RESEARCH ARTICLE

Spinopelvic Parameters among Healthy Volunteers in Iran

Hamid Rezaee, MD[1]; Gholamreza Bahadorkhan, MD[1]; Mohammadreza Ehsaei, MD[1]; Babak Ganjeifar, MD[1]; Ehsan Keykhosravi, MD[1]; Masoud Pishjoo, MD[1]

Research performed at Shahid Kamiab Hospital , Mashhad, Iran

Received: 31 July 2019 *Accepted: 02 June 2020*

Abstract

Background: Recently, in approach to spinal pathologies, the whole spine should be considered as a biomechanical unit. Studies have shown the great importance of sagittal and coronal balance and the relationship between the various parts of spine together and pelvis. Former studies have shown a close relationship between spinopelvic parameters and sagittal balance. A complete understanding of sagittal balance basics is needed to achieve the best outcome and avoiding future complications after treatment of spinal deformities. In this study, the normal range of spinopelvic parameters among healthy volunteers in Iran has been evaluated.

Methods: This cross-sectional study was conducted on healthy volunteers in 2017. The lateral whole-spine X-ray was obtained under the standard conditions. Two spine surgeons measured the parameters including pelvic incidence, pelvic tilt, sacral slope and lumbar lordosis.

Results: In this study 100 volunteers were studied; out of whom, 41 participants were male and the mean age was 47.5±11.7 years. The average pelvic incidence, pelvic tilt, and sacral slope were 51.5±10.9, 17.4±9.9, and 34.8±8.8 degrees, respectively. The pelvic tilt was significantly lower in women. It was found that with increasing age, the pelvic incidence and pelvic tilt increases while lumbar lordosis decreases (*P<0.05*).

Conclusion: This study is the first study on the normal range of spinopelvic parameters in healthy individuals in Iran.. Our data showed that PT and PI-LL are significantly lower in women, while, PT, PI and PI-LL increase and LL decreases in older ages.

Level of evidence: II

Keywords: Healthy people, Normal range, Parameter, Sagittal balance, Spinopelvic

Introduction

The spine plays an important role in the movement and transfer of force in the body (1). The degenerative diseases of the spine affect the lumbosacral region and require more invasive treatments during the lifetime (2). The prevalence of adult spinal deformities is over 60% in asymptomatic people in elderly ages (3).

Pelvis and spine are static stabilizing factors in maintaining the body balance in sagittal plane (4). Various studies have shown that sagittal imbalance causes back pain and subsequent disability (5, 6). Sagittal alignment is also indicated to be related to energy consumption in the body (7).

Recently, the diagnosis and treatment of spine pathologies has been based on sagittal balance parameters (1, 8). The effect of spinopelvic balance and its morphology on the diagnosis and treatment of degenerative or other types

Corresponding Author: Ehsan Keykhosravi, Department of Neurosurgery, Mashhad University of Medical Sciences, Mashhad, Iran
Email: Keykhosravie@mums.ac.ir

AB&JS THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

Arch Bone Jt Surg. 2020; 8(5): 620-624. Doi: 10.22038/abjs.2020.40734.2106 http://abjs.mums.ac.ir

Figure 1. Representative drawings of spinopelvic parameters. (A) PI stands for pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis. (B) TK stands for thoracic kyphosis; LL, lumbar lordosis.

of spondylolisthesis, adolescent idiopathic scoliosis, and adult spinal deformities have been proven in previous studies (9).

Studies have shown a close relationship between the spinopelvic parameters and sagittal balance (10). Standing lateral whole spine radiography is the gold standard imaging to assess the spinopelvic parameters (11). Lateral standing radiography is routinely performed for patients with back pain or disability. This image should include the upper plate of L1, sacral dome, and both femoral heads (12).

Pelvic Incidence (PI) refers to the angle between the line perpendicular to the midpoint of the sacral plateau and the line from that point to the center of the femoral head. This parameter is not position-dependent and remains constant after puberty (13). Pelvic tilt (PT) is the angel between the line that connects the center of the sacral plateau to the femur head, and the line perpendicular to the ground. Sacral slope is referred to the angle between the sacral plateau and the horizontal line. Lumbar lordosis is also referred to the angle between the upper plate of L1 and the upper plateau of sacrum [Figure 1] (13).

