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Normative Values of Spino-Pelvic Parameters in Healthy Delhi State Population

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Abstract: ***Objective: To elucidate baseline values of various spinopelvic parameters in healthy adults in standing position and to compare various spinopelvic parameters of Delhi State population with European population. Materials and Methods: A prospective cross sectional study was conducted in Central Institute of Orthopedics, VMMC Safdarjung Hospital New Delhi with Sample size of 100 in healthy adults between 20 to 45 years of age. Parameters calculated were Saggital vertical axis (SVA), Cervical lordosis, Thoracic kyphosis (TK), Lumbar lordosis (LL), Pelvic Tilt (PT), Pelvic Incidence (PI), Sacral slope (SS). Result: Mean values of spinopelvic parameters in present study for SVA, LL, TK, PT, PI, SS are 1.08 cm, 42.17, 32.86, 12.65, 50.44 and 37.85 respectively. Conclusion: On comparison with European population LL and TK are more in European population as compared with Indian population but no significant difference between PT, PI and SS values.***

1. Introduction

Two secondary curves develops after birth.CERVICAL LORDOSIS develops at around 6 months and LUMBAR LORDOSIS develops at around 9 to 15 months[3].These curves work like a coiled spring to absorb shock, maintain an upright balance and allow the spine to withstand great amounts of stress than what a straight column would otherwise absorb[4].Exaggregation or deficiencies in lordotic and kyphotic segments leads to sagittal imbalance or malalignment, There is dynamic correlation between spinal and pelvic parameters, as spinal parameters affects by pelvic parameters and vice versa[6]. Complete assessment of sagittal alignment must account for not only thoraco lumbar curvature but also pelvic alignment, as deterioation from normal angle gives rise to spinal disorders and hence explained back pain[10, 11, 12, 13].The human skeleton works like a "reverse pendulum" during standing, where the "cone of economy" is perfectly balanced with minimal muscle action and results compensated curve. In case of decompensated standing balance, the trunk shows an increased SVA, the pelvis retroversed, the hip extended, and the knee flexed, suggesting the uneconomic alignment affects and results poor quality of life. Therefore, a better understanding of alignment from the head to the feet will elucidate the "cone of economy" mechanism.Associations of sagittal standing posture with pain, physical disability and reduced health-related quality of life, and positive sagittal imbalance have emerged as the most reliable radiographic predictor of clinical symptoms[20, 21].Different population have different baseline values of these parameters. In European population normal values of these parameters have been calculated. But no such baseline values are available for Indian population. So in this study normative values of these spino pelvic parameters in healthy Indian (Delhi) population are calculated, which will be helpful to compare this normal population with pathologic population and to check the variations of the shape and balance in spinal disorders.

Inclusion Criteria
Individual of 20-45 years age group without any history of spinal disease..

Exclusion Criteria
Subjects not consenting for the study, female subjects who are pregnant. Subjects with 11 thoracic vertebra, scoliotic deviation[13], congenital anomalies/post polio residual paralysis/neuromuscular dystrophy, histroy of spinal disease, hip joint pathology, lumbarisation and sacralisation.

2. Methodology

A new scanning X-ray imaging system (EOS Imaging, Paris, France) was developed by multidisciplinary investigators to overcome the limitations of conventional X-ray measurement. Simultaneous anteroposterior and lateral X-rays of the whole body can be obtained using the three-dimensional bone external envelop technique, allowing for three-dimensional reconstruction at every level of the osteo-articular system, especially the spine, in the standing position. This X-ray system allows for more precise bone reconstruction, especially at the level of the spine, pelvis, and lower limbs, with limited X-ray exposure[51, 52].

Each subject will be asked to stand in his or her own neutral standing position. The knees should be straight and the patient should stand without use of orthotics or special shoes. The arms are placed on adjustable supports to remove arms from the field of view and provide support while standing. A standing left AP and 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[6]. Imaging is ideally acquired by using Digital Scannogram in ANTERIOPOSTERIOR and LATERAL view from cranio cervical junction to the mid thigh[53, 54].

3. Method of Measurement

Cervical Lordosis- A parallel line drawn from the inferior aspect of axis (C2)vertebra and another parallel line drawn from superior aspect of C7 vertebra.Two perpendicular lines drawn from respective horizontal lines and the angle made by interection of both perpendicular lines is angle of cervical lordosis.[58].

