ORIGINAL ARTICLE
http://dx.doi.org/10.1590/S1808-185120222104262613
BASIC SCIENCES/OTHERS

IMPACT OF THE SITTING POSITION ON LUMBAR LORDOSIS AND ITS CORRELATION WITH PELVIC PARAMETERS

IMPACTO DA POSIÇÃO SENTADA NA LORDOSE LOMBAR E SUA CORRELAÇÃO COM PARÂMETROS PÉLVICOS

IMPACTO DE LA POSICIÓN SENTADA EN LA LORDOSIS LUMBAR Y SU CORRELACIÓN CON PARÁMETROS PÉLVICOS

Roberto Topolniak[1], Nelson Astur[1], William Zarza Santos[1], Rodrigo Goes Medéa de Mendonça[1], Alberto Ofenhejm Gotfryd[1], Maria Fernanda Silber Caffaro[1,2], Robert Meves[1,2]

1. Irmandade da Santa Casa de Misericórdia de São Paulo, Department of Orthopedics and Traumatology, São Paulo, SP, Brazil.
2. Faculdade de Ciências Médicas da Santa Casa de São Paulo, São Paulo, SP, Brazil.

ABSTRACT

Objective: To evaluateboth the correlation between lumbar accommodation and pelvic parametersin different types of lordosis and the participation of different lumbar segments in the accommodation of lordosis in the standing and sitting positions.Methods: A retrospective study analyzingpatient images in standing and sitting positions. Correlations were conducted among the measured data: Cobb angle of the lumbar lordosis (LL,type of lordosis, pelvic incidence (PI),sacral slope (SS),pelvic tilt (PT), and the angulation of the L1-L2/L2-L3/L3-L4/L4-L5/L5-S1 segments. Results: Fortypatients were included, 20 men and 20 women. The mean age was 60.8 (±11.5). Of these patients, 10.3% were classified as Roussouly type 2, 35.9% as type 3, 25.6% as type 3A, and 28.2%as type 4.There was a weakcorrelation between LL and PT, however, an inverse correlation between the two (r=-0.183 and p=0.264) was observed. SS hadthe strongest correlation with LL (r> 0.75). Only the correlation between LL and PI was stronger when sitting than standing (p=0.014). The pelvic parameters and angulations of the segments and lumbar discs when standing and sitting were different (p<0.05). In both positions, there was a difference in the contribution of the segments to the LL (p<0.001). On average, the differences in LL between standing and sitting wereequal among theRoussouly classifications (p=0.332). Conclusions: There was a correlation between the LL and the pelvic parameters, being more evident with the SS than with the other parameters. There was no difference in the accommodation of the LL in the different Roussouly types either standing or sitting. Regardless of the position,the L4-S1 segments were predominant in the composition of LL. ***Level of evidence IV; Retrospective.***

Keywords: Spine;Lordosis; Pelvis.

RESUMO

Objetivo: Avaliar a correlação entre a acomodação lombar eos parâmetros pélvicosem diferentes tipos de lordose coma participação dos seguimentos lombares na acomodação da lordose nas posições ortostáticae sentada. Métodos: Estudo retrospectivo de análise de imagens de pacientes em ortostasia e sentados. Foi realizada correlação entre os dados mensurados: ângulo de Cobb da lordose lombar (LL); tipo de lordose; incidência pélvica (IP); inclinação sacral (IS); versão pélvica (VP) e angulação dos seguimentos L1-L2, L2-L3/L3-L4/L4-L5, L5-S1. Resultados: Foram incluídos 40 pacientes, 20 homens e 20 mulheres. Média de idade 60,8 anos (±11,5). Desses pacientes, 10,3% foram classificados como tipo 2 de Roussouly, 35,9% como tipo 3, 25,6% como tipo 3A e 28,2% como tipo 4. Observou-se baixa correlação entreLL eVP que, no entanto, apresentou correlação inversa entre as duas (r=-0,183 e p=0,264). A IS apresentou maior correlação com a LL (r>0,75). Apenas a correlação da LL com IPfoi maior na posição sentadado que na ortostática (p=0,014). Os parâmetros pélvicos, as angulações dos seguimentos e discos lombares em ortostasia e sentado apresentaram diferença entre si (p<0,05). Em ambas as posições houve diferença na contribuição dos seguimentos na LL (p<0,001). As diferenças da LL entre ortostasia e sentado foram em média iguais entre as classificações de Roussouly (p=0,332). Conclusões: Houve correlação da LL com os parâmetros pélvicos, sendo mais evidente com a IS do que com os demais parâmetros. Não houve diferença na acomodação da LL nos diferentes tipos de Roussouly em ortostasia ou sentado. Independentementeda posição, L4-S1 são predominantes na composição da LL. ***Nível de Evidência IV; Estudo Retrospectivo.***

Descritores: *Coluna vertebral; Lordose; Pelve.*

RESUMEN

Objetivo: Evaluar la correlación entre la acomodación lumbar y los parámetros pélvicos en diferentes tipos de lordosis con la participación de los segmentos lumbares en la acomodación de la lordosis en posición ortostática y sentada. Métodos: Estudio retrospectivo de análisis de imágenes de pacientes en ortostasis y sentados. Se realizó la correlación entre los datos medidos: ángulo de Cobb de la lordosis lumbar (LL); tipo de lordosis; incidencia pélvica (IP); pendiente sacra (PS); versión pélvica (VP) y angulación de los segmentos L1-L2/L2-L3/L3-L4/