Given that spinal deformities are now diagnosed and treated based on the spinopelvic parameters, knowing the normal range of these parameters among healthy people is very important. So far, various studies have been carried out on the measurement of the normal range of the spinopelvic parameters in different parts of the world, and different results have been reported based on different populations (4). However, no study has been conducted in Iran or even in the Middle East till now. In this study, we investigated the normal range of spinopelvic parameters among healthy volunteers in Iran.

Materials and Methods

This cross-sectional study was conducted on healthy volunteers in 2017. The study approved by the ethics committee of Mashhad University of Medical Sciences (#:IR.MUMS.MEDICAL.REC.1398.900). An informed consent was obtained from all healthy volunteers in the study.

The exclusion criteria were a history of brain or spinal surgery, pregnancy, neurologic diseases such as cerebral infarction or neuropathy, sensory or motor disorders, orthopedic disease of the lower limb or hip, and having low back pain. The volunteers' demographic data (age, gender, weight, and height) were collected in a checklist before the volunteers undergo the whole-spine radiography.

All radiographs were performed using a standard DR system (Toshiba x-ray tube Digital Radiography X Ray machine - DF-323H). Lateral whole spine radiographs with inclusion of pelvis and both femoral heads were obtained in standing position with the hands made into fists on the clavicles and the knees and hips fully extended. A 30×90 cm vertical cassette was used. The distance from the radiographic source to the film was about 2.5 m or more, if possible. The tube was directed to the iliac crest. The patient-tube distance during lateral lumbar radiography was 0.8 m. The mean parameters were: 90 kV/100 mA s and exposure time did not exceed 100 ms (6, 14). We used one radiographer to reduce the error.

Then the radiographs were saved in the picture archiving and communication system (PACS) for later analysis. Two spine surgeons measured the parameters. The inter-observer agreement (Kappa) was 0.78 and the average was used in cases of different measurements. The measurement of angles was done with RadiAnt DICOM Viewer 4.2.1 for windows and the parameters were recorded in the volunteers' forms.

Data was analyzed using SPSS 23.0 for windows (SPSS, IBM, Armonk, NY, USA). The quantitative data were reported as the mean±standard deviation (SD). The independent sample t-test and Pearson's test were used for analytical results. *P value* less than 0.05 was considered as statistically significant.

Results

In this study 100 volunteer were studied among whom 41 were male and 59 were female. The mean age, weight, height, and body mass index (BMI) were 47.5±11.7 years, 75.7±14.6 kg, 165.8±10.1 cm, and 27.5±4.7 kg/m^2, respectively [Table 1].

In order to examine the sagittal balance, C7 plump line was used and, it was compared to the posterior and superior corner of S1. In all cases, this distance was within the normal range (<2cm). PI, PT and SS were 51.5°±10.9°, 17.4°±9.9° and 34.8°±8.8°, respectively. Also LL (L1-L5), LL (L1-S1), T5 thoracic kyphosis (T5TK) and

Table 1. Demographic Data

Variable	Gender	Mean	Std. Deviation
Age (year)	Total	47.46	11.69
	Male	48.46	11.42
	Female	46.76	11.93
Weight (kg)	Total	75.73	14.57
	Male	81.19	2.35
	Female	71.93	1.69
Height (cm)	Total	165.80	10.07
	Male	169.09	2.09
	Female	163.52	0.78
BMI (kg/m^2)	Total	27.50	4.70
	Male	28.44	0.71
	Female	26.88	0.60

PI-LL was 37.7°±9.3°, 44.6°±9.8°, 34.0°±12.3°, 9.9°±5.7°, respectively. [Table 2; Figure 2]

T-test showed that PT and PI-LL in women were significantly lower (*P=0.001* and *P=0.006*, respectively) [Table 3].

Pearson's test showed that with increasing age, PI, PT, and PI-LL increase (*P=0.002* r=0.303, *P=0.021* r=0.230, and *P<0.001* r=0.424, respectively) and LL (L1-L5) decreases (*P<0.001* r=-0.412) significantly.

