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Research Article

Spino-Pelvic Alignment in Young Indian Patients with Spondylolesthesis: A Crossectional Study

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Abstract

Background: Abnormal spinopelvic parameters lead to sagittal imbalance and contribute to multiple spinal conditions, including degenerative spondylolisthesis, deformity of the spine, and isthmic spondylolysis. The restoration and maintenance of these parameters is crucial to avoid fixed sagittal imbalance following surgery. Many authors have found variations in these parameters. We undertook this prospective study to evaluate and correlate the spinopelvic alignment in young Indian adults presenting with low backache and spondylolisthesis.

Method: We included one hundred young (≤40 yrs) patients (mean age 29.60 ± 6yrs; M:F = 49:51) presenting with low backache. We divided them into a spondylolisthesis (SPL) group with 43 patients and no spondylolisthesis (NSPL) group with 57 patients. We measured the following parameters on whole spine radiographs in a standing position: sacral slope (SS), pelvic incidence (PI), pelvic tilt (PT), sagittal vertical axis (SVA), sacrofemoral distance (SFD), lumbar lordosis (LL), Cobb angle, coronal imbalance (CIB), segmental lumbar lordosis (SLL), and thoracic kyphosis (TK). We also assessed the ratios of various parameters/ PI.

Results: The sacral slope of the SPL group was significantly lower than the NSPL group (33.47 ± 6.48 vs 36.92 ± 6.98; p = 0.013). There was a significant positive correlation between PI and PT, SFD and PT, LL and SS, SLL and LL, LL/PI, SS/PI and SLL/PI, and TK/PI and SLL/PI in the SPL group. While, in the NSPL group there was a significant positive correlation between PI and SS, PT and PI, SFD and PT, LL and SS, LL/PI and SS/PI, SLL/PI and LL/PI, and TK/PI, SLL/PI and LL/PI in the NSPL group. There was a strong negative correlation between SS/PI and PT/PI in the SPL group. All patients with spondylolisthesis had grade 1 disease (Meyerding classification) and all except 04 had a single-level disease.

Conclusion: Our patient population revealed a significantly low sacral slope (SS) in the SPL group.

Keywords: Spino-Pelvic Alignment; Spondylolesthesis; Spinal Degenerative Disease

Introduction

Degenerative lumbar spondylolisthesis is considered to be of multifactorial origin and has been found to be related to age, trauma, sustained weight bearing, and congenital malformation [1,2]. Junghanns first defined this condition in 1930, [3]as the slipping of one vertebral body over the other. It is found 400% greater in women as compared to men and occurs mainly in women over the age of 50 years [4]. To date, the etiology remains uncertain. Recent literature has suggested that spinopelvic alignment plays a prominent role in its etiology [2,5].

It is now well-established that the shape and spatial orientation of the pelvis is closely related to the organization of the lumbo-thoracic spine [6]. The sagittal Spino-pelvic balance affects the shear and compressive forces on all three columns of the spine leading to structural disc changes which in turn play a key role in the biomechanical characteristics of the spine and can influence the surgical outcome [7].

Various studies have found variations in the spinopelvic alignment of the healthy population [8]. Analysis of these factors is essential in the management of spondylolisthesis, especially in cases of spinal instrumentation [9]. Several authors have studied these parameters in recent times. However, none of them take into account racial factors. The authors could not find any study on spondylolisthesis in the Indian population. Hence the purpose of our

study was to analyze these parameters in the Indian community. We present our findings in the younger (≤ 40 years of age) subset of our population with radiological evidence of spondylolisthesis.

Material and Methods

Permission was taken from the Institutional Review Board and clearance was obtained from the Ethical Committee. We also took informed consent from all participants of this study. The study was done according to the guidelines laid down by the declaration of Helsinki for human experiments.

Study design

We conducted this cross sectional study over a period of 18 months (1st September 2017- 31st March 2019).