Study conducted by the Irmandade da Santa Casa de Misericórdia de São Paulo, São Paulo, Brazil.
Correspondence: Hospital Central da Santa Casa de Misericórdia de São Paulo, Departamento de Ortopedia e Traumatologia – Pavilhão Fernandinho Simonsen, Grupo de Cirurgia da Coluna. R. Dr. Cesário Mota Júnior, 112, Vila Buarque, São Paulo, SP, Brazil. 01221-010. roberto.topolniak@outlook.com

Received on 03/30/2022 accepted on 06/30/2022
Reviewed by: Alexandre Fogaça Cristante

L4-L5/L5-S1. Resultados: Se incluyeron 40 pacientes, 20 hombres y 20 mujeres. La edad media fue de 60,8 (±11,5). De estos pacientes, el 10,3% fueron clasificados como tipo 2 de Roussouly, el 35,9% tipo 3, el 25,6% tipo 3A y el 28,2% como tipo 4. Se observó baja correlación de LL con VP, que, sin embargo,presentó una correlación inversa entre ambas (r= -0,183 y p=0,264). La PSpresentó la mayor correlación con la LL (r> 0,75). Solo la correlación de la LL con IP fue mayor en la posición sentada que en la ortostática (p=0,014). Los parámetros pélvicos, las angulaciones de los segmentos y los discos lumbares en ortostasis y posición sentadapresentaron una diferenciaentre ellos (p<0,05). En ambas posiciones, hubo una diferencia en la contribución de los segmentos a la LL (p<0,001). Las diferencias de LL entre ortostasis y posición sentada fueron, en promedio, iguales entre las clasificaciones de Roussouly (p=0,332). Conclusiones: Hubo una correlación entre la LL y los parámetros pélvicos, siendo más evidente con la PS que con los demás parámetros. No hubo diferencia en la acomodación de la LL en los diferentes tipos de Roussouly en ortostasis o posición sentada. Independientemente de la posición, L4-S1 predominan en la composición de la LL. **Nivel de Evidencia IV; Estudio Retrospectivo.**

Descriptores: *Columna vertebral; Lordosis; Pelvis.*

INTRODUCTION

Sagittal curvatures of the spine have been described since Hippocrates (400 BC),[1]and the terms lordosis and kyphosis were first used by Galen.[2]Spinal curves have been studied until the present day and we have observed the evolution of knowledge on this topic, which has culminated in the 21st century with the concepts of sagittal balance and the spinopelvic complex.[3-5]Pelvic and spinal parameters have been considered in the evaluation of the spine and determine the principles of treatment used to treat disease of the spine.[6]

The association between lumbar lordosis and pelvic parameters and its relationship with the hip was first described by During.[5]Legaye et al.[7] described the angles with better clarity and proposed the mathematical relationship between pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) as PI = PT + SS. They also presented the association between pelvic incidence and lumbar lordosis by correlating pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) with lumbar lordosis (Figure 1),[8,9]thus expanding the original concept.[5,10,11]

Lumbar lordosis is subdivided into anatomical and functional lordosis. Anatomical lumbar lordosis is described as the angle formed by the upper surfaces of L1 and S1. Functional lordosis is described by several geometric methods (circular arc, elliptical quadrant). The term distal lordosis was proposed to express functional lordosis to avoid confusion around the description.[5,12,13]

Berthonnaud[14] described a mathematical design for functional lumbar lordosis using the inflection point where the lordosis changes to kyphosis without using any specific anatomical reference. Lordosis is formed by two arcs: the upper and the lower. The lower arc is located between the horizontal line that passes through the apex of the lordosis and the endplate of S1. The upper arcis formed by the horizontal line that passes through the apex of the lordosis and the line perpendicular to the tangent of the inflection point (Figure 2).[5]

The lower arc or distal lordosis, or “distal spinal lordosis” according to Roussouly, has a value equal to the sacral slope (SS) in normal individuals. Pelvic incidence varies according to the sacral slope (SS), so there is a correlation between pelvic incidence and the lower lumbar lordosis arc. Based on the definition of the inflection point, the location of the apex of the lordosis, and the description of the lower arc, a classification for lumbar lordosis was proposed, whichconsidersnot only the angle of the lordosis, but also its distribution. Four types of lordosis have been defined (Figure 3).[5,15-17]

Type 1- Characterized by a low sacral slope (SS) value <35 degrees with the apex of the lordosis in the center of L5. The point of inflection is low and posterior and does not extend beyond the L2-L3 level. The lordosis is short.

Type 2- Characterized by a low sacral slope (SS) value <35 degrees with the apex at the base of the body of L4. The inflection point is higher and anterior. The lordosis is more extensive and flatter.

Type 3- Characterized by sacral slope values between 35 and 45 degrees with the apex at the upper partof L4 or the L3-L4 disc. The inflection point is in the thoracolumbar region and the curve is well-distributed.

