The correlation between the sagittal lumbopelvic alignments in standing position and the risk factors influencing low back pain

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Abstract

Low back pain (LBP) is the most common health problem. Many factors have been demonstrated to be fundamental risk factors of LBP such as body mass index (BMI), age and sex. However, so far there have been few studies demonstrating the association between lumbo-pelvic alignment (LPA) and these factors. This present study was aimed to clarify the correlation between the LPA and the risk factors contributing to LBP. Standing lateral X-rays were taken from 100 healthy volunteers (70 males and 30 females) with no history of low back pain before their participation. Average age of subjects was 33.3±6.8 years (rang 21-50). Mean body weight was 59.1±7.9kg (range 40-82), mean body height was 163.6±7.2 cm (range 145-178) and mean BMI was 22.1±2.4 kg/m^2 (range 18.0-29.3). The LPA was classified into 3 types according to the recently proposed pelvic orientation guidelines. No direct correlation was found between the pelvic orientation and age or BMI. Each LPA type was associated with sex but not BMI and age (P=0.00, 0.71, and 0.36, respectively). The results from this study demonstrated the differences in LPA between male and female, and also confirmed that the sagittal orientation of the pelvis remained constant in adults. The high prevalence of LPA type 1 in males may reduce the occurrence of LBP in obese male individuals.

Introduction

Low back pain (LBP) is one of the most common health problems and affects more than 80% of people over their lifetime.[1] It is an enormous clinical and public health problem that is associated with high health care burden and social costs.[1,2] Moreover, despite its benign nature, in many countries, LBP is the leading activity-limiting complaint, cause of disability and sick leave, and with the highest cost of workers' compensation.[1,3] In addition, regarding therapeutic interventions, a large number of systematic reviews have been published concerning the effectiveness of a large variety of treatment available for the LBP; unfortunately the results have not been convincingly demonstrated.[4] Therefore, preventive strategies might be beneficial in the management of LBP, with regard to treatment costs, outcomes and disease burden. Given this, it is essential to know the potential risk factors.

Numerous potential risk factors of the LBP have been suggested, such as age and gender,[3,5] body mass index (BMI),[6,7] or physical activity.[5] Unfortunately, despite many clinical studies, the associations between these factors and LBP have remained inconclusive. The alteration in sagittal spinal alignment is thought to be one of the potential risk factor of LBP.[8,9] However, there is great variability in spinal alignment in the normal population and this makes it difficult to clarify whether the alteration in spinal posture has any influence and there is still some conflicting evidence linking different spinal postures to LBP in adults.[10]

Recently, Pongsthorn *et al.* have suggested classifying lumbo-pelvic alignments (LPA) in the normal population.[11] In brief, LPA has been classified into 3 types according to the sagittal orientation of the pelvis: in type 1, the sacro-pelvis is relatively horizontal with low lumbar lordosis, whereas in type 3, the sacro-pelvis is more vertical with higher lumbar lordosis, and type 2 has the average sacro-pelvis and lumbar lordosis pattern. However, the association between the new LPA classification and the internal risk factors such as age, gender and BMI has not yet been studied. Therefore, the aim of this present study was to determine the correlation between LPA and the LPA classification and the contribution of internal risk factors to low back pain.

Materials and Methods

Demographic data and X-ray parameters from 100 asymptomatic Thai volunteers who had previously participated in studies on lumbo-pelvic alignment analysis were used in this present study. Inclusion study criteria were: i) age 20-60 years; ii) no prior spine surgery; and iii) no history of low back pain, except for occasional episodes after work or exertion, for at least six months before their participation in the study. Exclusion criteria were: i) definite diagnosis of lumbar spinal pathology, such as spinal stenosis, spondylolisthesis, degenerative disc disease or inflammatory spinal diseases, or definite clinical spine deformities from physical examination or X-ray; ii) definite diagnosis of diabetic mellitus, hypertension, rickets, osteoporosis; iii) history of smoking; and iv) incomplete demographic data records. Age, gender, body weight and height were recorded and then the body mass index (BMI) for each subject was calculated.

