Thoracic Kyphosis and Lumbar Lordosis Assessment by Radiography and Photogrammetry: A Review of Normative Values and Reliability

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Abstract

Objective: The purpose of this study was to review referential values for thoracic kyphosis and lumbar lordosis for radiography and photogrammetry analysis and search for information about the interrater and intrarater reliability.
Methods: The databases PubMed/Medline and LILACS were searched using the following keywords: radiograph and posture, postural alignment, and photogrammetry or photometry or biophotogrammetry. Studies containing values of thoracic kyphosis and lumbar lordosis or a reliability test assessed by radiography and photogrammetry were selected. Random numbers were generated in MATLAB from each study individually to establish normative values for the thoracic kyphosis and lumbar lordosis for both methods. After that, frequencies (median, first quartile, and third quartile) were obtained in SPSS 20.0 (IBM Corp, Armonk, New York).
Results: Twenty-six articles were selected, of which 23 studies contained values for thoracic kyphosis and lumbar lordosis and 10 tested the intra- and interrater reliability of both methods. For the studies with radiography that calculated the angle by the same method of assessment, the mean was 44.07° (4.75) for L1 to L5 and 58.01° (5.75) for L1 to S1, and for T1 to T12 the mean was 48.33° (6.24). Most studies used the intraclass correlation coefficient test, showing strong reliability.
Conclusion: No concordance among the results for both methods was shown. Also, it was not possible to perform the same procedure with the photogrammetry studies because of the great discrepancy in procedures and angle calculations. To assess the reliability, it is necessary to use the proper statistical test. (J Manipulative Physiol Ther 2018;41:712-723)
Key Indexing Terms: *Kyphosis; Lordosis; Photogrammetry; Radiography*

Introduction

In the sagittal plane, the thoracic kyphosis and lumbar lordosis angles can be measured through several methods, among them radiography and photogrammetry.[1,2]

Radiography is considered the gold-standard method[3-5]; however, this method is expensive and exposes the individual to ionizing radiation, making it impossible to evaluate periodically.[6-8] On the other hand, photogrammetry is a noninvasive method that enables quantification of the angles of the human body without any harm, providing an effective postural assessment.[9-11] Studies have been developed with both methods with the intention of detecting a normal curvature of thoracic kyphosis and lumbar lordosis.[12-14] However, there is an absence of consensus in the literature about the angle able to classify a normal pattern of spine curvature. Thus, some studies are testing the reliability of the aforementioned methods, and it is necessary to verify the findings of these studies and whether these methods are reliable or not.

Studies performed using radiography have presented different values of normality for thoracic kyphosis and lumbar lordosis measurements. In the 1960s to 1980s, several authors established values between 20° and 40° for thoracic kyphosis and 40° and 60° for lumbar lordosis.[15-18] However, Jackson and McManus[19] analyzed 100 asymptomatic adult volunteers and found a mean value of 42.1° (±8.9) varying from 22° to 68° for thoracic kyphosis and 60.9° (±12.0) varying from 31° to 88° for lumbar lordosis. In contrast, Macagno and O'Brien[20] defined a normal range for thoracic kyphosis as 10° to 40° and for lumbar lordosis as 30° to 80°, stating that these values may vary with age, sex, and pathological conditions. As seen, there is not a precise consensus to diagnose spine deviation using the radiographic method, which can be misleading during the assessment and result in absent or less effective treatment.

On the other hand, photogrammetry evaluates the spine without exposing the individual to radiation, allowing

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Paper submitted August 24, 2017; accepted March 23, 2018.
0161-4754

https://doi.org/10.1016/j.jmpt.2018.03.003

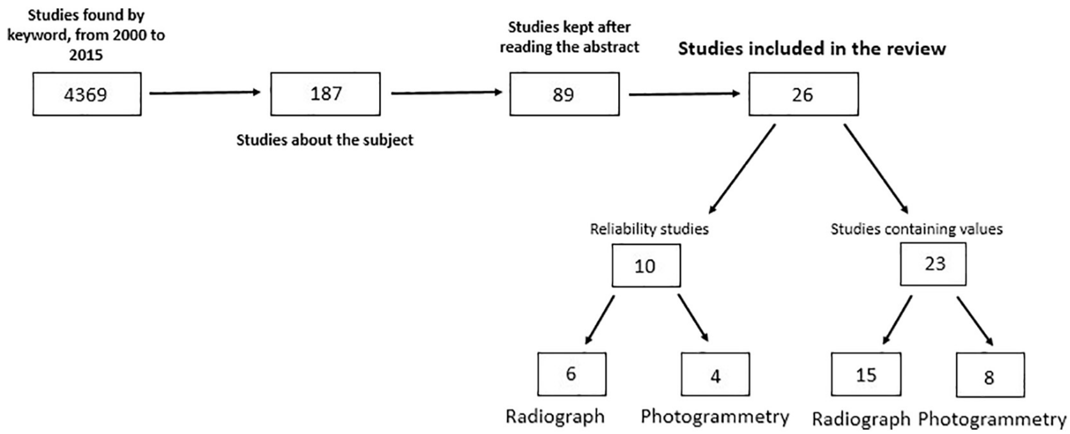

Fig 1. *Flowchart of the article selection.*

assessment of the treatment periodically.[21,22] In addition, photogrammetry is a simple and noninvasive method with low cost and high accuracy.[23] However, the studies involving photogrammetry for evaluation of postural alignment assess different populations and sex comparisons,[24,25] different shoes,[26,27] and athletes.[5] Furthermore, normative values of the thoracic kyphosis and lumbar lordosis angles are not evident in the literature. Thus, the divergence of a reference value for radiography and the absence of values for photogrammetry may lead to an incorrect deviation diagnosis, making it important to reach a consensus on such measures.