Type 4- Characterized by a high sacral slope (SS) value >45 degrees with the apex of the lordosis at the base of L3.The number of lordotic vertebraeis greater than or equal to five.

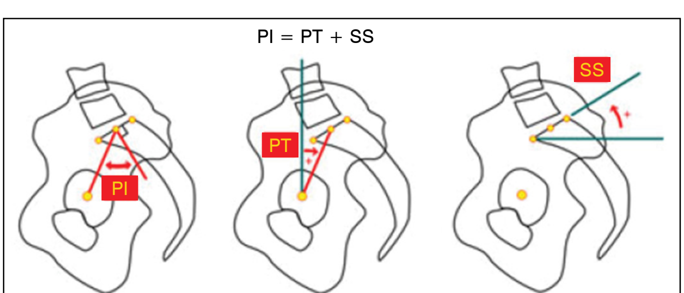

Figure 1. Pelvic parameters: pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS).[9]

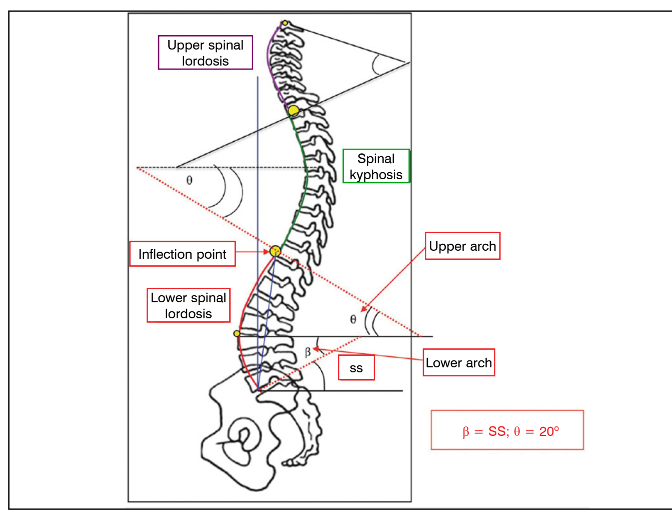

Figure 2. Representation of the spinal curves according to Berthonnaud’s inflection point.[5]

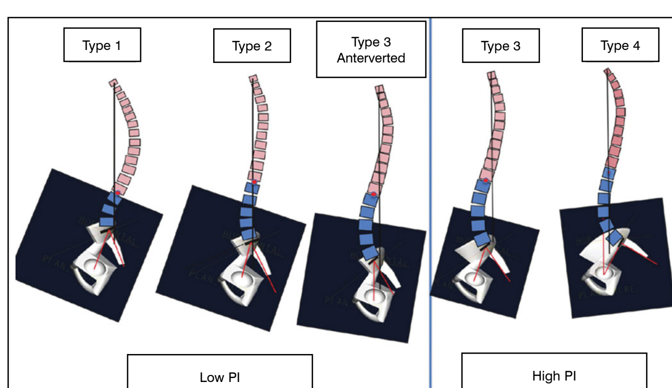

Figure 3. Types of lumbar lordosis according to the Roussouly classification.[18,19]

Types 1 and 2 have a low pelvic incidence (PI) value <50 degrees and types 3 and 4 have higher pelvic incidence (PI) values >50 degrees. There is a variant of type 3 that may present sacral slope (SS) between 35 and 45 degrees with pelvic tilt (PT) <5 degrees, called type 3 with anteversion (Figure 3).[18,19]

The pelvic parameters (pelvic incidence, pelvic tilt, and sacral slope) have a geometric correlation (PI=PT+SS). Pelvic incidence is a morphological parameter and does not change with the position of the pelvis. Pelvic tilt and sacral slope (SS) are parameters that are influenced by the position of the pelvis and reflect changes in their values according to the positioning of the pelvis. Pelvic anteversion decreases sacral slope and increases pelvic tilt.[20,21]Pelvic retroversion decreases sacral slope and increases pelvic tilt to accommodate the loss of lordosis. This ability to adapt is more pronounced in individuals who have higher pelvic incidence (Figure4).[22–25]

When standing or sitting there is a change in the functional pelvic parameters (pelvic tilt and sacral slope), while pelvic incidence remains constant as it is an anatomical parameter. Lumbar lordosis is related to the sacral slope and presents changes in its values in the standing and sitting positions (Figure 5).[26-29]

Sagittal balance is related to the spinal and spinopelvic complex parameters, creating a constellation of interactions throughout this complex. Lumbar lordosis is one of the elements of foremost importancein the spinopelvic complex and in the sagittal balance of the spine. The relationship between lumbar lordosis and the anatomical or functional pelvic parameters, the positioning of the pelvis, and the articulation of the hip has been studied and there is sufficient evidence of the interaction of lumbar lordosis with the pelvic parameters and the sagittal balance of the spine through its flexibility.[5,31–34]

The objective of this study was to evaluate the correlation between lumbar accommodation and the pelvic parameters, the correlation between lumbar accommodation and the different types of lordosis, and how the different segments of the lumbar spine participate in the degree of lordotic accommodation between the standing and sitting positions.

