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ANATOMIC AND FUNCTIONAL ANALYSIS OF THORACIC KYPHOSIS AND LUMBAR LORDOSIS

AVALIAÇÃO ANATÔMICA E FUNCIONAL DA CIFOSE TORÁCICA E LORDOSE LOMBAR

ANÁLISIS ANATÓMICA Y FUNCIONALDE LA CIFOSIS TORÁCICA Y LA LORDOSIS LUMBAR

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ABSTRACT

Objective: Rate and compare radiographic measurements of thoracic kyphosis and lumbar lordosis using anatomical and dynamic parameters. Methods: Measurements were performed on lateral radiographs of 10 adults of both sexes without spinal disease or deformity. Thoracic kyphosis and lumbar lordosis were measured using anatomical parameters (T1-T12, T4-T12, T5-T12 and L1-S1) or dynamic parameters (cervicothoracic or thoracolumbar inflection point). Thoracic kyphosis and lumbar lordosis were different in 30% of subjects. Differences in thoracic kyphosis values were observed according to the anatomical reference used for measurement. Lumbar lordosis wasn`t statistical difference considering the anatomical or dynamic reference, but in 30% of the individuals the inflection point was different from the anatomical reference. Conclusions: Thoracic kyphosis and lumbar lordosis values differ according to anatomical and dynamic references. The reference used must be considered in the measurement and interpretation of values. ***Level of evidence IV; Case series.***

Keywords: Adult; Kyphosis; Spine; Lordosis; References Parameters; Anatomic Landmarks.

RESUMO

Objetivo: Avaliar e comparar as mensurações radiográficas da cifose torácica e lordose lombar utilizando parâmetros anatômicos e dinâmicos. Métodos: As mensurações foram realizadas nas radiografias em perfil de 10 adultos de ambos os sexos sem doença ou deformidade da coluna vertebral. A cifose torácica e a lordose lombar foram mensuradas utilizando parâmetros anatômicos (T1-T12,T4-T12, T5-T12 e L1-S1) ou dinâmicos (ponto de inflexão cervicotorácico ou toracolombar) Resultados: As referências anatômicas e dinâmicas para a identificação da cifose torácica e lordose lombar foram diferentes em 30% dos indivíduos. Foi observado diferença dos valores da cifose torácica de acordo com a referência anatômica utilizada para a mensuração. A lordose lombar não apresentou diferença estatística considerando a referência anatômica ou dinâmica, mas em 30% dos indivíduos o ponto de inflexão era diferente da referência anatômica. Conclusões: Os valores da cifose torácica e lordose lombar apresentam diferenças de acordo com as referências anatômicas e dinâmicas. A referência utilizada deve ser considerada na mensuração e interpretação dos valores. ***Nível de evidência IV; Série de casos.***

Descritores: *Adulto; Cifose; Coluna Vertebral; Lordose; Parâmetros de Referência; Pontos de Referência Anatômicos.*

RESUMEN

Objetivo: Calificar y comparar medidas radiográficas de cifosis torácica y lordosis lumbar utilizando parámetros anatómicos y dinámicos. Métodos: Las mediciones se realizaron en radiografías laterales de 10 adultos de ambos sexos sin enfermedad o deformidad de la columna. La cifosis torácica y la lordosis lumbar se midieron mediante parámetros anatómicos (T1-T12, T4-T12, T5-T12 y L1-S1) o dinámicos (punto de inflexión cervicotorácico o toracolumbar). La cifosis torácica y la lordosis lumbar fueron diferentes en el 30% de los sujetos. Se observaron diferencias en los valores de cifosis torácica según la referencia anatómica utilizada para la medición. La lordosis lumbar no fue diferencia estadística considerando la referencia anatómica o dinámica, pero en el 30% de los individuos el punto de inflexión fue diferente de la referencia anatómica. Conclusiones: Los valores de cifosis torácica y lordosis lumbar difieren según referencias anatómicas y dinámicas. La referencia utilizada debe ser considerada en la medición e interpretación de los valores. ***Nivel de evidencia IV; Series de casos.***

Descriptores: *Adulto; Cifosis; Columna Vertebral; Lordosis; Parámetros de Referencia; Puntos Anatómicos de Referencia.*

INTRODUCTION

The spinal curves in the sagittal plane (kyphosis and lordosis) have been being identified and described since the time of Hippocrates in ancient Greece[1]. Interest in the study of these curves has been growing and has culminated in an understanding of the importance of the sagittal balance of the spine in the treatment of spinal diseases.[1,2]