Lastly, some studies analyzed the reliability of both methods[28-30]; however, little is known about whether they generally demonstrate reliability, either in inter- or intrarater assessment. This kind of assessment is important to establish whether the measurement tool or method used represents reliable values between different examiners or between different measures of the same examiner.[31,32] When assessing the spine using radiography, the most common way to calculate the angles is by the Cobb method, drawing perpendicular lines from the endplate of predetermined vertebrae. However, according to Harrison et al,[33] some errors may occur when drawing these lines, which can lead to misinterpretation of the angle. In the case of photogrammetry, there are some methodological issues that need to be taken into consideration, for example, the camera and tripod positioning, proper use of the plumbline, and the angle calculation.[34]

Thus, the objective of this study was to review the literature on postural assessment through radiography and photogrammetry for defining referential values for thoracic kyphosis and lumbar lordosis and search for information about the interrater and intrarater reliability of both methods.

Methods

The PubMed/Medline and LILACS databases were consulted to search for studies from 2000 to 2015. For this, the following keywords (in English and Portuguese) were entered: (1) radiograph and posture, (2) postural alignment, and (3) photogrammetry or photometry or biophotogrammetry.

The inclusion criteria were articles that contained values of thoracic kyphosis and lumbar lordosis with samples including asymptomatic individuals and those free from any deviation, realized by radiography and photogrammetry or a reliability test for radiographic and photogrammetric analysis. For the analysis of studies with reliability, studies in the supine position, samples with scoliosis patients, and those in the lateral and anteroposterior view were accepted. However, for thoracic kyphosis and lumbar lordosis analysis, only studies in the standing position and lateral view were used.

The exclusion criteria were studies without the radiographic or photogrammetric method for thoracic kyphosis and lumbar lordosis assessment; samples with patients with metabolic disease, cancer, or a surgical process of prosthesis placement in the spine; studies about dentistry, postural control, or range of motion; and review articles, meta-analyses, and case studies.

Firstly, the studies were selected by title and then by reading the abstract, considering the inclusion and exclusion criteria. Subsequently, all selected studies were fully analyzed and the data extracted.

With the purpose of establishing normative values for the thoracic kyphosis and lumbar lordosis for both methods, random numbers were generated in MATLAB from the samples, means, and standard deviation (SD) from each study individually. Therefore, from these simulated random numbers, frequencies (median, first quartile, and third quartile) were obtained in SPSS 20.0 (IBM Corp, Armonk, New York).

Results

Figure 1 shows the flowchart of the process of the article selection.

The search resulted in 26 articles, of which 23 studies contained values for thoracic kyphosis and lumbar lordosis and

Table 1. *Thoracic Kyphosis and Lumbar Lordosis Values in Studies With Radiography*

Author, Year	Sample	Age (y)		Values			
				Thoracic Kyphosis (Degrees)		Lumbar Lordosis (Degrees)	
		Mean	SD	Mean	SD (±)	Mean	SD (±)
Roussouly, et al[35]	160 healthy adults: 86 women and 74 men; Lyon, France; medical students, physical therapist, and nurses	27	-	46.4	-	61.4	±9.72
Harrison, et al[36]	15 men and 5 women, volunteers, Georgia (United States)	28	6,6	T1-T12: 47.5 T2-T11: 43.0	10.4 10.9	62.0	12.0
Araújo, et al[37]	489 participants from Porto, Portugal:						
	57 participants	< 40	-	-	-	64.0[a,b]	-
	238 participants	40-64	-	-	-	61.5[a,b]	-
	194 participants	>65	-	-	-	61.2[a,b]	-
De Carvalho, et al[38]	8 men without spine problem history, Canada	26.75	2.95	-	-	63.0	15.0
Mac-Thiong, et al[39]	180 normal children and teenagers: 68 males and 112 females	12.0	3.1	43.0	10.4	48.5	12.4
Endo, et al[40]	50 adults without LBP and spinal problems: 25 men, 25 women	31.5	7.4			33.32	11.25
Park, et al[28]	100 adults asymptomatic, un-operated and free from spinal problems 2 groups:						
	Younger group	23.4		39.0	11.5	49.46	11.4
	Older group	65.8		33.37[a]	17.9	45.59[a]	19.6
Lee, et al[29]	20 healthy Korean volunteers 2 groups:						
	Younger group (n = 10)	25.4	2.3			52.20	7.95
	Older group (n = 10)	66.7	1.7			53.90[a]	15.9
Karaaslam, et al[41]	34 women with breast hypertrophy that went to breast reduction	33.7	6.14	Preoperative = 40.53	6.3	Preoperative = 54.72	7.77
				Postoperative = 38.38 (12 mo)[a]	5.3	Postoperative = 53.18 (12 mo)[a]	7.95
Souza, et al[42]	20 healthy Brazilian volunteers.	22.7	2.3			70.5	15.0
Gonçalves and Pereira[43]	22 asymptomatic Brazilian adolescents	15.8	1.4			L1-L5: 44.4 L1-S1: 57.5	6.9 6.1
Pinto, et al[44]	50 Brazilian volunteers 25 men; 25 women	22.8	2.08			58.4	9.2
Ghandihari, et al[45]	98 healthy students 50 boys; 48 girls	13.6	2.9	47.47	12.17	39.62	12.4
Boulay, et al[46]	149 adults without history of pathology. 78 men; 71 women	30.8	6.0	53.77	10.0	66.36	9.4
Chaléat-Valayer, et al[47]	709 adults without history of pathology						