METHODS

This is a retrospective, analytic study of radiographic images. We collected data from patients scheduled for total hip arthroplasty surgery and treated at a referral hospital in the state of São Paulo from 2010 to 2019. Convenience sampling was conducted, including all patients who met the inclusion and exclusion criteria, that is, patients of both sexes who had adequate image records were included and patients with previous hip or spine surgery were excluded. The study was approved by the Institutional Review Board (CAAE: 38124820.2.0000.5479).

The radiographs were taken preoperatively in the standing and sitting positions according to the protocol of the orthopedic service of the hospital for patients undergoing hip arthroplasty. The radiographic parameters evaluated werethe Cobb angle of the anatomical lumbar lordosis (L1-S1), lower lordosis (upper arc, lower arc, apex), type of lordosis (Roussouly classification), pelvic incidence, sacral slope, pelvic tilt, and the angulation of the L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 segments. Surgimap® software (Nemaris Inc.™, New York, US), validated as a tool for this type of measurement, was used to measure the parameters.[35]

Patient demographic data were described as summary measurements (mean, standard deviation, median, minimum, and maximum) for age and as absolute and relative frequencies for the qualitative variables.[36]

All the parameters evaluated were described according to the position assessed using summary measurements and compared between the positions using paired Student's t tests.[36]The Pearson's correlation between the lumbar lordosis and the radiographic measurements of each position evaluated was calculated and the correlations between the positions were compared.[37]The relative angular values of each level and lumbar disc were calculated, described, and compared between measurements using generalized estimating equations (GEE) with normal marginal distribution and identity link function, assuming an exchangeable correlation matrix between the measurements of the same individual.[38]The results were followed by multiple Bonferroni comparisons to identify what the angle and the intradiscal distances contributed to the respective totals.[37]The differences in lumbar lordosis between the positions (standing – sitting) were calculated, and the differences were described according to Roussouly's classification, and the differencesbetween the classifications were compared using analysis of variances (ANOVA).[37]

The analyses were performed using IBM-SPSS for Windows version 20.0 software and tabulated using Microsoft-Excel 2003 software. The tests were conducted with a significance level of 5%.

RESULTS

A total of 40 patients, 20 male (50%) and 20 female (50%), were included in the data analysis. The mean age was 60.8 (±11.5) years. Of these patients, 4(10.3%) were classified as Roussouly type 2, 14 (35.9%) as type 3, 10 (25.6%) as type 3A, and 11 (28.2%) as type 4 (Table 1).

In Table 2, we can see that the correlation between lumbar lordosis and pelvic tilt was weak in both positions and statistically nonsignificant in the sitting position ($r= -0.183$ and $p= 0.264$). It was also the only parameter that had an inverse correlation with lumbar lordosis, that is, the higher the pelvic tilt, the lower the lumbar lordosis and vice-versa. Sacral slope was the parameter that presented the strongest direct correlation with lumbar lordosis in both positions ($r > 0.75$) in the comparison between standing and sitting. Only the correlation between lumbar lordosis and pelvic incidence was statistically stronger in the sitting than in the standing position ($p = 0.014$).

When we compared the parameters PT, PI, SS of segments L1-L2, L2-L3, L3-L4, L4-L5,and L5-S1 measured in the standing and sitting positions, we observed that most presented a statistically significant mean difference ($p<0.05$), all values being higher when standing than sitting, the only exception being PT in the sitting position, which on average was higher (Table 3).

Table 4 shows that in both positions there was a statistically significant mean difference between the contribution of the segments to lumbar lordosis ($p < 0.001$) and between the disc angulations in each position. The mean differences were also statistically significant($p < 0.001$). Table 5 shows that the mean differences betweenstanding and sitting LL were statistically equal among the Roussouly classifications of the patients ($p = 0.332$).

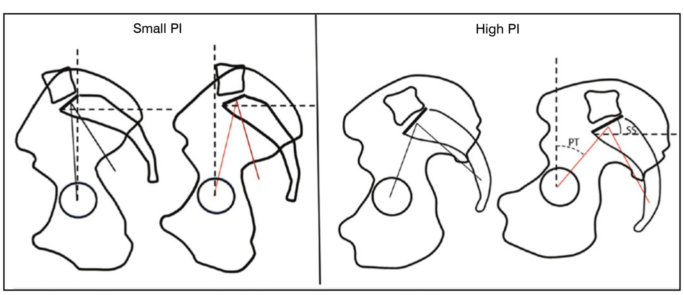

Figure 4. Drawings illustrating the greater adaptation ability of the pelvis in individuals with higher pelvic incidence (PI).[8]

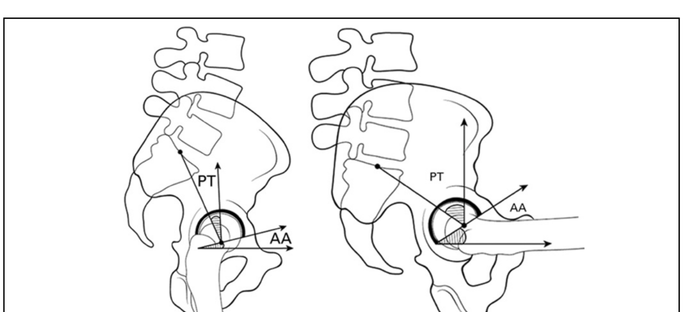

Figure 5. Illustration of the pelvis in the standing (left) and sitting (right) positions.[30]

Table 1. Description of the demographic characteristics of the patients and the Roussouly classification.