Segmentation of the spine has been defined using anatomical or functional parameters.[2-5] Segmentation by means of anatomical parameters considers the angle formed by the upper endplate of T1 and the lower endplate of T12 to evaluate thoracic kyphosis, and L1-S1 for lumbar lordosis.[1,6]

The superposition of the femoral head and ribs in lateral radiographs makes visualization of the proximal portion of the thoracic

Study conducted at theIrmandade Santa Casa de Misericórdia de São Paulo. São Paulo, SP, Brazil.
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spine difficult and T4 or T5 has been used as a proximal anatomical reference to measure thoracic kyphosis.[7,8,9] In the lumbar spine, L1-L5 were the anatomical references considered, and currently there is consensus on the use of the L1-S1 segment.[1,6]

Functional segmentation of the spine considers the orientation of the vertebrae to define the limits of the curvature. Lordosis is represented by the segment of successive vertebrae in extension, and kyphosis, by the vertebrae in flexion (Berthonnand).

The lack of consensus around the anatomical and functional definitions of the sagittal curves of the spine (kyphosis and lordosis) and their measurement was the motivation behind conducting this study. The objective of the study was to evaluate the correlation between thoracic kyphosis and lumbar lordosis measurements using anatomical and functional segmentation, considering the different anatomical references described in the thoracic spine.

METHODS

The study was approved by the Institutional Review Board of theIrmandade da Santa Casa de Misericórdia de São Paulo, CAAE 50530421.1.0000.5479, under opinion number 4.960.159.

Radiographs and data obtained from the medical records of 10 outpatients were used for the study. The inclusion criteria established were patients 20 years of age or older, of both sexes, withcomplete medical record information, and radiograph quality permitting measurement of the study parameters. Patients younger than 20 years of age, or those with spinal diseases, spinal deformities, a previous history of spine or hip surgeries, or incomplete visualization of all the segments selected for the study, were excluded.

Measurements of the study parameters were taken and the inflection points were identified using panoramic lateral radiographs, performed in the orthostatic position with the upper limbs resting on a support. The anteroposterior incidence was used to observe the absence of deformities and spinal deviations in the frontal plane (Figure 1).

The inflection point was determined by means of the angles adjacent to the cervicothoracic and thoracolumbar transitions. In the thoracolumbar transition, the inflection point corresponds to the vertebral segment with a reduction in the value of the angle of lumbar lordosis in the direction ofthoracic kyphosis. In the cervicothoracic transition, the inflection point corresponds to the vertebral segment with an increasein the value of the angle ofthoracic kyphosis towards cervicallordosis (Figure 2).

Thoracic kyphosis and lumbar lordosis were measured in accordance with the inflection points and anatomical references (T1-T12, T4-T12, T5-T12, and L1-S1). The angle formed by the upper surfaces of

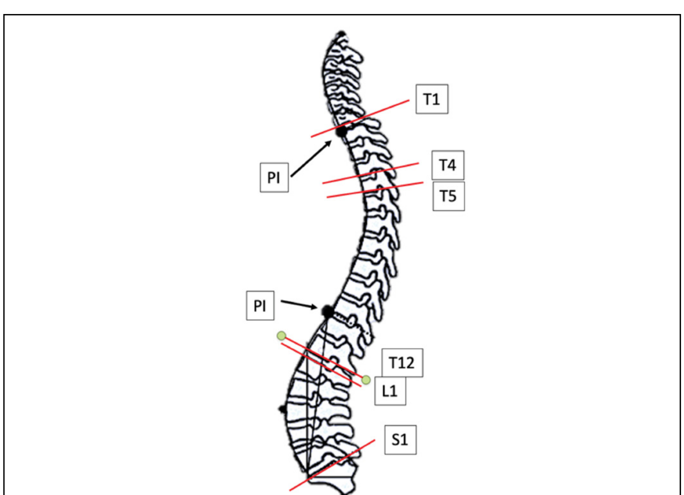

Figure 1. Drawing illustrating the anatomical references and the inflection points (cervicothoracic and thoracolumbar) used to measure the study parameters.