Study population

We included one hundred consecutive young (≤40 yrs) Indian patients presenting with low backache to the department over 18 months The age range was 17 to 40 years (mean 29.60 ± 6 years). Male: Female was 49:51. We divided them into a spondylolisthesis group (SPL) group with 43 patients and patients with degenerative spine and no spondylolisthesis (NSPL) with 57 patients. The SPL group consisted of 06 patients with congenital lumbar spinal stenosis (CLSS; canalicular AP dimension ≤ 10mm), 15 patients with severe discogenic canal stenosis, 43 patients with disc degeneration, and 17 patients with lumbosacral transitional vertebra (LSTV), whereas NSPL group consisted of 10 patients with CLSS, 02 patients with severe discogenic canal stenosis, 35 patients with disc degeneration and 24 patients with LSTV. All patients with spondylolisthesis had grade 1 disease (Meyerding classification). Four patients had spondylolisthesis at two levels. The exclusion criteria were: patients greater than 40 years of age, those with a recent and past history of significant trauma, those with previous surgery, those with inflammation or infections, those with suspected or diagnosed tumor, those with any congenital malformation except congenital lumbar spinal stenosis and those with systemic diseases.

Spinopelvic parameters

We measured the Spinopelvic parameters on whole spine radiographs taken in anteroposterior (AP) and lateral view in a standing position. We asked the patients to assume a comfortable position with the knees fully extended and arms by the side or raised horizontally forward resting on 02 arm supports, depending on the view. The following parameters were measured: sacral slope (SS), pelvic incidence (PI), pelvic tilt (PT), sagittal vertical axis (SVA), sacrofemoral distance (SFD), lumbar lordosis (LL), cobb angle, coronal imbalance (CIB), segmental lumbar lordosis (SLL), and thoracic kyphosis (TK). We also assessed the ratios of various parameters/PI.

Pelvic incidence (PI) is the angle between the line perpendicular to the first sacral (S1) end plate from the midpoint of the end plate and the connecting line from the midpoint of the S1 end plate to the center of the femoral head; PT is the angle between the connecting line from the midpoint of the S1 end plate to the center of the femoral head and the vertical line; SS is the angle between the tangent and the horizontal line of the S1 end plate; SVA is the horizontal distance between the vertical line of the C7 vertebral center and the posterior upper angle of the S1 end plate; TK is the angle between the upper end plate of T4 and the lower T12 endplate; LL is the angle between the upper L1 endplate and the upper sacral endplate; SLL is the angle between the upper L4 endplate and the upper sacral endplate; Cobb angle is the angle formed between the superior endplate of the uppermost vertebra of the scoliotic curve and the inferior endplate of the lowest vertebra of the curve; CIB is evaluated by measuring the distance between C7 plumb line and line perpendicular to the midpoint of the sacrum. SFD is the horizontal distance between the bi-coxo-femoral axis and the vertical line passing through the posterior corner of the sacrum.

Statistical analysis

We collected the data in accordance with the inclusion and the exclusion criteria. Statistical analysis was performed using the Statistical package for the Social Sciences version (SPSS) software. The values of various parameters were expressed as mean ± standard deviation. The Mann-Whitney U test was employed to analyze differences in non-categorical variables between the two groups. Overall differences of sagittal spinopelvic parameters between the SPL and NSPL groups were statistically analyzed. PI is a constant morphological parameter in an individual person. To minimize individual variations, spinopelvic parameters/PI ratios were assessed and compared between the two groups. Statistical *p*-values less than 0.05 were considered statistically significant.

Results

The mean age was 29.7 ± 5.26 years (range 18-40 years) and 29.5 years ± 6.5 (range, 17-40 years) in SPL and NSPL groups, respectively. The SPL group (43) consisted of 21 males and 22 females, while, the NSPL group (57) consisted of 28 males and 29 females.

The mean of various parameters in the two groups is shown in Table 1. The sacral slope of the SPL group was significantly lower than the NSPL group (33.47 ± 6.48 vs 36.92 ± 6.98) (p = 0.013).

The correlation between various parameters of Groups I and II is shown in Tables 2 and 3 respectively.