Increased height was significantly correlated to more thoracic kyphosis (*P=0.025* r=0.224). Also Pearson's test showed that PI, PT and PI-LL increase with increasing weight (*P=0.039* r=0.207, *P=0.001* r=0.337 and *P=0.007* r=0.268, respectively).

BMI also increases with PI, PT, and PI-LL, significantly. (*P=0.003* r=0.290, *P=0.003* r=0.293 and *P=0.006* r=0.271, respectively). No significant relationship was found between other demographic data and spinopelvic parameters.

Table 2. Spinopelvic Parameters

Variable	Mean (degree)	Std. Deviation
PI	51.48	10.92
PT	17.44	9.95
SS	34.85	11.87
LL (L1-L5)	37.75	9.27
LL (L1-S1)	44.64	9.85
T5TK	34.04	12.30
PI-LL	9.89	5.66

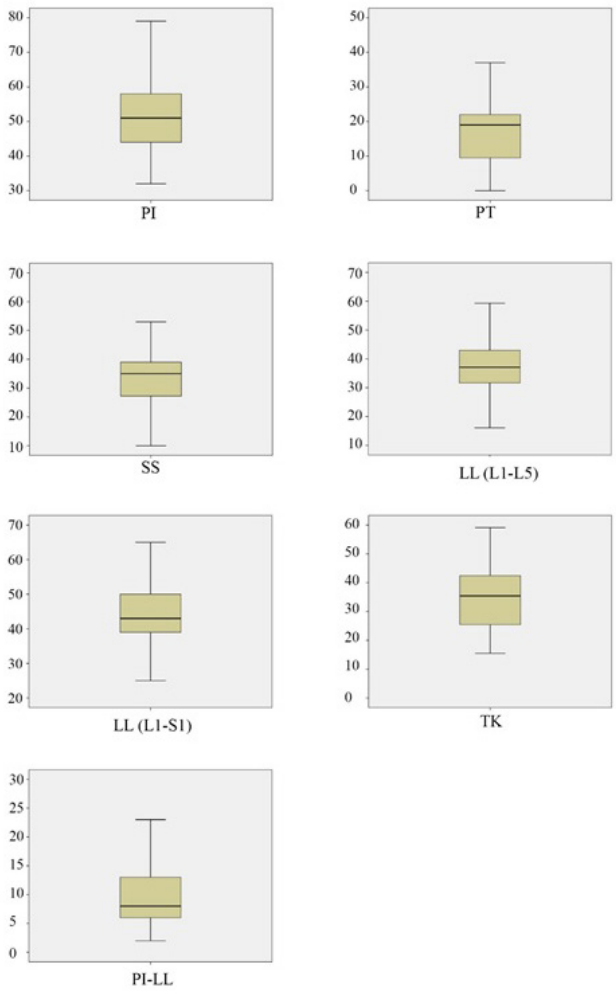

Figure 2. Spinopelvic Parameters. PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; TK stands for thoracic kyphosis; LL, lumbar lordosis.

Discussion

In this study we tried to determine the normal range of spinopelvic parameters. In a previous study, spinopelvic parameters were correlated with quality of life (15). Also, diagnosis and treatment of lumbosacral sagittal imbalance are based on spinopelvic parameters. Due to the lack of such study in Iran or even in the Middle East, we performed the first investigation in this region. Our data showed that PT and PI-LL are significantly lower in women, while, PT, PI and PI-LL increase and LL decreases in older ages.

PI is clearly related to the pelvic shape and reaches sustainability after maturation of the skeletal system that is unique to each individual and this parameter is not position-dependent. PI is angular measurement of the anterior or posterior distance between sacral endplate and hip joints. This angle also shows the load transmitted