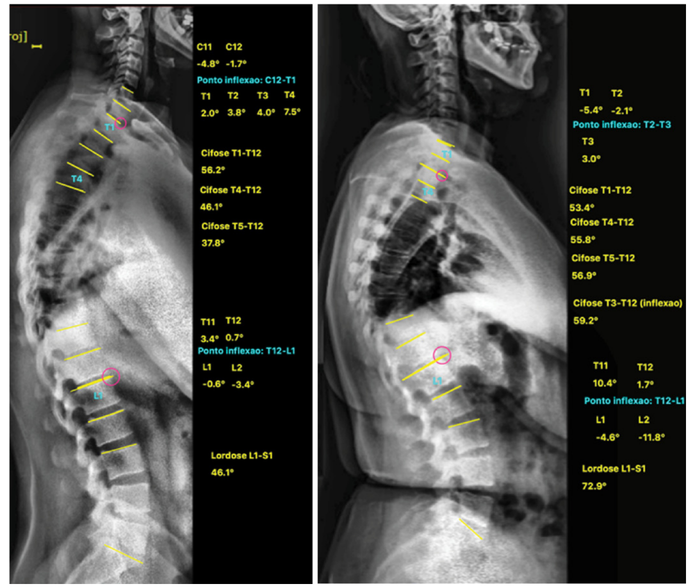

Figure 2. Lateral radiographs illustrating inflection point identification and parameter measurement.

the vertebrae of reference was considered for the measurement of the kyphosis or lordosis (Figures 1 and 2). Surgimap® software (Nemaris Inc.™, New York, US) was used to measure the study parameters.

The statistical study was performed using descriptive statistics (minimum value, maximum value, variance, mean, standard deviation, standard error of the mean, minimum confidence interval, maximum confidence interval, and the coefficient of variation) to characterize the groups studied. The Kolmogorov-Smirnov was used to evaluate the normality of the sample. Comparison of the kyphosis measurements was conducted using the ANOVA and Tukey tests. The Student's t test was used to compare the lordosis measurements. A significance level of 5% ($p<0.05$) was established to indicatestatistical difference.

RESULTS

General patient data and the parameter values are shown in Table 1. Seven patients (70%) were female. Patient age ranged from 19 to 71 years (42.2±19.64 years).

The location of the inflection point varied in relation to the anatomical references. The inflection point in the cervicothoracic region was located between C7 and T1 in 7 (70%) of the individuals, between T1 and T2in 2 (20%) individuals, and between T2 and T3 in one (10%) individual, while in the thoracolumbar transition it was located between T11 and T12 in 2 (20%) individuals, between T12 and L1 in 7 (70%), and between L1 and L2 in 1 (10%) individual.

Thoracic kyphosis evaluated using the inflection pointas the reference varied from 32.10 to 60.30 (mean 45.76 ± 11.00). Thoracic kyphosis evaluated using the anatomical references varied from 29.80 to 60.30 (mean 44.80 ± 10.68) for T11-T12, from 28 to 55.80 (mean 39.87 ± 8.29) for T4-T12, and from18 to 56.90 (mean 35.14 ± 9.77) for T5-T12 (Table 2).

Comparisons of the thoracic kyphosis values by reference used for the measurements are presented in Figures 3 and 4. Statistical differences were observed between the mean of the group where kyphosis was measured using T1-T12 and those of the T4-T12 and T5-T12 groups, and between the T1-T12 and T5-T12 points of inflection ($p< 0.05$).

No statistical difference was observed betweenlumbar lordosismeasured using the anatomical and functional references, however, incongruity between the inflection point and the anatomical reference was observed in 30% of the individuals (Figures 5 and 6). Lumbar lordosis measured using the points of inflection ranged from 42.40 to 72.90 (mean ± 9.55) and from 42.40 to 72.90 (mean 53.61 ± 9.52) using the anatomical references (L1-S1) for the measurements (Table 3).

Table 1. General patient data and measured parameter values.

Patient	Sex	Age	Proximal Inflection Point	Distal Inflection Point	Kyphosis Inflection	T1-T12 Kyphosis	T4-T12 Kyphosis	T5-T12 Kyphosis	Lordosis inflection	L1-S1 Lordosis
1	M	42	C7-T1	T12-L1	56.2	56.2	46.1	37.8	46.1	46.1
2	F	36	T2-T3	T12-L1	59.2	53.4	55.8	56.9	72.9	72.9
3	F	57	C7-T1	L1-L2	49.6	46.8	32.1	30.7	57.5	54.8
4	F	23	C7-T1	T12-L1	39.3	39.3	37.4	34.1	61.5	61.5
5	F	19	T1-T2	T12-L1	32.4	32.5	28	18	42.4	42.4
6	M	28	C7-T1	T12-L1	36.3	36.3	39.4	33.6	49.5	49.5
7	F	21	C7-T1	T12-L1	39.9	39.9	34.2	32.7	56.9	56.9
8	F	64	C7-T1	T11-T12	32..1	29.8	35.2	30.3	47.2	45.7
9	F	71	T1-T2	T11-T12	52.3	53.5	43.4	36.6	61.5	60.5
10	M	61	C7-T1	T12-L1	60.3	60.3	47.1	40.7	45.8	45.8