Table 1. (*continued*)

Author, Year	Sample	Age (y)		Values			
				Thoracic Kyphosis (Degrees)		Lumbar Lordosis (Degrees)	
		Mean	SD	Mean	SD (±)	Mean	SD (±)
	354 men	37.9	14.7	50.1	10.4	42.0	11.2
	355 women	35.7	13.9				

LBP, low back pain; *SD*, standard deviation.
[a] No significant difference between groups ($P > 0.05$).
[b] Median.

10 tested the intra- and interrater reliability of both methods. Tables 1 and 2 present the studies with values of thoracic kyphosis and lumbar lordosis through the radiography and photogrammetry methods, respectively. In addition, Tables 3 and 4 show the studies that tested the intra- and interrater reliability for radiography and photogrammetry, respectively.

Table 5 presents the frequency values in percentiles for the studies with radiography that calculated the angle by the same method of assessment. For the thoracic kyphosis assessment, most studies assessed the angle from the superior endplate of the T1 vertebrae and inferior endplate of the T12 vertebrae.[28,36,41,45] For the frequency values for lumbar lordosis, studies that calculated the angle from the superior endplate of L1 and inferior endplate of L5[3,28,38,43,44] and studies that calculated from the superior endplate of L1 and superior of L5[43-45] were considered. It was not possible to establish frequency values for percentiles of photogrammetric studies because of the divergence of procedures and angle calculation between the studies found. Figure 2 shows the frequency distribution for each region with the mean, SD, and size of the sample (N).

Discussion

Values

According to the results presented in this study, several factors may influence the angle measures of the spine, such as age and sex. These factors can lead to divergences in the normality values of the thoracic kyphosis and lumbar lordosis angles in the general population.

Roussouly et al[35] affirmed that the human spine alignment might vary greatly from individual to individual, even in a standing position. Fon et al[12] showed that the thoracic kyphosis degrees increase with age, and the rate of increase is higher in women. In addition, Cowan[53] compared the thoracic kyphosis values of patients aged 60 to 69 years with patients aged 70 to 79 years. Women between 60 and 69 years presented higher thoracic kyphosis compared with men ($\overline{X}$ = 50° and $\overline{X}$ = 42.6°, respectively), and for both, these values increased with age ($\overline{X}$ = 55.8° in women and $\overline{X}$ = 49.3° in men). According to the authors, the increase in thoracic kyphosis is correlated with the diminution in the chest area (for the method of chest area calculation, see Cowan[53]) with advancing age, caused by the decrease in strength and muscle tone of the chest muscles with age.

Bartynski et al[54] analyzed the thoracic kyphosis of patients without vertebral compression in different age groups. The authors noticed an angle variation of $\overline{X}$ = 26.9° (SD = 7.5) for the younger group (18 to 35 years old) to $\overline{X}$ = 43.6° (SD = 13.6) for the older group (over 65 years old), confirming the increase in thoracic angle with age. Therefore, the authors conclude that thoracic kyphosis values increase with age because of changes in tissue and support musculature, with a reduction in the tone of the extensor muscle and the hypermobility and, in women, with pre-menopausal hormonal changes.

Contrary to all studies cited above, however, Park et al[28] did not find differences in the thoracic kyphosis angle between 100 asymptomatic young and old adults ($\overline{X}$ = 39° and $\overline{X}$ = 33.37°, respectively). Furthermore, for lumbar lordosis angle measures, Park et al[28] also did not find differences between these groups ($\overline{X}$ = 49.46°, younger group and $\overline{X}$ = 45.59°, older group). Similarly, Lee et al[29] did not show differences between young and old adults in the angle measures of lumbar lordosis ($\overline{X}$ = 52.20° and $\overline{X}$ = 53.90°, respectively). Nevertheless, according to Lee et al,[29] global lumbar lordosis seems not to be affected by aging of the discs, joints, or vertebral bodies. In the same study, when the lumbar lordosis was divided into superior and inferior portions, the angle was greater in younger adults compared with older adults. On the other hand, studies that compared the spine curvature of young and old adults by photogrammetry were not found in this research.

Regarding the comparison between men and women, Chaleát-Valayer et al[47] compared the measures of the thoracic kyphosis and lumbar lordosis in men and women with low back pain (LBP) and a control group. There was no difference in either measure between men and women. On the other hand, differences were found for thoracic kyphosis measures between the LBP group and control group, in which the angles were lower for the LBP group. Damasceno et al[13] showed a lower lumbar lordosis angle in women ($\overline{X}$ = 59.33° and SD = 10.57) when compared with men ($\overline{X}$ = 63.19° and SD = 10.38). Moreover, Been and Kalichman[55] suggested that there is no evidence that effectively proves the association of lumbar lordosis angle with age and sex, indicating the need for more studies on this subject. In addition, it is understandable that spine curvature is not only affected by factors such as age and sex, but also by factors such as occupation, ethnicity, and daily activities. More studies are also suggested with photogrammetry comparing measures for men and women because of the lack of articles found about this method. However, the literature demonstrates the existence of divergences in opinion regarding normality values of reference and postural deviation.