Variable	Description (N = 40)
Age (years)	
mean ± SD	60.8 ± 11.5
median (min., max.)	61.5 (28, 81)
Sex, n (%)	
Male	20 (50)
Female	20 (50)
ROUSSOULY, n (%)	
2	4 (10.3)
3	14 (35.9)
3A	10 (25.6)
4	11 (28.2)

Table 2. Results of the correlation of lumbar lordosis and the radiographic parameters of interest by position and the results of the comparisons of the correlations between positions.

Variable	Standing			Sitting			p*
	Correlation	N	p	Correlation	N	p	
PT	-0.354	40	0.025	-0.183	39	0.264	0.215
PI	0.275	40	0.086	0.664	39	<0.001	0.014
SS	0.751	40	<0.001	0.853	39	<0.001	0.106

p - Test of significance of the correlation different than zero * - Test of the comparison of correlations.

DISCUSSION

In this study, we evaluated a homogeneous sample, evenly distributed between the sexes. Individuals with Roussouly types 3 and 3A lumbar lordosis made up a greater proportion, which is in agreement with the frequency encountered in previous studies.[39]We observed a higher frequency of type 3A (25.6%) than that described in the literature, but justifiable as the population studied was composed of patients with osteoarthritis of the hip, who may present hip flexion contracture, described as hip spine syndrome.[18]In Table 3, the comparison of the pelvic tilt and sacral slope parameters showed statistically significant differences between the standing and sitting positions. The same did not occur with pelvic incidence, because, as expected, it is an anatomical parameter that should not vary, regardless of the individual's position.[7]

We observed that most of the angulations, whether of the segments or the intervertebral discs, presented variations according to the position in which they were measured. All the parameters evaluated were greater with the patients standing than when sitting, except formean pelvic tilt, which was greater when seated and consistent with the compensatory mechanism which occurs: flexion of the hip with retroversion of the pelvis, an increase in pelvic tilt, a decrease in sacral slope, and a decrease in lumbar lordosis in the sitting position.[30]

Understanding that lumbar lordosis accommodation is related to pelvic incidence, pelvic tilt, and sacral slope, we can demonstrate these findings in our sample (Table 2). The greater the sacral slope, the greater the slope of L5 and, consequently, of the upper levels, tends to be. Therefore, the slope of the L5-S1 disc is directly related to the pelvic incidence and the lordosis.

The higher the pelvic incidence, the greater the sacral slope and the lumbar lordosis.[8]Table 2 shows that sacral slope had a stronger direct correlation with lumbar lordosis, both in the sitting and standing positions, than pelvic incidence, corroborating the findings of other authors.[18]

Pelvic tilt was weakly correlated with lumbar lordosis in both positions. However, it presented an inverse correlation with lumbar lordosis. This result can be explained by observing the pelvic incidence formula, expressed by the geometric equation PI=SS+PT. Therefore, the greater the pelvic tilt, the smaller the sacral slope.

Table 3. Description of the parameters evaluated by position and the results of the comparison between positions.

Variable	Position		p
	Standing	Sitting	
PT			**<0.001**
mean ± SD	13.7 ± 10.6	47 ± 13.5	
median (min.,max.)	14 (-7.8, 41.1)	46 (19.3, 81.5)	
PI			**0.069**
mean ± SD	56.7 ± 12	59.4 ± 15.9	
median (min.,max.)	54.8 (34.4, 80.5)	57.2 (32.8, 99.3)	
SS			**<0.001**
mean ± SD	44.1 ± 9	13.9 ± 12.8	
median (min.,max.)	44 (24.1, 63.1)	11.2 (-6.2, 41.4)	
LL: L1-S1			**<0.001**
mean ± SD	58.6 ± 16.9	23.5 ± 16.8	
median (min.,max.)	59.7 (-11.1, 83.9)	23.2 (-6.7, 65.4)	
COBB L1-L2			**0.214**
mean ± SD	5.6 ± 3.8	4.6 ± 3.4	
median (min.,max.)	5.1 (0.6, 14.5)	4.2 (0, 14.5)	
COBB L2-L3			**<0.001**
mean ± SD	11.1 ± 4.9	5 ± 5.3	
median (min.,max.)	10.8 (1.7, 26.5)	3.2 (0, 20.8)	
COBB L3-L4			**<0.001**
mean ± SD	15 ± 6.9	6.6 ± 6.2	
median (min.,max.)	15.3 (1.1, 30.5)	5.3 (0.7, 24.7)	
COBB L4-L5			**<0.001**
mean ± SD	23.2 ± 5.9	13.3 ± 7.5	
median (min.,max.)	24 (9.2, 33.5)	13.6 (0, 34.8)	
COBB L5-S1			**0.001**
mean ± SD	23.3 ± 8	18.4 ± 7.8	
median (min.,max.)	23.6 (4, 44)	17 (4.3, 43)	
D L1-L2			**<0.001**
mean ± SD	5.1 ± 2.8	2.1 ± 1.6	
median (min.,max.)	5.1 (0.7, 10.6)	1.7 (0, 5)	
D L2-L3			**<0.001**
mean ± SD	7.7 ± 3.3	2.9 ± 2.7	
median (min.,max.)	8.4 (1.2, 14.4)	2.1 (0, 12.2)	
D L3-L4			**<0.001**
mean ± SD	8.8 ± 3.5	3 ± 2.8	
median (min.,max.)	9.8 (1.2, 15.4)	2.9 (0, 10.7)	
D L4-L5			**<0.001**
mean ± SD	10.7 ± 4.6	3.6 ± 3.3	
median (min.,max.)	11 (2.4, 20.2)	2.6 (0, 12.9)	
D L5-S1			**0.004**
mean ± SD	14 ± 6.7	9.9 ± 5.8	
median (min.,max.)	13.4 (1.7, 29.2)	8 (3, 24.1)	