Table 2. Thoracic kyphosis values by reference used for the measurement.

	Inflection	T1-T12	T4-T12	T5-T12
Number	10	10	10	10
Minimum value	32.10	29.80	28.00	18.00
Maximum value	60.30	60.30	55.80	56.90
Variance	28.20	30.50	27.80	38.90
Mean	45.76	44.80	39.87	35.14
Standard Deviation	11.00	10.68	8.292	9.775
Standard error of the mean	3.479	3.377	2.622	3.091
Minimum CI value of the mean (95%)	37.89	37.16	33.94	28.15
Maximum CI value of the mean (95%)	53.63	52.44	45.80	42.13
Coefficient of variation	24.04%	23.84%	20.80%	27.82%

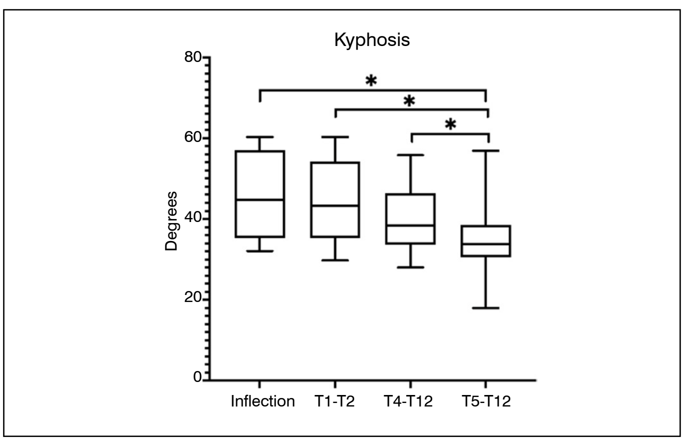

Figure 3. Graph illustrating mean kyphosis by reference used. The asterisk (*) indicated statistical difference ($p < 0.05$) (Tukey test).

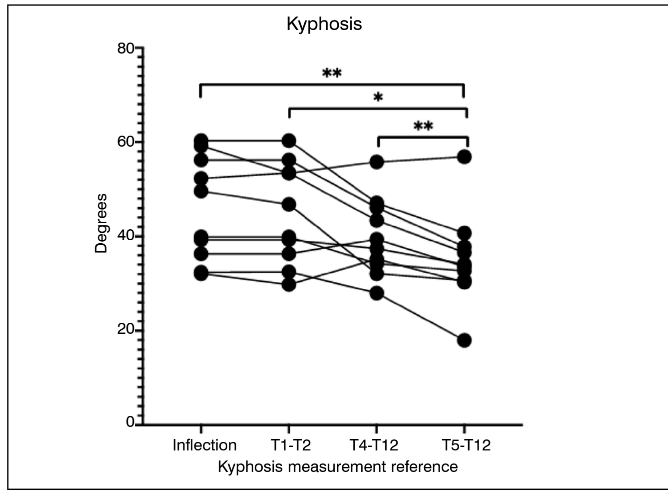

Figure 4. Distribution of the kyphosis measurements by the different references used.

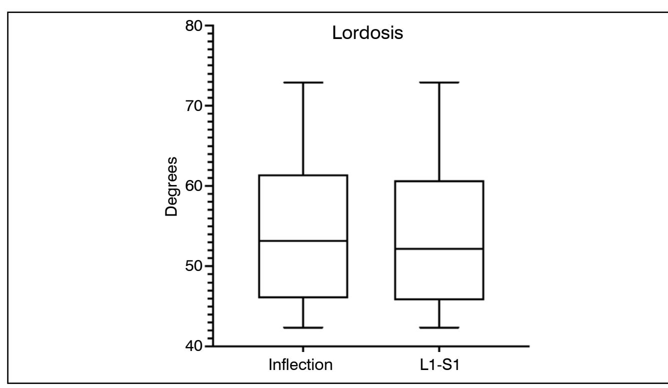

Figure 5. Graph illustrating lordosis measurement values by inflection points and anatomical reference (L1-S1).