Table 3. Spinopelvic Parameters in terms of gender

Variable	Gender	Mean (degree)	Std. Deviation	*P value*
PI	Male	53.75	11.28	0.083
	Female	49.90	10.46	
PT	Male	21.69	11.40	<0.001
	Female	14.48	7.61	
SS	Male	34.57	15.26	0.84
	Female	35.05	8.94	
LL (L1-L5)	Male	37.84	8.52	0.68
	Female	37.68	9.83	
LL (L1-S1)	Male	44.15	10.50	0.934
	Female	44.98	9.45	
TK	Male	35.37	9.81	0.36
	Female	33.11	13.77	
PI-LL	Male	11.74	6.98	0.006
	Female	8.60	4.13	

to the sacral plateau. PI has a direct correlation with the spinal balance (13, 16). So far, it has been assumed that this angle remains constant as age rises, while, a number of new studies have proven that PI increases with the aging (17,18). However, according to the previous reports, PI does not differ significantly between males and females (19). The results from previous studies have shown that the spinopelvic parameters including PI clearly differ among different ethnic groups (18).

PT represents the compensatory changes of the pelvis relative to the overall changes in the spine. This angle increases when the pelvic retroversion is increased. SS measures the rotation of the sacral endplate relative to the horizontal line and changes according to the retroversion (16). In addition to the importance of the normal range of these parameters, it is also important to know the correlations between these parameters in each person. For example, as the sagittal vertical axis increases, the PI-LL increases compensatively (20).

So far, various studies have been conducted in different populations to elucidate the normal range. In a meta-analysis by Noshchenko et al. in 2017 including 17 studies, the pooled means and the optimal ranges were: LL (L1–S1), 54.6°; LL (L1–L5), 37.0°; pelvic incidence, 50.6°; sacral slope, 37.7°; pelvic tilt, 12.6°. The authors declared that LL decreases with age as a result of progressive disc degeneration. Also, PI has a significant correlation with age (18).

A study by Chung et al. in 2017 stated that the use of lateral lumbosacral radiographs has several advantages over the whole-spine radiographs in examining the spinopelvic parameters. These advantages include lack of need for special film or chassis, reduced radiation exposure, and easy procedure. Also, measurements of spinopelvic parameters and LL on lateral lumbosacral radiographs would be more reliable than measurements obtained from the lateral whole-spine radiographs (6).

Yukawa and colleagues in a study in 2016 showed that a remarkable change of spinopelvic sagittal alignment was seen from the 7th to the 8th decade in asymptomatic subjects. They demonstrated a relatively large gender difference in LL and PT (5).

On the other hand, a complete understanding of the sagittal balance basics is needed to achieve the best outcome and avoid future complications after treatment of the spinal deformities. It has also been shown that there is a direct relationship between thoracic kyphosis and lumbar lordosis (21).

Garbossa et al. in 2014 conclude that spinal surgery is not acceptable without knowing the global balance of the spine and spinopelvic junction. The lack of information and calculation of these parameters is associated with the failure of the surgery and the persistence of the symptoms (16).

In this study we tried to determine the normal range of spinopelvic parameters.. Our data showed that PT and PI-LL are significantly lower in women, while, PT, PI and PI-LL increase and LL decreases in older ages.

Given that this study was conducted in this subject for the first time in Iran, sagittal balance disorders in this region can be better diagnosed and treated.

Conflict of interests: The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Hamid Rezaee MD[1]
Gholamreza Bahadorkhan MD[1]
Mohammadreza Ehsaei MD[1]
Babak Ganjeifar MD[1]
Ehsan Keykhosravi MD[1]
Masoud Pishjoo MD[1]
1 Department of Neurosurgery, Mashhad University of Medical Sciences, Mashhad, Iran