In order to better understand the correlation between the types of the lumbo-pelvic alignment and the demographic parameters, we divided subjects into 3 subcategories according to age: group 1, under 30 years of age (n=30); group 2, aged between 30 and 39 years (n=46); and group 3, over 40 years of age (n=20), according to the risk of low back pain in the Thai worker population.[3] The BMI was also subcategorized into 3 groups: group 1, BMI less than 19 kg/m^2; group 2, BMI between 19 and 24.5 kg/m^2; and group 3, BMI over 24.5 kg/m2 according to the World Health Organization (WHO) criteria for the Asian population.[12]

The previous standing lateral standing X-rays of the lumbar spine and pelvis in a standardized position that were used in a previous study were reviewed by 2 of the authors (PC and SW) and then used for this correlation study. Details of the X-ray techniques were: i) all subjects had standing lateral X-ray of the spine and pelvis performed by the same radiotechnologist using the same radiographic equipments; ii) X-ray cassettes were set into a standard upright cassette adjustment device then adjusted for a 72-inch long focal film distance from the radiation source; iii) the volunteers were carefully positioned with their right side against the cassette. They were asked to stand up straight, but to remain in a relaxed position with the knees extended. The arms

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were brought upward with hands held together behind the neck (Figure 1). Previous X-ray measurements using a pelvic radius measurement technique[13] were retrieved.

Measurements were: i) hip axis (HA); ii) pelvic radius (PR); iii) pelvic angle (PA); iv) anatomic PR-S1 angle; v) total lumbo-sacral lordosis angle (T12-S1 angle) and total lumbo-pelvic lordosis angle (PR-T12 angle); vi) regional lumbo-pelvic lordosis angles (PR-L2,PR-L4 and PR-L5 angles); vii) sacral translation distance (HA-S1). Nomenclature for the parameters used is outlined in Table 1. Figure 2 shows the methods of measurement. Subsequently, all parameters were evaluated and then sub-classified into 3 groups of lumbo-pelvic alignments (LPA) according to the distribution of the PR-S1 angle in studied subjects as an average (35-45°), lower than average (less than 35°), and higher than average (over 45°) as shown in Table 2.[11] This study was reviewed and had been approved by the hospital ethical research committees.

Statistical analysis

Data were analyzed using the SPSS 15.0 software (SPSS Inc., Chicago, IL, USA). Correlations between parameters were determined using Pearson's correlation coefficient. χ^2 test was used to study the correlation between the lumbo-pelvic alignment classification (LPA) and the categorized data of each demographic parameter which had been previously described. P< 0.05 was considered statistically significant.

Results

The previous lumbo-pelvic alignment parameters and the demographics data from 70 males and 30 females were retrieved for analysis in this present study. Average age of subjects was 33.3±6.8 years (range 21-50; mean body weight was 59.1±7.9 kg (range 40-82) and mean body height was 163.6±7.2 cm (145-178). Mean BMI was 22.1±2.4 kg/m2 (range 18.0-29.3).

The correlation between lumbo-pelvic alignment parameters, age and body mass index

Mean values, ranges and standard deviations (SD) of all measurement parameters describing the lumbo-pelvic morphology were demonstrated and the correlations between that individual parameter, age and BMI are shown in Table 3. No correlation between age, BMI and any individual parameters describing the lumbo-pelvic morphology was demonstrated in this present study.

The correlation between lumbo-pelvic alignment (LPA) classifications, gender age and body mass index subgroups

The LPA classification according to the pelvic morphology (PRS1) found in our previous study is shown in Table 2 and Figure 3. The SPA type 1 had high PRS1 with relatively low lumbar lordosis pattern, LPA type 2 had average PRS1 and lumbar lordosis pattern, and LPA type 3 had low PRS1 with relatively high lumbar lordosis pattern. A further analysis in our present study showed a strong correlation between the LPA classifications and gender but not between BMI and age subgroups (P=0.00, 0.71 and 0.36, respectively) (Table 4). The prevalence of each LPA type and gender is shown in Figure 3. LPA type 1 was mainly found in males (27.1% *vs* 13.3%). In contrast, the prevalence of LPA type 2 and type 3 was higher in females than in males (50% *vs* 40% in LPA type 2 and 36.7% *vs* 32.8% in LPA type 3).

