Acta Orthop. Belg., 2014, **80**, 522-528

ORIGINAL STUDY

Correlation between clinical outcomes and spinopelvic parameters in osteoporosis

Jung Sub LEE, Jong Ki SHIN, Sung Jin AN, Kuen Tak SUH, Sung Shik KANG

From Medical Research Institute, Department of Orthopaedic Surgery, Pusan National University School of Medicine, Busan, Republic of Korea

Introduction : **Little data is available on the relationship between sagittal spinopelvic parameters and health related quality of life (HRQOL) in osteoporotic patients. The aim of this study was to identify relationships between spinopelvic parameters and HRQOL in osteoporosis.**

Material and methods : **The patient and control groups comprised 138 osteoporotic patients and 40 controls. All underwent anteroposterior and lateral radiography of the whole spine, including hip joints, and completed clinical questionnaires. The radiographic parameters examined were ; sacral slope, pelvic tilt, pelvic incidence, thoracic kyphosis, lumbar lordosis, and sagittal vertical axis. Lumbar spinal bone mineral density (LSBMD) and femoral neck BMD (FNBMD) of the non-dominant proximal femur were measured. A Visual Analogue Scale (VAS : 0-10) was used to assess back pain, and the Oswestry disability index (ODI) questionnaire and the Scoliosis Research Society (SRS-22) questionnaire to evaluate QOL. Statistical analysis was performed to identify significant differences between the patient and control groups. In addition, correlations between radiological parameters and clinical questionnaires were sought.**

Results : **Patients and controls were found to differ significantly in terms of sagittal vertical axis, sacral slope, pelvic tilt, lumbar lordosis, and thoracic kyphosis. However, no significant intergroup difference was observed for pelvic incidence (*P* > 0.05). Correlation analysis revealed significant relationships between radiographic parameters and clinical outcomes. Multiple regression analysis was performed to identify predictors of clinical outcome, and the results obtained revealed that sagittal vertical axis, sacral slope, and FNBMD significantly predicted VAS, ODI, and SRS-22 scores and that LSBMD predicted SRS-22 scores.**

Conclusions : **Osteoporotic patients and controls were found to be significantly different in terms of sagittal spinopelvic parameters. Correlation analysis revealed significant relationships between radiographic parameters and clinical outcome variables. In particular, sagittal vertical axis, sacral slope, and FNBMD significantly predicted clinical outcomes in osteoporotic patients.**

Keywords : osteoporosis ; sagittal parameters ; quality of life.

■ Jung Sub Lee, MD, PhD, Orthopaedic Surgeon, Professor.
■ Jong Ki Shin, MD, Orthopaedic Surgeon, Assistant professor.
■ Sung Jin An, MD, Orthopaedic Surgeon.
Medical Research Institute, Department of Orthopaedic Surgery, Pusan National University School of Medicine, Busan, Republic of Korea.
■ Kuen Tak Suh, MD, PhD, Orthopaedic Surgeon, Professor.
■ Sung Shik Kang, MD, Orthopaedic Surgeon, Assistant professor.
Medical Research Institute, Department of Orthopaedic Surgery, Pusan National University Yangsan Hospital, Yangsan, Republic of Korea.

Correspondence : Jung Sub Lee, Medical Research Institute, Department of Orthopaedic Surgery, Pusan National University School of Medicine, 1-10 Ami-Dong, Seo-Gu, Busan, Republic of Korea, 602-739. E-mail ; jungsublee@pusan.ac.kr

This work was supported by a 2-Year Research Grant of Pusan National University.
The authors report no conflict of interests.

INTRODUCTION

Osteoporosis is a major issue in the elderly. Furthermore, the incidence of vertebral fractures is expected to increase, and those that suffer an osteoporotic vertebral fracture are known to have poorer health-related quality of life (HRQOL) (*19*). In addition, patients with osteoporosis have weaker back extensor strength and poor balance, which result in a propensity to fall (*23*). Kyphosis is considered a result of osteoporotic vertebral fracture, and vertebral fractures presenting with an anterior wedge deformity are a possible cause (*3,4*). In addition, patients with an abnormal kyphotic posture often complain of pain and a reduced ability to walk (*9,25*) which indicates sagittal spinal alignment is important for normal spinal function. Therefore, the identification of correlations between sagittal spinopelvic parameters and HRQOL would provide information of benefit for treatment decision making and planning.