Variables	SPL (N = 43)	NSPL (N = 57)	P-value
SS (◦)	33.47 ± 6.48	36.92 ± 6.98	0.013
PI (◦)	48.78 ± 8.81	51.79 ± 9.69	0.113
PT (◦)	13.35 ± 7.56	12.71 ± 7.96	0.684
SVA (mm)	29.99 ± 21.39	22.60 ± 16.79	0.056
SFD (mm)	39.81 ± 14.52	34.57 ± 13.46	0.065
LL (◦)	52.80 ± 9.25	54.64 ± 9.83	0.343
Cobb Angle (◦)	6.57 ± 4.60	6.85 ± 3.19	0.714
CIB (mm)	8.58 ± 6.68	10.82 ± 7.95	0.139
SLL (◦)	33.06 ± 8.41	34.34 ± 7.11	0.414
TK (◦)	36.69 ± 12.46	37.01 ± 11.88	0.896

Table 1: Comparison between Spondylolisthesis (SPL) and Non-Spondylolisthesis (NSPL).

	SS	PI	PT	SVA	SFD	LL	COBB	CIB	SLL	TK
SS	1									
PI	0.207	1								
PT	-0.283	.705*	1							
SVA	0.046	0.06	0.163	1						
SFD	-.390*	.560*	.866*	0.155	1					
LL	.699*	0.224	-0.216	0.04	-.312*	1				
COBB	-0.088	-0.132	-0.021	-0.047	-0.144	0.023	1			
CIB	-0.194	0.08	0.134	0.098	0.026	-0.183	.381*	1		
SLL	0.293	-0.143	-.318*	0.037	-0.27	.572*	-0.003	-0.084	1	
TK	0.224	-0.024	-0.051	-0.228	-0.035	.347*	0.087	-0.166	0.214	1

Table 2: Correlation of Parameters in 43 patients (SPL).

	SS	PI	PT	SVA	SFD	LL	COBB	CIB	SLL	TK
SS	1									
PI	.546*	1								
PT	-0.075	.528*	1							
SVA	-0.001	0.034	0.084	1						
SFD	-0.243	.511*	.562*	-0.217	1					
LL	.553*	.281*	-0.023	0.229	-0.22	1				
COBB	0.105	0.16	0.061	0.186	0.019	0.044	1			
CIB	0.022	.368*	.297*	0.212	0.26	-0.097	0.028	1		
SLL	0.165	0.045	0.038	0.09	-0.091	.476*	0.023	-0.012	1	
TK	0.068	0.042	0.121	0.204	-0.038	.453*	-0.061	-0.076	.407*	1

Table 3: Correlation of Parameters in 57 patients (NSPL).

	PT/PI	SS/PI	LL/PI	SLL/PI	TK/PI
PT/PI	1				
SS/PI	-.675*	1			
LL/PI	-0.269	.541*	1		
SLL/PI	-.436*	.600*	.586*	1	
TK/PI	-0.192	.391*	.450*	.504*	1

Table 4: Correlation of Parameters in 43 patients (SPL).

	PT/PI	SS/PI	LL/PI	SLL/PI	TK/PI
PT/PI	1				
SS/PI	-.465*	1			
LL/PI	-.291*	.601*	1		
SLL/PI	-0.156	.365*	.692*	1	
TK/PI	-0.023	.324*	.619*	.665*	1

Table 5: Correlation of Parameters in 57 patients (NSPL).