Discussion

Pelvic morphology has been shown to affect the standing lumbo-sacral lordosis[14,15] and is suggested to be one of the potential risk factors of low back pain (LBP).[8,9] However, there is still conflicting evidence to link the different spinal postures to this condition because of the great variability in spinal alignment in normal populations.[10] More recently, a new classification of the lumbo-pelvic alignments (LPA) on an asymptomatic population has been introduced by Pongsthorn *et al.*[11] using the PR-S1 angle. According to this, Type 1 LPA is PR-S1 angle of more than 45° and is correlated to the low lumbar lordosis pattern. In contrast, type 3

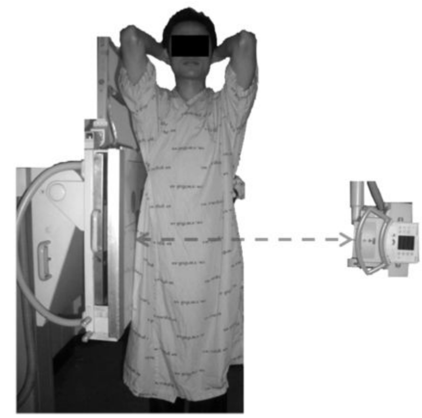


Figure 1. Positioning technique for standing lateral X-ray of the spine and pelvis. X-rays were taken 72-inches from X-ray source (dashed arrows).

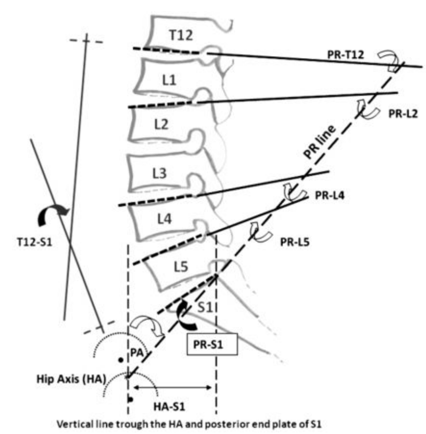


Figure 2. Line drawing showing pelvic radius (PR line) and the pelvic radius measurement technique used in this study. Nomenclature and descriptions are to be found in Table 1. Black dashed lines, vertical line trough HA and posterior superior corner of S1; gray lines, s T12-S1 measurement. Arrows indicate angles of representation.

Table 1. Nomenclature for parameters measured on standing lateral X-rays.

Measurement	Abbreviation	Description
Hip axis	HA	Midpoint between approximate centers of both femoral heads. The other parameters are measured from this point.
Pelvic radius	PR	Distance from the HA to the posterior superior corner of S1
Pelvic radius line	PR Line	Line connecting the HA and the posterior superior corner of S1
Pelvic morphology	PR-S1	Angular measurement between the PR line and a tangent line along the S1 endplate
Pelvic angle	PA	Angular measurement between the PR line and a vertical line draw through the HA
Sacral translation	HA-S1	Horizontal distance between the vertical line troughs HA
Total lumbosacral lordosis	T12-S1	Angular measurement between inferior endplate of T12 vertebral body and superior endplate of S1
Total lumbopelvic lordosis	PR-T12	Angular measurement from the PR line and a tangent line along the inferior endplate of T12 vertebral body
Regional lumbopelvic lordosis	PR-L2,PR-L4 PR-L5	Angular measurement from the PR line and a tangent lines along the superior endplate of L2, L4 and L5 respectively

From Chanplakorn *et al.*[11] Lumbopelvic alignment on standing X-ray of adult volunteers and the classification in the sagittal alignment of lumbar spine.

LPA is PR-S1 angle less than 35° and is correlated to the higher degree of lumbar lordosis. Type 2 LPA is the average PR-S1 angle between 35°and 45° in which the lumbar lordosis pattern is in the average between types 1 and 3 (Table 2). However, in that study, there is still a lack of information about the association between the LPA classification and some factors related to the LBP, in particular, age and body mass index (BMI). Thus, in this study we aim to determine the association between age, BMI and the new classification of LPA.