Paired Student's t test.

In other words, when the sacral slope approaches zero, pelvic tilt tends to be equal to pelvic incidence, thus explaining the inverse correlation with lumbar lordosis.[22-25]

When comparing the correlations in the standing and sitting positions, only the correlation of lumbar lordosis with pelvic incidence was statistically stronger when seated than in the standing position, since patients with higher pelvic incidence have a compensatory mechanism. According to the description by Le Huec,[9]the pelvis can rotate around the femoral heads, following the hip axis. When the pelvis performs a retroversion, the pelvic tilt parameter increases. When the pelvis performs an anteversion, pelvic tilt decreases. Pelvic tilt and sacral slope are positional parameters. The possibility of the pelvis rotating around the axis of the femoral heads is a critical mechanism for the regulation ofsagittal balance.[9]

Table 4. Description of the relative contribution of the vertebral segments to lumbar lordosis and of the disc angulations in each position and the results of the comparison between the parts.

Variable	Standing	p	Sitting	p
COBB L1-L2 (%)		**<0.001**		**<0.001**
mean ± SD	7.1 ± 4.4		12.8 ± 16.2	
median (min.,max.)	6.7 (0.6, 16.4)		8.7 (0, 100)	
COBB L2-L3 (%)				
mean ± SD	14 ± 5.3		10.3 ± 9.3	
median (min.,max.)	13.8 (3, 30)		8.3 (0, 46)	
COBB L3-L4 (%)				
mean ± SD	18.6 ± 6.8		12.6 ± 8.6	
median (min.,max.)	18.7 (2.1, 34.3)		12.9 (1.1, 32.2)	
COBB L4-L5 (%)				
mean ± SD	29.9 ± 6.5		26.2 ± 10.9	
median (min.,max.)	29.8 (18, 43.7)		27.7 (0, 46.6)	
COBB L5-S1 (%)				
mean ± SD	30.4 ± 9.9		40.1 ± 13.5	
median (min.,max.)	30.8 (5.9, 52.4)		40.8 (16.2, 64.4)	
D L1-L2 (%)		<0.001		<0.001
mean ± SD	10.6 ± 6.2		9.4 ± 6.9	
median (min.,max.)	10.4 (1.8, 32.5)		8 (0, 27.3)	
D L2-L3 (%)				
mean ± SD	15.5 ± 6.3		12.5 ± 10	
median (min.,max.)	15 (4.6, 30.1)		10.4 (0, 42.4)	
D L3-L4 (%)				
mean ± SD	17.8 ± 6.5		11.9 ± 10.9	
median (min.,max.)	18.2 (4.4, 29.5)		9.8 (0, 39.2)	
D L4-L5 (%)				
mean ± SD	21.2 ± 7.9		14.7 ± 11.7	
median (min.,max.)	20.4 (7.8, 45.2)		11.6 (0, 55.1)	
D L5-S1 (%)				
mean ± SD	28.2 ± 11.7		40.4 ± 14.5	
median (min.,max.)	28.3 (3.7, 51.8)		38.8 (12.8, 66.8)	

GEE with normal distribution and identity link function, assuming exchangeable correlations between the locations

Table 5. Description of the differences between lumbar lordosis in the standing and sitting positions according to the Roussouly classification and the results of the comparison between the categories.

Variable	ROUSSOULY				Total	p
	2	3	3A	4		
Difference in LL (Standing - Sitting)						0.332
mean ± SD	33.8 ± 21.6	31.1 ± 20	44.3 ± 12.2	35.9 ± 15.5	36.1 ± 17.3	
median (min., max.)	33.8 (12.1, 55.7)	36.9 (-3, 62.8)	45.5 (23.4, 67.5)	39.6 (17.4, 57.8)	41.5 (-3, 67.5)	

ANOVA

When we evaluated the contribution that each vertebral segment and each intervertebral disc makes towards the composition of lordosis (Table 4), we realized that the lower levels, L4-L5 and L5-S1, as well as their discs, correspond to approximately 60% of lordosis,[40-42] demonstrating that, even with a change in position, the lower levels are fundamental for the maintenance of lumbar lordosis.