Correlations between HRQOL and kyphotic spinal alignment, such as, with spinopelvic parameters, have been previously described, but few osteoporosis cases were included. Some authors have described sagittal alignment in older populations (*8,16,24*) but no relationships have been established between sagittal spinopelvic parameters and HRQOL in osteoporosis. Thus, we considered that a more comprehensive understanding of relationships between the lumbar spine and pelvis was needed in osteoporosis, because correlations between radiographic parameters of the pelvis and HRQOL in osteoporosis. Accordingly, the aims of this study were to document relationships between spinopelvic parameters and HRQOL in osteoporotic patients, and to identify spinopelvic parameters that predict HRQOL.

MATERIAL AND METHODS

One hundred and thirty eight consecutive female patients with osteoporosis were enrolled prospectively at examinations conducted between January 2012 and March 2013. Osteoporotic patients were recruited from among patients attending the orthopaedic outpatient clinic. Demographic and clinical characteristics and Visual Analogue Scale (VAS : 0-10) scores for back pain were recorded, and the Oswestry disability index (ODI) questionnaire (*13*) and Scoliosis Research Society (SRS-22) questionnaire (*15*) were administered. Forty age-matched subjects with no history of osteoporosis who underwent whole spine radiographs for simple health checkup were recruited as a control group. The study was approved by the Clinical Research Ethics Committee of our institution.

Osteoporotic patients met the diagnostic criterion for osteoporosis (T-score ≤-2.5) (*22*) and patients were considered eligible if they had been treated for at least the previous year. Pain originating from the spine was scored, but pain originating from any other part of the body was excluded. The study exclusion criteria were a concomitant neurological or psychiatric disease. Patients with a history of or a current orthopaedic condition of the spine (spinal disc herniation, degenerative scoliosis, and spinal surgery, etc) or a lower extremity (prosthesis) were also excluded. However, patients with a history of an osteoporotic vertebral fracture, but not a current symptomatic vertebral fracture, were included.

Anthropometric measurements included body height and body weight. Body mass index (BMI) was determined by dividing weight (kg) by uncorrected height squared (m^2). Lumbar spinal bone mineral density (LSBMD) and femoral neck BMD (FNBMD) of the nondominant proximal femur were measured by dual-energy X-ray absorptiometry (DEXA) (XR-36 ; Norland Corp., Fort Atkinson, Wisc., USA). LSBMD was measured from L1 to L4 (inclusive) in anterior-posterior view.

Participants underwent anteroposterior and lateral whole spine radiography. Radiographs were taken by one technician at a distance of 72 inches using a standard technique and the same machine in the standing position. All lateral radiographs included both hip joints and the C7 vertebra.

Radiographic parameters, such as, sacral slope, pelvic tilt, pelvic incidence, thoracic kyphosis, lumbar lordosis, and sagittal vertical axis were measured using a picture achieving computer system (PACS Expertise, Marosis, South Korea). Sacral slope was defined as the angle between the sacral end plate and the horizontal ; pelvic tilt as the angle between the line joining the middle of the sacral end plate and hip axis and the vertical ; pelvic incidence as the angle between a line perpendicular to the sacral end plate and a line joining the middle of the sacral plate and the hip axis ; and thoracic kyphosis was measured between the upper endplate of T1 or T2 and the lower endplate of the T12 using Cobb's method. T1-T12 kyphotic angle was used in most of the 138 patients and T2-T12 only in 13 patients. Lumbar lordosis was measured between the upper endplate of L1 and the upper endplate of S1 using Cobb's method. Sagittal balance was measured using the sagittal vertical axis, and was defined as the horizontal distance between a plumbline dropped from the center of the C7 body to the posterior-superior corner of the S1 body ; anterior displacement of the sagittal plumbline was defined as positive. All measurements were performed twice independently by three spine surgeons with an interval of 2 weeks between measurements to decrease intraobserver (Pearson correlation coefficient = 0.919, range : 0.871 to 0.928) and interobserver errors (Pearson correlation coefficient = 0.903, range : 0.869 to 0.926).

Statistical analysis was performed using SPSS ver. 11.5 for Windows (SPSS, Chicago, IL, USA). Data are expressed as means ± standard deviations. The patient and control groups were compared using the t-test and correlation analysis was performed using Pearson's correlation analysis to explore relationships between variables. Multiple regression analysis was used to identify parameters that effectively predicted clinical outcomes. Statistical significance was accepted for p values < 0.05.