Regarding age, our results showed that none of the parameters described on the sacro-pelvic orientation or the lumbo-pelvic alignment (LPA) were correlated to age (Table 3). Furthermore, the LPA classification and age subgroups also were not statistically significant (Table 4). These findings confirmed that the saggital orientation of the pelvis remained constant in adults regardless of age, as pointed out in previous studies.[16-18] This observation was also confirmed in the recent study by Mac-Thiong *et al.* who found only a small correlation between pelvic orientation and age (correlation coefficient=0.03).[19] In study we could not demonstrate a significant correlation between LPA and age. In contrast, Vialle *et al.* observed a small correlation between age and global lumbar lordosis (correlation coefficient=0.14).[20] However, the age of the study population reported by Vialle *et al.* ranged from 20 to 70 years whereas in our study age ranged from twenty to fifty years. Thus, we believe that the difference between the 2 studies is due to the high variability in lumbar sagittal alignments, especially in older populations.

In contrast to age, the results from our present study indicated a difference in LPA between females and males (Table 4). In our results, the LPA type 1 illustrated by high PRS1 and low lumbar lordosis, was predominately found in males. This observation was comparable to the previous reports by Janssen *et al.*[21] and Vialle *et al.*[20] who both demonstrated the relatively vertical sacral inclination pattern in males. However, Janssen *et al.* reported no significant statistical difference in lumbar lordosis and sacro-pelvic paremeters which may be due to the great variability of the spinal alignment mentioned previously. On the contrary, Vialle *et al.* demonstrated a difference in global lumbar lordosis between genders, as females showed higher global lumbar lordosis than males. Our results demonstrated the higher prevalence of LPA type 2 and type 3 with lower PRS1 and relatively higher lumbar lordosis than LPA type 1 in females (Figure 3). These results confirm our conclusions. However, these observations are in contrast to those of Mac-Thiong *et al.* who report no significant difference in pelvic orientation between genders.[19]

The findings from the study of Mac-Thiong *et al.* are in contrast with the results from the study of Vialle *et al.* demonstrating the significant difference between male and female pelvic orientation using the same measurement methods and pelvic incidence technique. These conflicting results are due to the great variability in individual sagittal alignment. Therefore, these conflicting results from these studies confirm that LPA classification should be utilized to obtain a clearer understanding of lumbo-pelvic balance. Furthermore, we believe that the correlation study between genders and classification of the sacro-pelvic orientation is more useful than a direct comparison in order to determine the difference in the sacro-pelvic orientation between genders.

In this study, no significant correlation was found between BMI and any of the angular parameters described in sacro-pelvic alignments and lumbo pelvic alignments (Table 3). This result was similar to the previous report by Vialle *et al.*[20] Moreover, in this present study, a significant correlation between LPA classification and BMI was not demonstrated (Table 4). This is in contrast to some studies that revealed the association between standing postures,

Table 2. The characteristics and classification of the lumbar lordosis according to the PR-S1 angle.

Parameters	Low PR-S1 PR-S1 <35°	Average PR-S1 PR-S1 ~35-45 °	High PR-S1 PR-S1 >45 °
T12-S1	61.6±8.0	53.9±7.7	45.9±8.5
PR-L2	82.1±7.4	87.8±6.8	91.5±7.1
PR-L4	64.1±8.4	73.2±6.1	78.9±6.2
PR-L5	48.5±9.7	59.3±6.4	68.0±5.7

Data showed means value (in degree)±SD. T12-S1, Total lumbosacral lordosis.

Table 3. Correlation among pelvic and lumbar alignment parameters to the individual parameters.

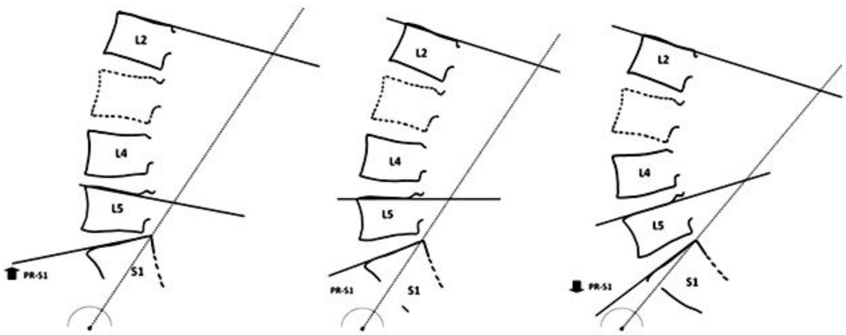
Parameter variables*	Age	BW	BMI
Pelvic alignments			
PR	-0.175 (0.082)	0.270 (0.007)°	0.033 (0.742)
PR-S1	0.090 (0.372)	0.006 (0.956)	-0.049 (0.632)
PA	0.104 (0.303)	-0.056 (0.579)	0.038 (0.711)
HA-S1	0.075 (0.457)	0.001 (0.994)	0.058 (0.568)
Lumbar alignments			
PR-T12	-0.046 (0.648)	0.006 (0.953)	-0.042 (0.679)
T12-S1	-0.099 (0.326)	0.000 (0.999)	0.015 (0.881)
PR-L2	-0.086 (0.397)	-0.115 (0.256)	-1.112 (0.269)
PR-L4	-0.060 (0.553)	-0.034 (0.734)	-0.086 (0.395)
PR-L5	0.106 (0.295)	0.051 (0.615)	0.003 (0.978)