Roaf[15] affirmed that thoracic kyphosis values between 20° and 40° are within the normality; on the other hand, when the curvature exceeds 40°, it is considered defective. However, Fon et al[12] analyzed 316 individuals aged between 2 and 79 years with values of thoracic kyphosis from 13° to 66°. Thereby, such values would classify the postures of these young and old participants as abnormal according to Roaf.[15] A more recent study of Chaleát-Valayer et al[47] demonstrated mean values of $\overline{X}$ = 50.1° (SD = 10.4) for thoracic kyphosis in 709 adults of both sexes. In addition, Boulay et al[46] found values of $\overline{X}$ = 53.77° (SD = 10.0) for thoracic kyphosis in 169 asymptomatic participants. In addition, according to the definition of Roaf,[15] the posture of the sample of these studies would be considered abnormal for kyphosis curvature.

According to Cobb (apud Moe[17]), lumbar lordosis varies from 40° to 60°, in which an angle lower than 40° indicates a rectification and greater than 60° implies hyperlordosis. However, Fernand and Fox[56] define hypolordosis as a curvature with values lower than 23° and hyperlordosis as a curvature with values greater than 68°. Moreover, in this present review, 15 studies were found which used the radiographic method to assess the curvature angles, and 5 of them showed mean values over 60°.[35,36,38,42,46] According to Cobb (apud Moe[17]), this population would be hyperlordotic. On the other hand, Endo et al[40] and Ghandihari et al[45] presented a population with lumbar rectification when following Cobb's classification. Furthermore, it is difficult to find a classification to define values of normality and abnormality for thoracic kyphosis and lumbar lordosis. This may occur owing to different populations analyzed in each study, resulting in divergent angle values.

The absence of consensus between values of both regions may occur because of several factors that involve the human being, such as age, sex, ethnicity, and also the daily predominant activities and physical exercise practice.[57] Moreover, it is necessary to find an optimal value for the spine angles for the general population, to avoid major stresses, tension, and pain, when a spine deviation is identified. However, even in the absence of normative parameters, it is possible to standardize the classification of thoracic and lumbar angulation.

From the studies with radiography analysis, a categorical classification was proposed from statistical references of mean and SD. This procedure was performed by the simulation of each individual found in the studies that used the same method for angle calculation and same reference vertebrae for each region. Therefore, the values between one SD in relation to the obtained mean would represent typical behavior because it incorporates approximately 68% of the sample values grouped in the present study. The values found between 1 and 2 SDs would be classified as a "tendency to rectification" or the increase of the curvature (hyperkyphosis and hyperlordosis, respectively, for thoracic and lumbar region). These values would cover about 27% of the individuals analyzed. Finally, values higher than 2 SDs, which covers around 10% of the analyzed individuals, represent values related to "rectification" and angle increase (hyperkyphosis/hyperlordosis; Fig 3A and B).

From this point of view, the thoracic kyphosis classification was performed on studies containing the Cobb method, with calculations from the superior endplate of the T1 vertebrae and inferior endplate of the T12 vertebrae. The thoracic kyphosis curvature was considered "typical" when values between 52.35° and 63.85° were found. Values between 46.6° and 52.35° were considered a "tendency to rectification" and less than 46.6° were considered "rectification." On the other hand, values between 63.85° and 69.6° would classify the thoracic kyphosis as a "tendency to hyperkyphosis" and above 69.6° as a "hyperkyphosis" (Fig 3A). This classification does not agree with the values proposed by Roaf,[15] in which angulation between 20° and 40° is defined as normal curvature. However, the studies analyzed in this review are recent (between 2000 and 2015), and changes in posture pattern owing to habits and culture, advances in technology, and medical knowledge may have occurred over time.

The lumbar lordosis classification was performed from studies that involved the angle calculation from the superior endplate of the L1 vertebrae and inferior endplate of the L5 vertebrae, also realized by the Cobb method. The values for "typical" lumbar lordosis would be between 39.61° and 48.53°. Values between 35.15° and 39.61° would be classified as a "tendency to rectification" of this part of the spine and below 35.15° as "rectification." In contrast, values between 48.53° and 52.99° would be classified as a "tendency to hyperlordosis" and above 52.99° as "hyperlordosis" (Fig 3B). The values considered typical in this study would agree with Tachdjian's[58] study, in which the normality values were between 35° and 40°.

The studies found in this review did not provide sufficient information to define a classification for the photogrammetric method owing to lack of method standardization. Therefore, it is extremely important to establish standardization for this method to compare results in the future.[34] In particular, more postural alignment analysis by photogrammetry is necessary to create normative values and further studies associating postural alignment with pain, lesion, and pathologies. In addition,

Table 2. *Thoracic Kyphosis and Lumbar Lordosis Values in Studies With Photogrammetry*