RESULTS

Measurements of parameters

The average age of the 138 osteoporotic patients was 67.2 ± 6.9 years. Patient mean weight and BMI were 56.4 ± 4.1 kg and 23.0 ± 1.5 kg/m^2, respectively, and mean LSBMD and mean FNBMD were 0.775 ± 0.106 g/cm^2 and 0.689 ± 0.092 g/cm^2, respectively. Of the 138 patients, 72 (52.3%) had history of vertebral fracture. The mean kyphotic angle of the 113 vertebral fractures (2 T7, 7 T8, 3 T9, 4 T10, 13 T11, 33 T12, 27 L1, 15 L2, 6 L3, 2 L4 and 1 L5) of these 72 patients was 15.3 ± 6.2°.

Table I summarizes sagittal parameter measurements in the 138 patients and 40 controls. Patients and controls were found to be significantly different in terms of sagittal vertical axis, sacral slope, pelvic tilt, lumbar lordosis, and thoracic kyphosis. However, no significant intergroup difference was observed for pelvic incidence ($P > 0.05$).

Correlation between parameters

Table II summarizes correlations between spinopelvic parameters. Statistically significant correlations were observed between the following variables after stratification (Fig. 1) : pelvic incidence and sacral slope (r = 0.607, $P < 0.001$), pelvic incidence and pelvic tilt (r = 0.580, $P < 0.001$), pelvic incidence and lumbar lordosis (r = 0.295, $P < 0.001$), pelvic incidence and thoracic kyphosis (r = 0.200, $P = 0.019$), sacral slope and lumbar lordosis (r = 0.630, $P < 0.001$), sacral slope and thoracic kyphosis (r = 297, $P < 0.001$), pelvic tilt and lumbar lordosis (r = -0.282, $P < 0.001$) and lumbar lordosis and thoracic kyphosis (r = 0.662, $P < 0.001$).

Correlations between spinopelvic parameters and clinical outcomes

Correlation analysis revealed significant relationships between parameters and clinical outcomes

Table I. — Details of the patients

	Control (n = 40)	Osteoporosis (n = 138)	*P* value
Age	60.7 ± 10.5	67.2 ± 6.9	0.121
Height	158.9 ± 4.4	156.6 ± 4.1	0.041
Weight	56.8 ± 5.0	56.4 ± 4.0	0.532
BMI	22.5 ± 1.7	23.0 ± 1.5	0.094
Sagittal vertical axis	-26.1 ± 13.4	36.0 ± 39.3	< 0.001
Sacral slope	36.8 ± 6.0	24.9 ± 9.2	< 0.001
Pelvic tilt	13.8 ± 6.7	24.6 ± 8.8	< 0.001
Pelvic incidence	50.3 ± 3.6	49.6 ± 10.8	0.708
Lumbar lordosis	45.3 ± 3.9	36.8 ± 15.5	< 0.001
Thoracic kyphosis	38.7 ± 5.5	31.9 ± 16.1	0.009

Table II. — Correlations of the parameters in osteoporotic patients

		Age	BMI	FNBMD	LSBMD	SS	PT	PI	LL	TK
Sagittal vertical axis (SVA)	*r*	0.304**	0.020	-0.319**	-0.115	0.025	0.157	0.139	-0.251**	-0.108
Age	*r*		0.021	-0.198*	0.079	-0.001	0.131	0.095	-0.169*	-0.014
BMI	*r*			-0.107	-0.079	-0.096	0.126	0.049	-0.051	0.028
FNBMD	*r*				0.445**	0.029	-0.135	-0.123	0.047	0.043
LSBMD	*r*					0.073	-0.355**	-0.245**	-0.032	-0.001
Sacral slope (SS)	*r*						-0.260**	0.607**	0.630**	0.297**
Pelvic tilt (PT)	*r*							0.580**	-0.282**	-0.076
Pelvic incidence (PI)	*r*								0.295**	0.200*
Lumbar lordosis (LL)	*r*									0.662**
Thoracic kyphosis (TK)	*r*									

*Significant correlation was established at the 0.01 level.
** Significant correlation was established at the 0.05 level.