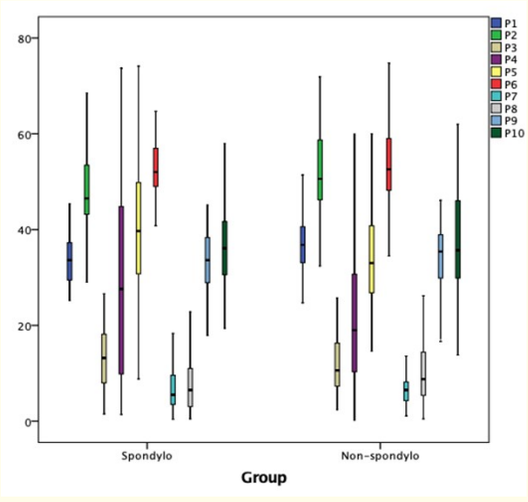

Figure 1

There was a significant positive correlation between PI and PT, PT and SFD, LL, and SS, and LL and SLL. While, in the NSPL group there was a significant positive correlation between PI and SS, PT and PI, SFD and PT, and LL and SS. It is also shown in Figure 1. There was a significant correlation between SS/PI with SLL/PI and LL/PI, and SLL/PI and TK/PI, and a significant negative correlation between PT/PI and SS/PI in the SPL group. While, in the NSPL group there was a significant positive correlation between LL/PI and SS/PI, SLL/PI and LL/PI, and TK/PI with SLL/PI and LL/PI. The correlation between various ratios is shown in Tables 4 and 5 respectively for SPL and NSPL groups.

Discussion

It is well established that the sagittal morphology of a healthy spine and that of the pelvis are closely related. Because of their interaction, the center of gravity and visual balance is maintained [10-12]. There also exists a significant variation in sagittal spino-pelvic alignment in the healthy population [10,12,13]. With sagittal imbalance, there is a retroversion of the pelvis in relation to the feet [12-14]. As a result, there is stress on the spine leading to spinal degeneration and instability in some cases. Anono found the incidence of SPL to be 12.7% in their study of 142 females [15]. The L4-S1 segment is hypermobile and hence is the most frequent site where instability occurs [5]. In our study, there were 14 patients with spondylolisthesis at L4-L5, 33 at L5-S1 and four patients at both these levels.

Hanson., *et al.* [16] found PI to be significantly higher in spondylolisthesis of higher grade, and there was a linear correlation with the grade. Lai., *et al.* [1]. found higher PI, SS, TK, and LL in the SPL group with no significant change in PT and SVA. SS was more strongly correlated with PI than LL in the SPL group and with LL in the NSPL group. We found SS to be strongly correlated with LL rather than PI in both of our groups. Lai., *et al.* [1]. also reported a correlation between the degree of esthesis and PI, SS, and LL with these parameter values increasing as a function of the grade of slippage. In their study, LL and PI values did not vary significantly among the patients with grade I and grade II DLS as was the case in our study. All the patients in our study were young and had grade I spondylolisthesis.

Vialle., *et al.* [8]. studied 244 patients with developmental L5-S1 spondylolisthesis and compared them with 300 healthy volunteers and found the mean values of SS, PT, and LL to be significantly higher, while TK was significantly lower. They found that there was a negative correlation between the grade of L5 anterior slipping and PI, SS, and TK. PI and SS, PT and PI, PI, and LL were also negatively correlated. The difference in the SS was more significant for lower grades and higher grades of SPL However, even in patients with lower grades of spondylolisthesis the mean of SS was more than that in the control group (45.76^0 in 27 patients with Grade 1 spondylolisthesis vs 41.86^0 in 300 controls) whereas PI was more significantly increased for higher grades. In our study, SS was significantly lower in the SPL group. PI was also lower in the SPL group of our study patients, but it was not statistically significant. We attribute these findings to the lower grade of listhesis which is grade I in all of our patients. Further, in the SPL group, there were 43 patients with disc degeneration, 6 patients with CLSS, 15 patients with severe discogenic canal stenosis which could have also affected our findings.

Lim., *et al.* [15] found a significantly higher PI and SVA in patients with degenerative spondylolisthesis (DSPL) than that of degenerative spinal stenosis (DSS). This may be due to anterior

slippage in DSPL leading to less compensatory mechanisms as compared to DSS. In our study, some patients with SPL also had severe discogenic stenosis possibly leading to the compensatory mechanism of pelvic retroversion and hence near normal PI.