Author, Year	Sample	Age (y)		Values			
				Thoracic Kyphosis (Degrees)		Lumbar Lordosis (Degrees)	
		Mean	SD	Mean	SD (±)	Mean	SD (±)
Pezzan, et al[48]	100 adolescents					Barefoot [a]	
	2 groups:					UG = 40	5.3
	Non-high heels users (NUG)	16.7	2.74			NUG = 62 [b]	4.3
	High heel users (UG)	17.8	2.42				
						High-heeled [a]	
						UG = 38	4.1
						NUG = 79 [b]	3.2
Lima, et al[49]	21 pregnant women						
	3 groups:						
	1st trimester (n = 7) = 1TG	23,57	4.23	42.87 [c]	1.59	18.32 [c]	1.70
	2nd trimester (n = 7) = 2TG	23.42	4.29	47.21 [c]	3.11	16.87 [c]	1.80
	3rd trimester (n = 7) = 3TG	22,28	4.27	45.82 [c]	4.21	16.84 [c]	3.43
Graup, et al[24]	288 adolescents					Boys = 26	9.09
	156 boys	16	1.06			Girls = 34	8.62
	132 girls	15.87	1.05			General = 30	9.6
Morais, et al[26]	20 women	33.68	14.07	Barefoot [a]		Barefoot [d]	
	3 conditions: barefoot, sneakers, and high heels			0° = 90.1	10.4	0° = 47.1	9.8
	3 conditions for arm position with shoulder flexion in: 0°, 45°, 90°			45° = 109.8	11.9	45° = 53.3	9.4
				90° = 113.5	13.4	90° = 54.9	9.4
				Sneakers [a]		Sneakers [d]	
				0° = 91.1	9.6	0° = 46.0	10.2
				45° = 108.0	12.3	45° = 52.7	11.2
				90° = 109.1	14.3	90° = 51.2	11.7
				High heels [a]		High heels [d]	
				0° = 91.1	9.4	0° = 47.5	11.0
				45° = 104.7	13.3	45° = 50.5	12.4
				90° = 113.9	11.8	90° = 56.0	11.7
Penha, et al[25]	230 children	7 and 8		7 years (boys and girls) = 28.07	7.73	7 years (boys) = 38.49	15.32
	130 girls and 100 boys			8 years (boys and girls) = 30.32	7.73	7 years (girls) and 8 years (boys) = 42.29	7.15
Ferreira, et al[10]	115 adults	26	6.9	55.4	7.4	47.7	15.4
Iunes, et al[27]	40 women			Barefoot [d]		Barefoot [d]	
	2 groups:			G1 = 84.88		G1 = 56.06	
	Everyday high heel users	23.5	2.86	G2 84.42 [c]		G2 = 57.35 [c]	
	(n = 20) = G1	22.55	2.68	Platform heels [d]		Platform heels [d]	
	Sporadically high heel users			G1 = 83.21		G1 = 58.54	
	(n = 20) = G2			G2 = 83.29 [c]		G2 = 56.57 [c]	
				Stiletto heels [d]		Stiletto heels [d]	
				G1 = 81.8		G1 = 57.6	
				G2 = 83.28 [a]		G2 = 58.65 [a]	
Basso, et al[50, e]	20 participants	20-35				Pre RPG practice = 4.13 [d]	1.23
						Post RPG practice = 4.61	0.57

NUG, non-high heels users group; *SD*, standard deviation; *TG*, trimester group; *UG*, high heels users group.
[a] Conditions statistically significant.
[b] Group statistically significant.
[c] Group not statistically significant.
[d] Conditions not statistically significant.
[e] Single study with values in cm.

Table 3. *Studies With Inter- and Intrarater Reliability Assessed by Radiography*

Author, Year	Interrater Reliability	Intrarater Reliability	Statistical Test
Kado, et al[51] (supine position)		Cobb angle—manually = 0.99 Cobb angle—digitalized = 0.98 3-month interval	ICC
De Carvalho, et al[38]	0.13° difference between the measures mean Paired *t* test = no difference	Rater 1: 0.1° difference (SD = 2.3) Rater 2: 0.55° difference (SD = 3.12) Paired *t* test = no difference	Bland-Altman and paired *t* test
Lee, et al[3] (posteroanterior, scoliosis)	ICC = 0.7	Rater 1: ICC = 0.9 Rater 2: CCI = 0.89 2-week interval	ICC
Park, et al[28]	ICC = 0.67	ICC: 0.77	ICC
Lee, et al[29]	ICC = 0.98	ICC: 0.97	ICC
Boulay, et al[46]	No significant difference	No significant difference 3 raters: 2 radiographs, assessed 3 times	Pearson's correlation

ICC, intraclass correlation coefficient.

studies analyzing different interventions, aiming at rehabilitation or work/exercise performance improvement, are also necessary. Despite the importance of a categorical classification of the spine region with respect to its angulation, it is also important to understand that rectified or enhanced angulations are not always related to pain or lesion. Therefore, some authors have proposed a wide analysis of the spine also considering the pelvis angulation.[35,59,60]

Legaye et al[59] affirmed that the classifications proposed in the literature are based on curvature measures, angulations, and normal population parameters, making this data more descriptive rather than analytical. Therefore, the authors discuss that changes in curvature in the sagittal plane are related to other changes in pelvic orientation. Thereby, 3 pelvic parameters are presented and need to be analyzed to better understand lumbar lordosis. These parameters are pelvic incidence, sacral slope, and pelvic tilt.