References

1. Mac-Thiong JM, Labelle H, Roussouly P. Pediatric sagittal alignment. European spine journal. 2011; 20(5):586.
2. Davis H. Increasing rates of cervical and lumbar spine surgery in the United States, 1979-1990. Spine. 1994; 19(10):1117-23.
3. Schwab F, Dubey A, Gamez L, El Fegoun AB, Hwang K, Pagala M, et al. Adult scoliosis: prevalence, SF-36, and nutritional parameters in an elderly volunteer population. Spine. 2005 30(9):1082-5.
4. Jacob CJ, Cardoso IM, Batista JL, Maia TC, Roncaglio B. Spinopelvic parameters evaluation in a Brazilian population sample. European Journal of Orthopaedic Surgery & Traumatology. 2015; 25(1):21-4.
5. Yukawa Y, Kato F, Suda K, Yamagata M, Ueta T, Yoshida M. Normative data for parameters of sagittal spinal alignment in healthy subjects: an analysis of gender specific differences and changes with aging in 626 asymptomatic individuals. European Spine Journal. 2018; 27(2):426-32.
6. Chung NS, Jeon CH, Lee HD, Won SH. Measurement of Spinopelvic Parameters on Standing Lateral Lumbar Radiographs. Clinical spine surgery. 2017; 30(2):E119-23.
7. Henneman SA, Antoneli PH, Oliveira GC. Incidência pélvica: um parâmetro fundamental para definição do equilíbrio sagital da coluna vertebral. Coluna/ Columna. 2012; 11(3):237-9.
8. Li WS, Gang L, Chen ZQ, Wood KB. Sagittal plane analysis of the spine and pelvis in adult idiopathic scoliosis. Chinese medical journal. 2010; 123(21):2978-82.
9. Sudhir G, Acharya S, Kalra KL, Chahal R. Radiographic analysis of the sacropelvic parameters of the spine and their correlation in normal asymptomatic subjects. Global spine journal. 2016; 6(2):169-75.
10. Labelle H, Roussouly P, Berthonnaud É, Transfeldt E, O'Brien M, Chopin D, et al. Spondylolisthesis, pelvic incidence, and spinopelvic balance: a correlation study. Spine. 2004; 29(18):2049-54.
11. Morvan G, Mathieu P, Vuillemin V, Guerini H, Bossard P, Zeitoun F, et al. Standardized way for imaging of the sagittal spinal balance. European Spine Journal. 2011; 20(5):602.
12. Berjano P, Damilano M, Bozzaro M, Pejrona M, Cecchinato R, Lamartina C. Standing lateral lumbar spine and pelvis (SLLP) radiograph: a screening, reduced radiation method, for sagittal imbalance. European Spine Journal. 2013; 22(6):842-6.
13. Drummond Filho ML, Risso Neto MÍ, Lechoczi MA, Cavali PT, Veiga IG, Zuiani GR, et al. Evaluation of spino-pelvic parameters according to intraoperative position in lumbosacral spine arthrodesis. Coluna/ Columna. 2013; 12(3):228-31.
14. Morvan G, Mathieu P, Vuillemin V, Guerini H, Bossard P, Zeitoun F, et al. Standardized way for imaging of the sagittal spinal balance. European Spine Journal. 2011; 20(5):602.
15. Gussous Y, Theologis AA, Demb JB, Tangtiphaiboontana J, Berven S. Correlation between lumbopelvic and sagittal parameters and health related quality of life in adults with lumbosacral spondylolisthesis. Scoliosis Research Society (SRS) 50th Annual meeting. Minneapolis, MN: SRS; 2015:232.
16. Garbossa D, Pejrona M, Damilano M, Sansone V, Ducati A, Berjano P. Pelvic parameters and global spine balance for spine degenerative disease: the importance of containing for the well-being of content. European Spine Journal. 2014; 23(6):616-27.
17. Vrtovec T, Janssen MM, Likar B, Castelein RM, Viergever MA, Pernuš F. Evaluation of pelvic morphology in the sagittal plane. The Spine Journal. 2013; 13(11):1500-9.
18. Noshchenko A, Hoffecker L, Cain CM, Patel VV, Burger EL. Spinopelvic parameters in asymptomatic subjects without spine disease and deformity. Clinical Spine Surgery. 2017; 30(9):392-403.
19. Mac-Thiong JM, Roussouly P, Berthonnaud E, Guigui P. Age-and sex-related variations in sagittal sacropelvic morphology and balance in asymptomatic adults. European Spine Journal. 2011; 20(5):572.
20. Merrill RK, Kim JS, Leven DM, Kim JH, Cho SK. Beyond Pelvic Incidence–Lumbar Lordosis Mismatch: The Importance of Assessing the Entire Spine to Achieve Global Sagittal Alignment. Global Spine Journal. 2017; 7(6):536-42.
21. Roussouly P, Nnadi C. Sagittal plane deformity: an overview of interpretation and management. European spine journal. 2010; 19(11):1824-36.