Thoracic kyphosis-A parallel line drawn from superior aspect of T4 vertebra and another parallel line drawn from inferior aspect of T12 vertebra. Two perpendicular lines drawn from respective parallel lines and the angle made by

interaction of both perpendicular lines is angle of thoracic kyphosis[59].

Lumbar Lordosis-A line drawn parallel from superior aspect of L1 vertebra and another parallel line drawn from inferior aspect of L5 vertebra. Two perpendicular lines drawn from respective parallel lines and the angle made by interaction of both perpendicular lines is angle of lumbar lordosis[60].

Sagittal Vertical Axis- Defined as the horizontal offset from the posterosuperior corner of S1 to the vertebral body of C7[55].

Pelvic tilt-The pelvic tilt is the angle created between a line drawn from the midpoint of the femoral heads to the center of the superior endplate of the sacrum and a vertical plumb line through midpoint of femoral heads.

Pelvic incidence- The pelvic incidence is the angle created by intersecting lines drawn from the midpoint of the femoral heads to the midpoint of the superior endplate of the sacrum and a line perpendicular to the superior endplate of the sacrum as measured on lateral images.

Sacral slope- The sacral slope is defined as the angle between a line drawn parallel to the superior endplate of S1 and a horizontal reference line or line drawn parallel to the floor.

Sacral slope plus pelvic tilt equals pelvic incidence, and therefore changes to sacral slope are inversely proportional to changes in the pelvic tilt.

Low pelvic incidence decreased sacral slope and the lordosis is flattened, High pelvic incidence increased sacral slope and the lordosis is more pronounced.

4. Assessment

Mean values of the minimum, maximum and standard deviation of each variable will be measured.

	Minimum	Maximumm	Mean	SD
SVA	0.6	1.7	1.08	0.25
LL	29	57	42.17	6.97
TK	19	46	32.86	6.81
PT	7	19	12.65	2.8
PI	44	60	50.44	3.71
SS	26	49	37.85	4.21

Comparison of normal spino-pelvic parameters in Delhi state healthy population and European population.

	Delhi State Population	European population
SVA(cm)	1.08	0.9
LL	42.17	46.5
TK	32.86	47.0
PT	12.65	12.3
PI	50.44	51.7
SS	37.85	39.4

5. Discussion

The present study yields a physiologic standard for several angular pelvic and spinal parameter that describe saggital whole spine alignment, in a cohort of 100 healthy adult volunteers (Table 1).Thus standing saggital alignment were similar to previous studies. The correlation among the radiographic parameters of sagittal alignment were also comparable with previous reports[62, 63].The correlation was stronger between the parameters of the adjacent structures, indicating the chain of balance advocated by Duboussat. More than two decades ago Duval-Beaupere's group found PI, which is the most significant unique parameter of individual standing spinal alignment, i.e. a large PI is associated with a great SS and a pronounced LL, and a low PI is associated with a smaller SS and subtle LL, leading to a basic concept of "equilibree conomique" in standing. Itoi et al[64] investigated the relationship between sagittal posture of the spine and the lower extrimities in osteoporotic subjects, and found that thoracic kyphosis, a primary deformity, was compensated for by the lumbar spine, sacro iliac joint, hip joint and knee joint.

El Fegoun et al[66] reported a highly significant negative correlation between the gravity line and plumline in the saggital plane based on simultaneous assessment of full length free standing spine radiographs and the floor projection of the centre of pressure(gravity line), suggesting that the value of the plumb line as a marker of true postural balance must be questioned. We investigated balance using a force plate measurement during Xray scanning and found that a representative balance parameter, ENV, had a tendency of positive correlation with PI-LL, suggesting that spino-pelvic mismatch affects not only the static saggital alignment but also dynamic alignment, balance.

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 parameters. In present study mean age of population was 31.34±7.01 and there is no difference in the SS, PT, PI and LL between men and women but the TK is higher in men compared with women. Mean LL was 42.17±6.97, PI was 50.44±3.71, PT was 12.65±2.8, SS was 37.85±4.21, SVA was 1.08±0.25 cm and TK was 32.86±6.81.