The pelvic incidence is formed by the angle between the perpendicular line of the sacral endplate, at its midpoint, and the line that links this point to the femural head axis (Fig 4A). It is considered an anatomical parameter, exclusive to each individual and independent of the pelvic spatial orientation. This parameter is constant because it is age independent after growth is complete. The sacral slope is defined as an angle between the superior endplate of S1 and a horizontal line (Fig 4B). Finally, pelvic tilt is defined as an angle between the line that connects the sacral endplate midpoint and the femural head axis (Fig 4C). These angles are geometrically related, thus the pelvic incidence is the sum of the sacral slope and pelvic tilt.[35,59,60]

Legaye et al[59] concluded that lumbar lordosis is strongly related to pelvic orientation, expressed by the sacral slope, which is strongly influenced by the pelvic incidence. Therefore, the pelvic incidence determines the pelvic orientation and the size of lumbar lordosis because it is the only parameter independent of the sagittal special orientation. However, a low value of pelvic incidence is related to low values of the other pelvic parameters and consequently to a rectified lordosis. On the other hand, high values of pelvic incidence lead to a well-tilted pelvic orientation and a pronounced lordosis.

Roussouly et al,[35] therefore, established a classification of lumbar lordosis according to the parameters described by Legaye et al.[59] This classification describes 4 types of lumbar lordosis. In type 1 lordosis the sacral slope is less than 35° and normally associated with a low pelvic incidence. The lower lordosis arc is minimal and decreases toward zero as the sacral slope approaches the horizontal. The upper portion of the spine shows a significant kyphosis at the thoracolumbar junction and thorax. In type 2 lordosis the sacral slope is less than 35°. The lower lordosis arc is relatively rectified. The entire spine is presented as hypolordotic and hypokyphotic. In type 3 lordosis the sacral slope is between 35° and 45°. The lower lordosis arc becomes more salient and the spine is balanced. In type 4 lordosis the sacral slope is over 45° and is associated with a high pelvic incidence. The lower lordosis arc is also more salient. Thereby, postural assessment of the thoracic kyphosis and lumbar lordosis should be analyzed from the pelvic parameters. Hence, the 3 parameters cited above should be analyzed and then the kyphosis and lordosis classified; from that, the lordosis can be classified within the 4 lordosis types defined by Roussouly.[35]

Regarding the foregoing, it is understandable that postural alignment depends on several factors such as

Table 4. *Studies With Inter and Intrarater Reliability Assessed by Photogrammetry*

Author, Year	Interrater Reliability	Intrarater Reliability	Statistical Test
Pezzan, et al[48]	Barefoot: ICC = 0.85 (users and nonusers of high heels) High heels: ICC = 0.87 (users and nonusers of high heels)	Barefoot: ICC = 0.85 (users and nonusers of high heels) High heels: ICC = 0.86 (high heel users) and 0.86 (non-high heel users) 1-week interval	ICC
Saad, et al[52]	Thoracic: r = 0.93 ($P < 0.01$) Lumbar: r = 0.45 ($P < 0.042$)	Thoracic: r = 0.94 ($P < 0.01$) Lumbar: r = 0.92 ($P < 0.01$)	Pearson's correlation and analysis of concordance
Saad, et al[30]	Thoracic (right): ICC = 0.97 Thoracic (left): ICC = 0.97 Lumbar (right): ICC = 0.89 Lumbar (left): ICC = 0.85	Thoracic (right): ICC = 0.93 Thoracic (left): ICC = 0.95 Lumbar (right): ICC = 0.90 Lumbar (left): ICC = 0.85 15-day interval	ICC
Iunes, et al[2]	Thoracic: ICC = 0.66 Lumbar: ICC = 0.66 3 raters	Thoracic: ICC = 0.031 Lumbar: ICC = 0.99 Minimum 4-week interval	ICC

ICC, interclass correlation coefficient.

Table 5. *Frequency Values of Percentiles of the Studies With the Same Method of Assessment by Radiograph*

	Percentile 25	Percentile 50	Percentile 75
Kyphosis T1-T12	43.25°	47.74°	53.80°
Lordosis L1-L5	41.20°	44.31°	47.41°
Lordosis L1-S1	54.69°	58.50°	61.79°

age, sex, and ethnicity. However, spine morphology in the sagittal plane varies from individual to individual, and any change in the curvature in this plane is associated with other changes in pelvic orientation. Stress and undue tension on the bone, joints, ligaments, and muscles can result in frailty in postural alignment. These problems in postural alignment can lead to pain, which can appear in an acute and chronic way.[61] Oftentimes, a bad postural alignment may not cause pain and hinder the individual in daily activities initially. However, with time wear may occur, causing postural problems. Therefore, the typical postural pattern of an ethnicity or specific population cannot be established as a general pattern. Thereby, individual assessment of posture is necessary, taking into consideration all factors discussed in this review (age, sex, ethnicity, occupation).