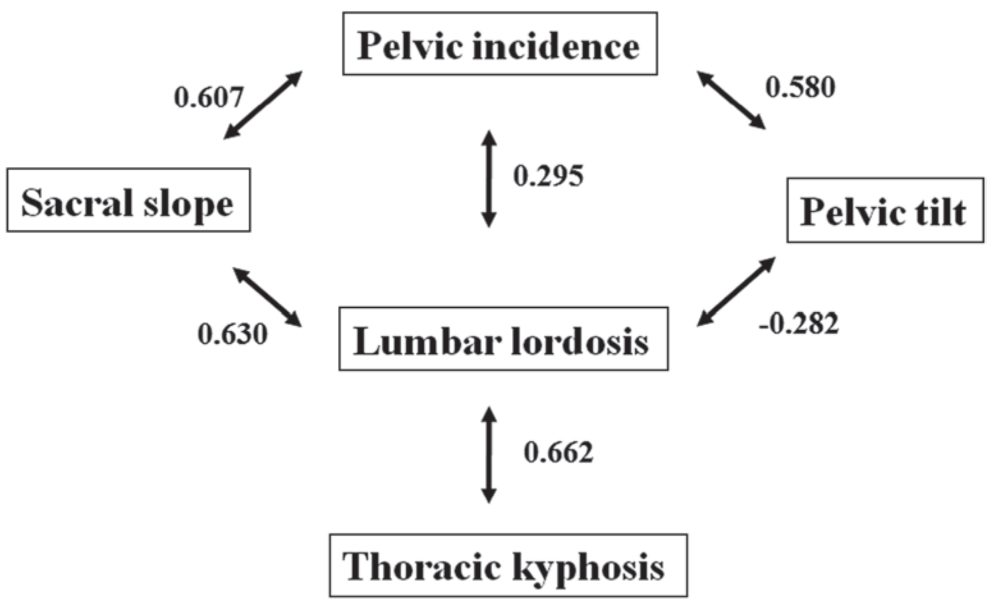

Fig. 1. — Correlations between spinopelvic parameters

(Table III). However, BMI and pelvic incidence were not found to be correlated with any of the three clinical outcome scores, and thoracic kyphosis was not correlated with ODI or SRS-22 scores.

Multiple regression analysis was performed to identify contributors to clinical outcome, and showed that sagittal vertical axis, FNBMD, and sacral slope significantly predicted VAS, ODI and SRS-22 scores, and that LSBMD significantly predicted VAS and SRS-22 scores (Table IV).

DISCUSSION

Although the treatment of spinal deformities associated with osteoporosis has become an increasingly important component of spinal surgery practice, the relevance of pelvic measures in osteoporosis remains unclear. Previous studies have addressed sagittal spinal alignment in the elderly (*8,24*) and several authors have investigated relationships between HRQOL instruments and radiographic mea-

Table III. — Correlations of the spinopelvic parameters and clinical outcomes in osteoporosis patients

		VAS (2.7 ± 1.3)	ODI (36.6 ± 11.3)	SRS-22 (67.3 ± 8.7)
Age	*r*	0.176*	0.149	-0.168*
BMI	*r*	0.067	0.087	-0.057
FNBMD	*r*	-0.494**	-0.513**	0.420**
LSBMD	*r*	-0.456**	-0.293**	0.422**
Sagittal vertical axis	*r*	0.444**	0.434**	-0.440**
Sacral slope	*r*	-0.323**	-0.332**	0.286**
Pelvic tilt	*r*	0.272**	0.162	-0.279**
Pelvic incidence	*r*	-0.033	-0.137	-0.001
Lumbar lordosis	*r*	-0.298**	-0.296**	0.258**
Thoracic kyphosis	*r*	-0.172*	-0.128	0.144

*Significant correlation was established at the 0.01 level.
** Significant correlation was established at the 0.05 level.

Table IV. — Multiple regression analysis in osteoporosis patients

Variables	Coefficient	t	*P* value
VAS			
Sagittal vertical axis	0.012	5.235	< 0.001
FNBMD	-3.671	-3.495	< 0.001
LSBMD	-3.610	-4.142	< 0.001
Sacral slope	-0.044	-4.938	< 0.001
Constant	8.734		
ODI			
Sagittal vertical axis	0.091	4.650	< 0.001
FNBMD	-49.967	-5.986	< 0.001
Sacral slope	-0.408	-5.155	< 0.001
Constant	77.828		
SRS-22			
Sagittal vertical axis	-0.078	-5.163	< 0.001
FNBMD	15.190	2.103	0.037
LSBMD	24.738	4.119	< 0.001
Sacral slope	0.236	3.797	< 0.001
Constant	-9.798		

surements in order to define objective criteria for the surgical treatment of adult spinal deformities. However, relatively few studies have addressed relations between osteoporosis and specific radiologic pelvic parameters. Furthermore, the relationships established between sagittal spinopelvic parameters and preoperative HRQOL in osteoporosis are lacking.