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. In contrast to these studies, we found that Indian men have a higher TK compared with women. According to Mac-Thiong et al, the mean ± 2 SD range was 52.6 ± 10.4 degrees, 13.0 ± 6.8 degrees, and 39.6 ± 7.9 degrees for the PI, PT, and SS, respectively, [16] whereas the values given by Zhu et al were 44.6 ± 11.2 degrees for the PI, 11.2 ± 7.8 degrees for the PT, and 32.5 ± 6.5 degrees for the SS, respectively.[18] Vialle et al postulated mean values ± 2 standard deviations as 60 ± 10 degrees for LL, 41 ± 8.4 degrees for the SS, 13 ± 6 degrees for the PT, 55 ± 10.6 degrees for the PI.[14] A strong correlation was found between the SS and the PI ($r = 0.8$) and PT and TK ($r = 0.9$) in their

study which is comparable to present study. However, in contrast to other studies, this study did not show a statistically significant correlation between the LL and PI. The impact of sex on spino pelvic parameters remains controversial. Vialle et al reported a significant differences in LL nd PI between male and female subjects. Although there were statistically significant differences in TK, LL, PT, and PI between man and women in the current study, the difference in the mean value of each parameter was quite small. Recently, there have been some reports to support racial difference in saggital spino pelvic parameters, and most of them have exaggerated the smaller PI are LL in Asian population then in Caucasian population. Recently, more researchers have focussed on spino-pelvic alignment because of the increasing number of adult patients in the aging society with back pain related to spinal malalignment.

Surgeries to correct the spinal deformities ideally should aim at a proper relationship between the sacropelvic parameters and the TK and LL.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 (r = -0.476) 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.

Overall present study shows significant regression coefficient between SS and PI (ß=0.761), between LL and age (ß= -0.578), between PI and SS(ß= 0.761)and LL and TK(ß= -0.522). But when regression coefficient was calculated in different age group, significant relation was found only between PI and SS(ß= 0.910 in ≤30 years of age and ß=0.891 in 31-45 years of age). Similarly when regression coefficient was calculated in group male and group female, significant relation was found between PI and SS (ß=0.788 in female and ß=0.749 in male), and between LL and TK (ß= -0.483 in female and ß= -0.560 in male).

6. Conclusion

The current study presents the largest cohort of normal asymptomatic subjects for the evaluation of the spinopelvic parameters in the Delhi state population. The range of values of the PI, PT, and SS corresponding to the mean ± 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 correlation between these parameters is of profound importance in calculating the corrections required in spinal deformities.

7. Summary

Aim of our Study was to calculate normative values of Spinopelvic Parameters in Healthy Delhi State Population and to compare these with European population. This was a prospective cross sectional study where a total of 100 individual with 20-45 years age group without any history of spinal disease were recruited. In present study, Mean age of population was 31.34±7.01, LL was 42.17±6.97, PI was 50.44±3.71, PT was 12.65±2.8, SS was 37.85±4.21, SVA was 1.08±0.25 cm and TK was 32.86±6.81.Statistically significant relation of LL, PI, PT, SS and TK with age was present but no significant relation between age and SVA was found.

Correlation of PT with TK (r = 0.913)and of TK with PT(r = 0.913) was strong and significant .In females the values of correlation coefficient of LL and PI was found low in comparison to male and values of PT, SS and TK was found more and no difference found between value of SVA and sex.

Significant relation of Regression coefficient between SS and PI, between LL, age and TK and between PI and SS. Significant regression coefficient between PI and SS in both ≤30 and 31-45 years of age. And no relation was found between LL and TK, in 20-45 years of age. Statistically significant regression coefficient between PI and SS, and between LL and TK in both male and female.In European population in previous studies values for SVA, LL and TK are 0.9, 46.5 and 47 respectively and 12.3, 51.7 and 39.4 for PT, PI and SS respectively. From the study we can observe that spinal parameters LL and TK are more in European population as compared to Indian population but there is no significant difference between PT, PI and SS values. Due to influence of spinopelvic balance and morphology in the evaluation and treatment of developmental spondylolisthesis, degenerative spondylolisthesis, adolescent idiopathic scoliosis, adult spinal deformity and surgical treatment of hip osteoarthritis, it is therefore important to document the spinopelvic balance and morphology in the normal healthy adult.