Pelvic incidence (PI) is a constant parameter at the end of bone growth and is related to SS, PT, and LL [17]. It has been reported that PI exhibits lower values in lumbar disc degeneration as against SPL [12]. The association of disc degeneration could be another cause of the normal range of PI in our study. For a precise analysis of other variables, spinopelvic parameters/PI ratio were also assessed between the two groups. No significant correlation was found in the mean of the two groups.

Legaye., *et al*. [10] and Vaz., *et al*. [18] found a linear correlation between PI and LL in the general population. They also reported a similar correlation between SS and LL. In our study population, on comparing patients with lower grade disc degeneration (Phirrmann grad <3) and those with higher grade (≥3), we found significantly lower values of LL in patients with a higher grade of degeneration. This could also account for lower SS values when we compared patients with SPL and those with non-SPL.

As per Lai., *et al*. [1] an association between DLS, PI, PT, LL, and SS remains controversial despite previous studies. Barrey., *et al*. [19] proposed that an increase in PI is indicative of degenerative spondylolisthesis. However, a loss of SS and LL was observed in the three disorders studied by them i.e. disc herniation (DH), degenerative disc disease (DDD), and degenerative spondylolisthesis (DSPL). In our study, only SS was significantly lower in the SPL group.

Singh., *et al*. [20] studied lateral radiographs of 50 normal healthy Indian volunteers (M: F = 29:21). They found The mean values of PI and LL to be 48.52 ± 8.99 ◦ and 58.78 ± 9.51 ◦ , respectively. The value of PI was 48.78 ± 8.81 ◦ in the SPL group and 51.79 ± 9.69 ◦ in the NSPL group in our study. While the value of LL was 52.80 ± 9.25 ◦ and 54.64 ± 9.83 ◦ in the SPL and the NSPL group respectively. Bhat., *et al*. [21] studied lateral radiographs of 200 healthy volunteers from Kashmir aged 18-50 and found The average LL, SS, PI, PT, and SVA values were average 55.61 ± 10.68, 38.38 ± 8.33, 47.94 ± 10.24,10.16 ± 6.2 3 and 17.27 ± 9.72 respectively. In our study, the value of SS was 33.47 ± 6.48 in the SPL group and 36.92 ± 6.98 in the NSPL group. Similarly, PT was 13.35 ± 7.56, and 12.71 ± 7.96 in the two groups respectively. SVA was 29.99 ± 21.39, and 22.60 ± 16.79 respectively. Mahato., *et al*. [22] Performed a case-control study in the Indian population with chronic low back ache. They found LL to be 30.11 degrees in the patient group and it was significantly different in the control group (33.68 degrees). Pelvic tilt was also significantly different in the two groups (13.77 vs 13.63). However, PI was not significantly different between the two groups (52.61 vs 54.68). Singh et al found that PI was positively correlated with LL. The authors could not find any study on spondylolisthesis from the Indian population.

The value of PI is constant at the end of bone growth [10]. Hence, we also calculated the ratios of various parameters with PI. Wang., *et al*. [23] found that PT/SS, LL/PI, and SS/PI were lower in single-level degenerative SPL than normal. In our study, we observed similar findings for LL/PI and SS/PI.

Different individuals have different lumbar curvatures. Rousoully., *et al*. [24] divided them into 04 types based on SS and LL. In Type I where SS is $<35^0$ PI is also small. The value of SS in the SPL and NSPL groups of our study was 33.47 ± 6.48 and 36.92 ± 6.98 respectively. A smaller PI corresponds to small lumbar curvature with a sharp corner at L5. Also when the SVA tends to be in the normal range PI is decreased as was the case in our study.

Morphology of the spine, including vertebral shape and strength of posterior spinal muscles which shows racial differences, will also affect individual sagittal alignment. Lumbar vertebral morphology directly affects LL while the weak erector spinae leads to vertical sacrum and flat lordosis [25].

Conclusion

In conclusion, the spinopelvic alignment varies between individuals and is related to multiple factors, which include the various manifestations of spinal degeneration, vertebral shape, and the strength of paraspinal muscles amongst other conditions. A proper understanding of these factors will lead to the effective management of these patients.

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