In the normal population, sacral inclination, pelvic tilt, and pelvic incidence can be used to assess the effects of lumbosacral pelvic orientation on sagittal alignment of the spine (*2,10,11,17,18*). However, changes in lumbar lordosis, sacral inclination angle, and sagittal vertical axis are known to occur with age (*5,8,24*) and little is known about the contribution made by osteoporosis to sagittal curvature. In the present study, sagittal parameters were found to be significantly different in osteoporosis patients and controls, and to be interrelated. Although correlations between sagittal parameters and the developments of spinal disorders have not been confirmed in osteoporosis, differences and relationships between sagittal radiological parameters can provide clues when examining spinal deformities in osteoporosis patients. In the present study, osteoporotic patients exhibited more pelvic tilt and lumbar hypolordosis, which suggests that spinopelvic orientation is significantly different in osteoporosis. In addition, mean sagittal vertical axis was positive in osteoporotic patients. Thus, it appears that spinal misalignment and pelvic abnormalities are closely related in osteoporosis.

With regard to relationships between HRQOL instruments and radiographic measurements, gross orientation and spinopelvic balance are believed to be important measures of spinal deformity (*6,7,17,21*). However, evidence supporting this concept is not strong. In an early study on 95 patients, Schwab *et al.* (*21*) identified correlations between radiologic parameters and self-perceived pain measured using a VAS scale, and in a later report, loss of lordosis was found to be correlated with lower Short Form 36 (SF-36) scores (*20*). The present study also confirms the relationship between lumbar lordosis and clinical outcomes. Thus, it appears that lumbar lordosis is significantly correlated with HRQOL measures and a key consideration when analyzing radiographic alignment. Lafage *et al.* (*17*) found that pelvic tilt is associated with HRQOL in the setting of adult deformity, and Glassman *et al.* (*6,7*) reported that global alignment of the sagittal vertical axis is associated with pain and reduced function, which is consistent with our findings. In fact, in the present study, sagittal vertical axis, measured from the C7 plumbline with respect to S1, was significantly related to HRQOL and significantly predicted clinical outcomes in osteoporotic patients by multiple regression analysis. Contrary to the observations of Glassman *et al.* (*7*) clinical outcome scores were significantly influenced by age in the present cohort, which suggests younger patients are better able to compensate for spinal deformities.

In the present study, clinical outcome scores were significantly correlated with sagittal vertical axis, sacral slope, pelvic tilt, and lumbar lordosis. In particular, sagittal vertical axis, sacral slope, and FN-BMD significantly predicted HRQOL in osteoporosis by multiple regression analysis. Some authors have reported a significant correlation between age and spinal sagittal vertical axis, but no other significant correlation between sagittal vertical axis and spinopelvic parameters (*24*). In the present study, age and FNBMD were significantly correlated to sagittal vertical axis, which was not unexpected, because BMD decreases with age. In general, correlations between lumbar lordosis and sacral slope or pelvic tilt at the pelvic level are stronger for sacral slope than for pelvic tilt (*1,14,17*) which are consistent our observations. To some extent, a reduction in lumbar lordosis can be compensated for by a similar reduction in sacral slope to maintain the relative position of the C7 plumb line (*12*) which is in line with the finding that sacral slope and lumbar lordosis were significant associated with HRQOL in the present study. Thus, it appears that spinal misalignment and pelvic abnormalities are closely related in osteoporosis. Furthermore, the unbalanced condition caused by decreased lumbar lordosis and/or thoracic kyphosis could increase pain, and thus, requires consideration by surgeons treating osteoporosis.

This study has several limitations that require consideration. First, the number of normal controls tested was relatively small, and thus, diminished the statistical power of this study and its ability to detect correlations. Second, sagittal vertical axis was used to determine sagittal balance, and recently described more relevant indexes of global sagittal balance based on analyzing the position of C7 were not utilized.

This study shows that significant relationships between sagittal spinopelvic parameters in osteoporotic patients, and that osteoporotic patients and controls are significantly different in terms of sagittal spinopelvic parameters. In addition, correlation analysis revealed significant relationships between parameters and clinical outcomes. In particular, sagittal vertical axis, sacral slope, and FNBMD were found to predict clinical outcomes significantly in osteoporotic patients.

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