Data shown by r value (P value) calculated from Pearson's correlation. *See Table 1 and Figure 1 for abbreviations and description of measurement. °Statistical significance. BMI, body mass index.

Table 4. Correlation among the lumbo-pelvic alignment type and the individual parameters.

	P*	LPA type 1 %	LPA type 2 %	LPA type 3 %
Gender	0.000°			
Male		27.1	40.0	32.8
Female		13.3	50.0	36.7
Age	0.361			
<30		21.2	42.4	36.4
30-40		17.0	46.8	36.2
>40		40.0	35.0	25.0
BMI	0.713			
<19		28.5	57.1	14.3
19-24.5		23.2	40.2	36.6
>24.5		18.2	54.5	27.3

Data showed the percentage of lumbo-pelvic alignment (LPA) type for the individual parameters.*calculated from χ^2 test. °Statistical significance. See Figure 2 for the illustration of each LPA type. BMI, body mass index.



	LPA type 1	LPA type 2	LPA type 3
Male	27.1%	40%	32.8%
Female	13.3%	50%	36.7%

Figure 3. Line drawing showing the lumbo-pelvic alignment (LPA) classification from our previous study and the prevalence of LPA type according to gender. Details of the LPA classification are to be found in Table 2.

sway and hyperlordotic postures in particular, and BMI.[10,21] However, in contrast to previous reports, in our study measurements were taken by standing X-rays. For this reason, results may not be comparable and intensive study is needed to clarify global spinal orientations.

Heuch *et al.*[6] performed a large population-based study and reported a higher prevalence of LBP among individuals with a higher BMI in both sexes, although there was a stronger association in women. Shiri *et al.*[7] performed a cross-sectional study in an obese population (mean BMI >25kg/m^2) and reported a lower prevalence of LBP in men while no association was found in women. Results from the 2 studies show that gender may affect the occurrence of LBP in obese populations. However, the mechanism underlying this is not yet clear.[6] The results from this present study demonstrated the difference in LPA types among males and females. It is possible that relative vertical sacral orientation and low lumbar lordosis in LPA type 1 may provide better biomechanical loading conditions, as the vertebral body withstands the vertical axial loads and protects the spine from the dorsally shear loads. This may reduce the occurrence of LBP in obese males.[22] However, further clarification is needed.

There are some limitations to our study. First, we only focused on pelvic radius measurement to illustrate the lumbar spine orientation, and only used standing lumbo-pelvic X-rays that represent only one aspect of global sagittal balance. Therefore, the important parameters described in global spinal balance, such as degree of thoracic kyphosis, C7 sagittal plumb line or sagittal vertical axis (SVA), may have been missed. Therefore, future studies should focus on the alteration in global sagittal alignment with changes in lumbo-pelvic orientation. Second, here we analyzed data from our previous study and added information regarding the LPA classification. In spite of this, the information we obtained in this study can be confirmed in the previous findings regarding lumbo-pelvic orientation. However, our study population was limited and large population based studies are needed.

Conclusions

Results from this study demonstrate the differences between lumbo-pelvic alignments between males and females, and also confirmed that the saggital orientation of the pelvis remained constant in adults regardless of age. Furthermore, no significant correlation was found between BMI and any of the angular parameters described in lumbo-pelvic alignments and its classification. In addition, the high prevalence of LPA type 1 in males may reduce the occurrence of LBP in obese males, as observed in previous studies. However, this hypothesis needs to be further clarified.

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