistically significant but a large number of subjects with change in their PI when the position was changed to anterior (84%) or posterior (90.1%) position, show that PI can vary among healthy adult subjects. Although, future studies with larger sample size can be undertaken to evaluate differences between PI in a different position and ultimate significance of our finding.

References

1. Legaye J, Duval-Beaupere G, Hecquet J, Marty C. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 1998;7:99-103.
2. Duval-Beaupere G, Schmidt C, Cosson A. Barycentremetric study of the sagittal shape of spine and pelvis: The conditions required for an economic standing position. Ann Biomed Eng 1992;20:451-62.
3. Vaz G, Roussouly P, Berthonnaud E, Dimnet J. Sagittal morphology and equilibrium of pelvis and spine. Eur Spine J 2002;11:80-7.
4. Hammerberg EM, Wood KB. Sagittal profile of the elderly. J Spinal Disord Tech 2003;16:44-50.
5. Berthonnaud E, Dimnet J, Roussouly P, Labelle H. Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. J Spinal Disord Tech. 2005;18:40-7.
6. Boulay C, Tardieu C, Hecquet J, Benaim C, Mouilleseaux B, Marty C, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: standard values and prediction of lordosis. Eur Spine J 2006;15:415-22.
7. Morris WZ, Fowers CA, Yuh RT, Gebhart JJ, Salata MJ, Liu RW. Decreasing pelvic incidence is associated with greater risk of cam morphology. Bone Joint Res 2016;5:387-92.
8. Jin H.M, Xu D.L, Xuan J, Chen JX, Chen K, Goswami A, et al. Changes in Pelvic Incidence, Pelvic Tilt, and Sacral Slope in Situations of Pelvic Rotation. Clin Spine Surg 2017;30:E923-30.
9. Place HM, Hayes AM, Huebner S, Hayden A, Israel H, Brechbuhler J. Pelvic incidence: a fixed value or can you change it? Spine J 2017;17:1565-9.
10. Vrtovec T, Janssen M, Likar B, Castelein RM, Viergever MA, Pernus F. A review of methods for evaluating the quantitative parameters of sagittal pelvic alignment. Spine J 2012;12:433-46.
11. Weinberg DS, Morris WZ, Gebhart JJ, Liu RW. Pelvic incidence: An anatomic investigation of 880 cadaveric specimens. Eur Spine J 2016;25:3589-95.
12. Mac-Thiong JM, Labelle H, Berthonnaud E, Betz RR, Roussouly P. Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J 2007;16:227-34.
13. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal

balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J 2007;16:1459-67.
14. Mac-Thiong JM, Berthonnaud E, Dimar JR, Betz RR, Labelle H. Sagittal alignment of the spine and pelvis during growth. Spine 2004;29:1642-7.
15. Janssen MM, Drevelle X, Humbert L, Skalli W, Castelein RM. Differences in male and female spino-pelvic alignment in asymptomatic young adults: a three-dimensional analysis using upright low-dose digital biplanar X-rays. Spine 2009;34:E826-32.
16. Mac-Thiong JM, Roussouly P, Berthonnaud E, Guigui P. Sagittal parameters of global spinal balance: normative values from a prospective cohort of seven hundred nine Caucasian asymptomatic adults. Spine 2010;35:E1193-8.
17. Vialle R, Levassor N, Rillardon L, Templier A, Skalli W, Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Joint Surg Am 2005;87:260-7.