Reliability

Deciding the test that better suits a reliability study is a difficult task for researchers because of the existence of a diversity of statistical approaches.[62] Most studies included in this review used the intraclass correlation coefficient (ICC) to analyze the reliability of the radiography and photogrammetry assessments. The ICC is found from the variance analyses and several components of variance.[63] However, when the ICC is used alone, it is not possible to obtain the true reliability and it is necessary for it to be complemented by hypothesis testing and confidence interval. Therefore, the ICC cannot be clinically interpreted because there is no indication of the magnitude of the discordance of the measures.[62] Nevertheless, the test can be complemented by the Bland-Altman plot, which provides a strong visual representation of the data, allowing identification of the bias and outliers and any relation between the measures variance and size of the mean.[63,64]

The Bland-Altman test can be used to analyze the reliability of the individual measures or to compare measures between observers[64] and also to find the level of concordance between 2 clinical methods.[63] According to Rankin and Stokes,[62] the utilization of the ICC and Bland-Altman tests has increased in statistical analysis when it is necessary to check the raters' reliability, and they suggest that they be used together. Therefore, Pearson's correlation is inadequate to test reliability because this kind of test measures the power of a linear association and not the concordance between the measures.[64,65]

The studies selected in this review presented different references regarding the ICC classification. Lee et al[3] classified the ICC agreement values as poor (between 0 and 0.2), fair (between 0.3 and 0.4), moderate (between 0.5 and 0.6), strong (between 0.7 and 0.8) and, near perfect (>0.8). On the other hand, Lee et al[29] reported only what would be a strong reliability (index between 0.8 and 1) and Kado et al[51] found an ICC of 0.68 and defined it as an imperfect agreement and values. Mac-Thiong et al[39] and Park et al[28] also used ICC, but they did not report any classification.

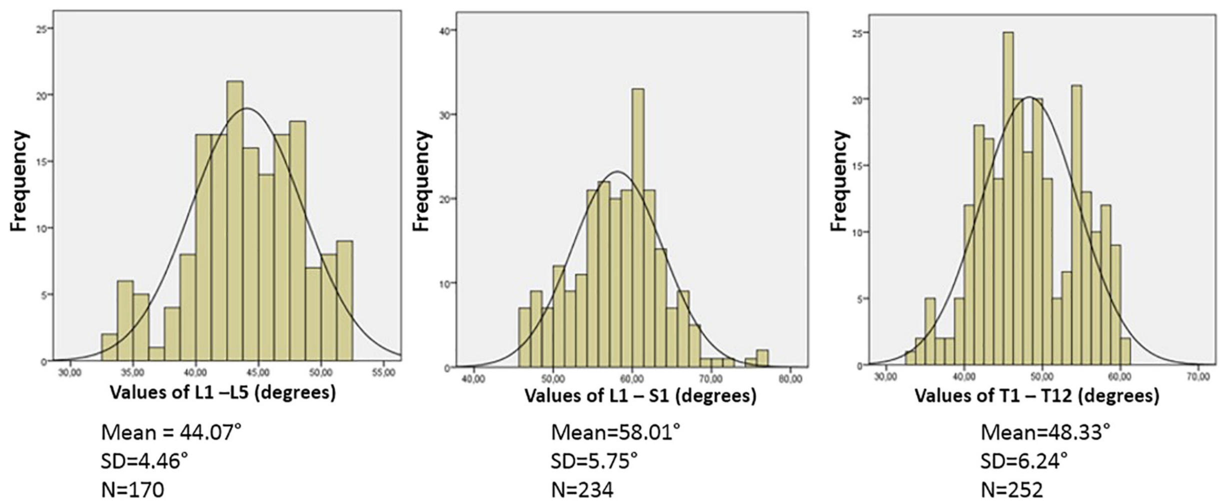

Fig 2. *Graphic of frequency for each spine region.* SD, *standard deviation.*

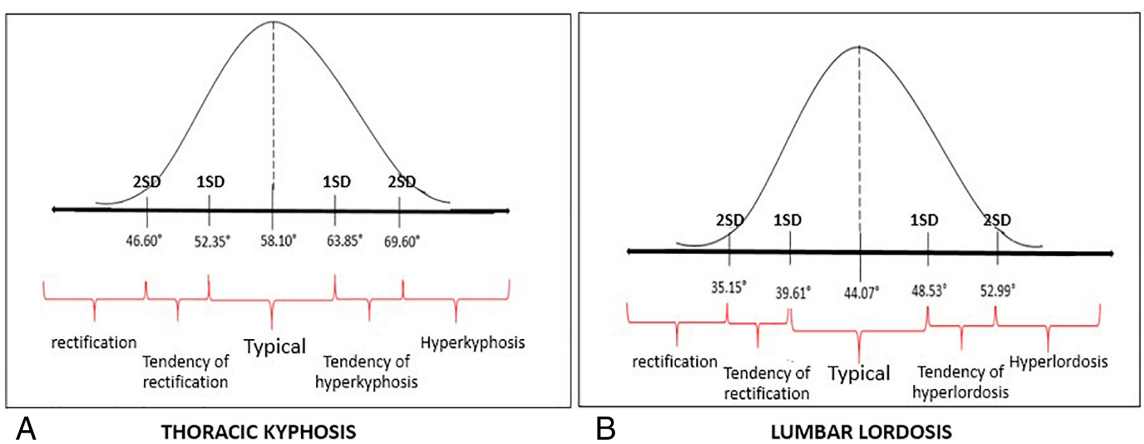

Fig 3. *Classification of (A) thoracic kyphosis and (B) lumbar lordosis.*

Three studies testing photogrammetry reliability with the ICC test used the classification from Wahlund et al.[65] These authors classified the ICC as unacceptable (<0.7), acceptable (between 0.7 and 0.79), very good (between 0.8 and 0.89), and excellent (>0.9); values equal to 1 are considered identical or perfect concordance.[2,30,48] However, Atkinson and Nevill[66] did not find any reference in the literature of exercise science and sport related to the ICC classification for any analytical objective of research. Therefore, the reliability index found in studies with radiography was greater than 0.77 in most studies, and in photogrammetry, it was greater than 0.85.