When we compared the changes in lumbar lordosis according to Roussouly's[17] morphological classification of types, there was no difference among the types, with the difference between standing and sitting positions being similar for the different types.

CONCLUSIONS

This study demonstrated that there is a correlation between lumbar lordosis and the pelvic parameters, being more evident inthe sacral slope than in the other parameters. There was no difference in the accommodation of lumbar lordosis among the Roussouly morphological types in the standing and sitting positions. We also showed that, regardlessof the position, the L4-S1 levels are predominant in the composition of lumbar lordosis.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: Each author made significant individual contributions to this manuscript. RT and NA: study design, data collection, writing, creation of the research project; WZS: discussion of the results, review, and approval of the final version of the work; RGMM: discussion of the results, review, and approval of the final version of the work; AOG: discussion of the results, review, and approval of the final version of the work; MFSC: discussion of the results, review, and approval of the final version of the work; RM: study design,discussion of the results, review, and approval of the final version of the work.

REFERENCES

1. Breasted JH, University of Chicago. Oriental Institute. The Edwin Smith surgical papyrus, published in facsimile and hieroglyphic transliteration with translation and commentary in two volumes. 1930 [Acesso em: Mar 2022].Disponível em: https://oi.uchicago.edu/research/publications/oip/edwin-smith-surgical-papyrus-volume-2-facsimile-plates-and-line-line
2. Galen Siegel RE. Galen on the affected parts. Translation from the Greek text with explanatory notes [Internet]. 1976 [Acesso em: Mar 2022]. p. 233. Disponível em: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1081972/?page=1.
3. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparativestudyabout 85 cases. EurSpine J. 2007;16(9):1459-67.
4. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age5 sex, and size:A prospective controlled clinical study. Spine. 1994;19(14):1611-8.
5. Roussouly P, Nnadi C, Labelle H, Gehrchen M. Sagittal balance of the spine. 1st ed. New York: Thieme; 2019. 243 p.
6. Lafage R, Ferrero E, Henry JK, Challier V, Diebo B, Liabaud B, et al. Validation of a new computer-assisted tool to measure spino-pelvic parameters. Spine. 2015;15(12):2493-502.
7. Legaye J, Duval-Beaupère G, Hecquet J, Marty C. Pelvic incidence: A fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. EurSpine J. 1998;7(2):99-103.
8. Duval-Beaupère G, Legaye J. Sagittal component of the static spineRev du Rhum (Ed Fr). 2004;71(2):105-19.[Accesoem:Abr 2020]. Disponívelem: https://linkinghub.elsevier.com/retrieve/pii/S1169833003005817.
9. le Huec JC, Aunoble S, Philippe L, Nicolas P. Pelvic parameters: origin and significance. Eur Spine J. 2011;20(Suppl 5):564-71.
10. Barrey C, Roussouly P, Le Huec JC, D'Acunzi G, Perrin G. Compensatory mechanisms contributing to keep the sagittal balance of the spine. Eur Spine J. 2013;22(Suppl6):834-41.
11. Barrey C, Roussouly P, Perrin G, Le Huec JC. Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms?.Eur Spine J. 2011;20(Suppl5):626-33.
12. Kobayashi T, Atsuta Y, Matsuno T, Takeda N. A Longitudinal Study of Congruent Sagittal Spinal Alignment in an Adult Cohort. Spine. 2004;29(6):671-6.
13. LazennecJY, Brusson A, Rousseau MA. Lumbar-pelvic-femoral balance on sitting and standing lateral radiographs. OTSR. 2013;99(Suppl 1):S87-103.
14. Berthonnaud E, Dimnet J, Roussouly P, Labelle H. Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. J Spinal Disord Tech. 2005;18(1):40-7.
15. Roussouly P, Gollogly S, Noseda O, Berthonnaud E, Dimnet J. The vertical projection of the sum of the ground reactive forces of a standing patient is not the same as the C7 plumb line: A radiographic study of the sagittal alignment of 153 asymptomatic volunteers. Spine. 2006;31(11):E320-5.
16. Roussouly P, Nnadi C. Sagittal plane deformity: An overview of interpretation and management. Eur Spine J. 2010;19(11):1824-36.
17. Roussouly P, Berthonnaud E, Dimnet J. Analysegéométrique et mécanique de la lordoselombaire dans une population de 160 adultesasymptomatiques: Essai de classification. RevChirOrthopReparatriceApparMot. 2003;89(7):632-9. [Acesso em:Abr 2020]. Disponível em: https://www.em-consulte.com/en/article/147604.
18. Laouissat F, Sebaaly A, Gehrchen M, Roussouly P. Classification of normal sagittal spine alignment: refounding the Roussouly classification. EurSpine J. 2018;27(8):2002-11.
19. Roussouly P, Nnadi C, Labelle H, Gehrchen M. Sagital balance of the spine. 1st ed. New York: Thieme; 2019. 243 p.
20. Ben-Galim P, Ben-Galim T, Rand N, Haim A, Hipp J, Dekel S, et al. Hip-spine syndrome: The effect of total hip replacement surgery on low back pain in severe osteoarthritis of the hip. Spine. 2007;32(19):2099-102. [Acessoem:Abr 2020]. Disponível em: http://journals.lww.com/00007632-200709010-00011.
21. Obeid I, Hauger O, Aunoble S, Bourghli A, Pellet N, Vital JM. Global analysis of sagittal spinal