Only 1 study with photogrammetry analyzed the reliability of marker replacement.[52] In this case, some care must be taken into consideration. The intervertebral discs lose water over the day hours because of compression on the spine,[67] thus the test and retest must be realized under the same environment conditions, at the same time of day, and if possible, practicing the same physical activities between tests. Therefore, it is not advisable to wait a long period to realize the retest because of physiological changes in the body over the days (gain or loss of bone or muscular mass, physical exercise practice, and postural reeducation).

In case of interrater reliability, the tests must be realized on the same day, under the same environmental conditions and same participant physical condition. When the reliability is analyzed from radiographs or photo digitalization, the raters must analyze under the same conditions of light, zoom, and method of angle assessment. It is not advisable to wait a long period to realize the retest because the rater time of practice between the test and retest may interfere in the analysis because both a lack of and excess practice can alter the measures.

Good achievement of postural assessment can be guaranteed with the utilization of an appropriate procedure of test and retest, the specific statistical tests for testing reliability, and experienced and previously trained raters. Moreover, photogrammetry is a low-cost, easily applied, noninvasive, nonharmful method and presented good to

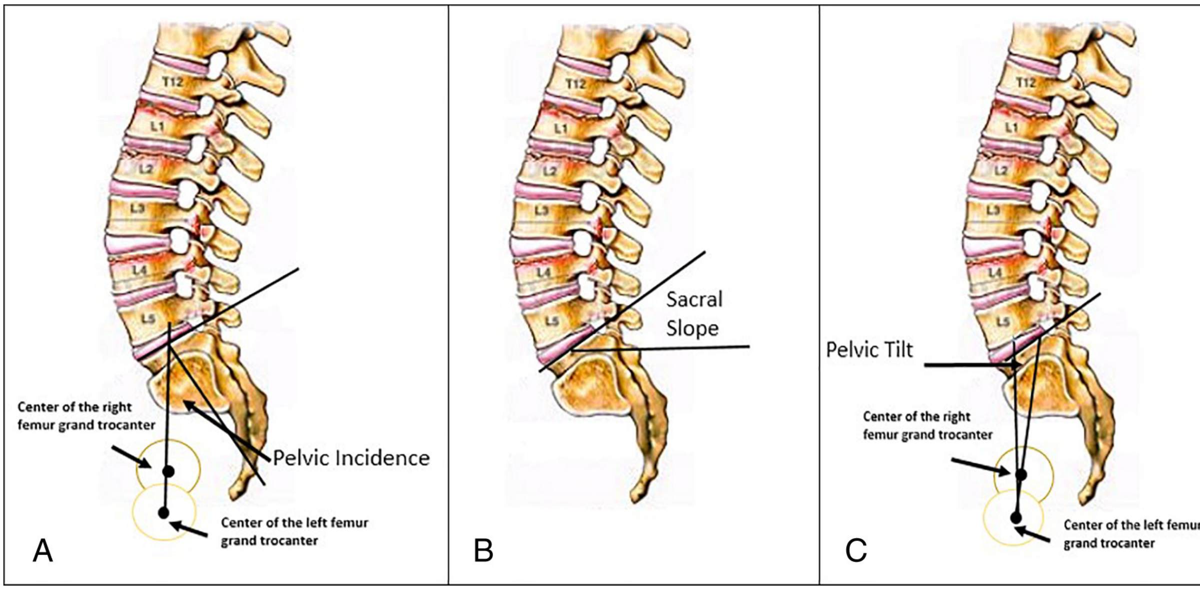

Fig 4. *Representation of the 3 pelvic parameters. (A) Pelvic incidence. (B) Sacral slope. (C) Pelvic tilt.*

excellent reliability, showing that it is possible to use it in the detection, prevention, and evolutional attendance of postural problems.

Conclusion

The studies presented in this review showed no concordance among the results for both methods regarding the divergence in their values. However, to solve this problem, a classification for the thoracic kyphosis and lumbar lordosis curvature from the means and SDs from the studies with radiograph was suggested. It was not possible to perform the same procedure with the photogrammetry studies because of the great discrepancy in procedures and angle calculations. Moreover, the spine curvature may experience influence from the pelvic parameters (pelvic incidence, sacral slope, and pelvic tilt) and other factors, such as ethnicity, sex, and age. Therefore, the thoracic kyphosis and lumbar lordosis curvature should be analyzed individually, considering all the factors that may influence the measures. The reliability tests of both methods have demonstrated reliability in their results. However, the utilization of appropriate statistical tests is necessary for better data analysis.

Funding Sources and Conflicts of Interest

This paper was supported by funding by CAPES. No conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): A.B.P., V.H.A.O.
Design (planned the methods to generate the results): A.B.P.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): V.H.A.O.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): A.B.P.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): A.B.P., V.H.A.O.
Literature search (performed the literature search): A.B.P., V.H.A.O.
Writing (responsible for writing a substantive part of the manuscript): A.B.P., V.H.A.O.

Practical Applications

- This study provides a normative value for thoracic kyphosis and lumbar lordosis analyzed by radiography.
- This study shows the absence of normative value for thoracic kyphosis and lumbar lordosis analyzed by photogrammetry.
- This study shows how reliable the radiography and photogrammetry methods are and discusses the appropriate statistical test for reliability.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): V.H.A.O.

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