alignment in major deformities: correlation between lack of lumbar lordosis and flexion of the knee. EurSpine J. 2011;20(Suppl 5):681-5. [Acesso em:Abr 2020]. Disponível em: http://link.springer.com/10.1007/s00586-011-1936-x.
22. Morvan G, Mathieu P, Vuillemin V, Guerini H, Bossard P, Zeitoun F, et al. Standardized way for imaging of the sagittal spinal balance. Eur Spine J. 2011;20(Suppl 5):602-8.
23. WengWJ, Wang WJ, Wu M Da, Xu ZH, Xu LL, Qiu Y. Characteristics of sagittal spine–pelvis–leg alignment in patients with severe hip osteoarthritis. Eur Spine J. 2015;24(6):1228-36.
24. Weng W, Wu H, Wu M, Zhu Y, Qiu Y, Wang W. The effect of total hip arthroplasty on sagittal spinal–pelvic–leg alignment and low back pain in patients with severe hip osteoarthritis. Eur Spine J. 2016;25(11):3608-14.
25. Zhu J, Wan Z, Dorr LD. Quantification of pelvic tilt in total hip arthroplasty. ClinOrthopRelat Res.2010;468(2):571-5.
26. Buckland AJ, Vigdorchik J, Schwab FJ, ErricoTJ, Lafage R, Ames C, et al. Acetabular Anteversion Changes Due to Spinal Deformity Correction: Bridging the Gap between Hip and Spine Surgeons. J Bone Joint Surg Am. 2014;97(23):1913-20.
27. Kanawade V, Dorr LD, Wan Z. Predictability of acetabular component angular change with postural shift from standing to sitting position. J Bone Joint Surg Am. 2014;96(12):978-86.
28. Lazennec JY, Riwan A, Gravez F, Rousseau MA, Mora N, Gorin M, et al. Hip Spine Relationships: Application to Total Hip Arthroplasty. HIP International. 2007;17(Suppl 5):91-104.
29. Lazennec JY, Boyer P, Gorin M, Catonné Y, Rousseau MA. Acetabular anteversion with CT in supine, simulated standing, and sitting positions in a THA patient population. ClinOrthopRelat Res. 2011;469(4):1103-9.
30. Phan D, Bederman SS, Schwarzkopf R. The influence of sagittal spinal deformity on anteversion of the acetabular component in total hip arthroplasty. BJJ. 2015;97-B(8):1017-23. [Acesso em:Abr 2020]. Disponível em: http://online.boneandjoint.org.uk/doi/10.1302/0301-620X.97B8.35700.
31. BabischJW, Layher F, Amiot LP. The rationale for tilt-adjusted acetabular cup navigation. J Bone JtSurg- Series A. 2008;90(2):357-65.
32. Day LM, DelSole EM, Beaubrun BM, Zhou PL, Moon JY, Tishelman JC, et al. Radiological severity of hip osteoarthritis in patients with adult spinal deformity: the effect on spinopelvic and lower extremity compensatory mechanisms. EurSpine J. 2018;27(9):2294-302.
33. Phan D, Bederman SS, Schwarzkopf R. The influence of sagittal spinal deformity on anteversion of the acetabular component in total hip arthroplasty. BJJ. 2015;97-B(8):1017-23.
34. Van Royen BJ, Toussaint HM, Kingma I, Bot SDM, Caspers M, Harlaar J, et al. Accuracy of the sagittal vertical axis in a standing lateral radiograph as a measurement of balance in spinal deformities. EurSpine J. 1998;7(5):408-12.
35. Lafage R, Ferrero E, Henry JK, Challier V, Diebo B, Liabaud B, et al. Validation of a new computer-assisted tool to measure spino-pelvic parameters.Spine. 2015;15(12):2493-502.
36. Kirkwood BR, Sterne JAC, Kirkwood BR. Essential medical statistics. 2nd ed. Massachusetts: Blackwell Science; 2003. 501 p.
37. Neter J, Kutner MH, Nachtsheim CJ, Wasserman W. Applied linear statistical models. 4th ed. Ilinois: Irwin; 1996. 720 p.
38. McCullagh P, Nelder JA. Generalized linear models. 2nd ed. New York: Chapman and Hall; 1989. 511 p.
39. Bassani T, Galbusera F, Luca A, Lovi A, Gallazzi E, Brayda-Bruno M. Physiological variations in the sagittal spine alignment in an asymptomatic elderly population. Spine. 2019;19(11):1840-9.
40. Damasceno LHF, CatarinSRG, Campos AD, Defino HLA. Lordose lombar: estudo dos valores angulares e da participação dos corpos vertebrais e discos intervertebrais. ActaOrtop Bras. 2006;14(4):193-8.
41. Korovessis P, Stamatakis M, Baikousis A. Segmental roentgenographic analysis of vertebral inclination on sagittal plane in asymptomatic versus chronic low back pain patients. J Spinal Disord. 1999;12(2):131-7.
42. Bernhardt M, BridwellKH. Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. Spine. 1989;14(7):717-21.