DISCUSSION

Curvature and sagittal balance areboth emphasized in contemporary spinal surgery for their importance in treatment planning and outcomes. Unsatisfactory results of functional disability, pain, junctional kyphosis, and reoperation related to sagittal balance have been widely reported.[10,11]

Incongruity between functional and anatomical points of inflection was observed, in equal proportions in the cervicothoracic and thoracolumbar transitions in 30% of the individuals in our study. Despite the small sampled used in our study, the results corroborated reports in the literature that address the inflection points of spinal curves.[12-14] Historically, segmentation of the spine has been performed using anatomical references and divided into cervical lordosis, thoracic kyphosis, and lumbar lordosis.[1,6,12] Functional segmentation considers the orientation of the vertebrae to define the sagittal curves, allows real measurement of the sagittal curves, and their limits are individually determined.[6,14]

The location of the inflection point has been reported between T8 and L5 in the thoracolumbar transition and from C5 to T11 in the cervicothoracic transition,[14]although predominant in L1-L2 and T1-T2, respectively.[7,14-16] Stagnara and Park, Roussouly, Yamato, Harrinson, Vavari Vacari.This variation in the location of the inflection point highlights the importance of individualized analysis of spinal curves and sagittal balance.The spectrum of inflection point variability (T7-L4) explains why it is not reasonable for us to consider fixed anatomical references for all individuals,[12,14] and the influence of other parameters like age, sex, weight, and race must also be taken into account.[14,17] Despite the small size of the sample used in our study, it was possible to observe the differences between the points of inflection defined by anatomical and dynamic segmentation[12,14,17](Vaz,

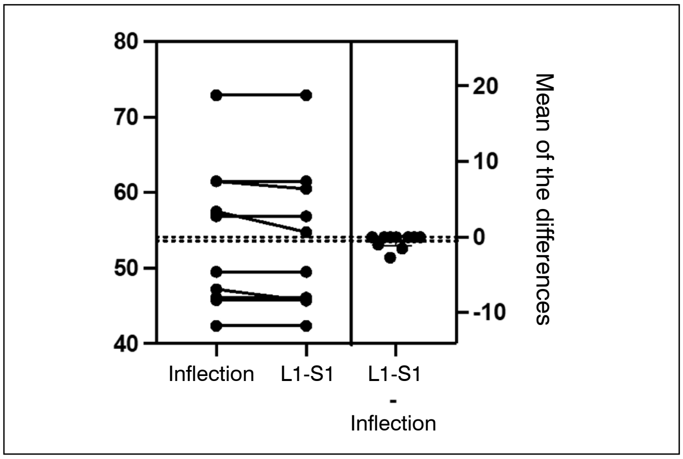

Figure 6. Graph illustrating the comparison of mean lordosis measurement values by points of inflection and anatomical references.

Table 3. Lordosis values in the study groups by reference used for the measurements.

	Inflection	**L1-S1**
Number	10	10
Minimum value	42.40	42.40
Maximum value	72.90	72.90
Variance	30.50	30.50
Mean	54.13	53.61
Standard Deviation	9.550	9.525
Standard error of the mean	3.020	3.012
Minimum CI value of the mean (95%)	47.30	46.80
Maximum CI value of the mean (95%)	60.96	60.42
Coefficient of variation	17.64%	17.77%

Stagnara, Berthonnaud).The inflection pointhas beenused to classify the different types of spinal sagittal alignment (Roussouly), and the influence of age (Boyle) and pelvic incidence has also been observed.[1,6,14]

Thoracic kyphosis has been measured using different anatomical references and use of the inflection point has increased with the contemporary concept of vertebral segmentation.[17,18] There were statistical differences both between the thoracic kyphosis measurements using the different anatomical references (T1-T12, T4-T12, and T5-T12) and those using the inflection point.Similarresults have been reportedand emphasizethe kyphosis measured between T1 and T12 as representing real thoracic kyphosis.[11] These findings reinforce the need for individual evaluation of the sagittal parameters and observation of the references usedfor that evaluation. Thoracic kyphosis measured considering T5-T12 has been presented in the literature and considered as a reference in the classification of idiopathic scoliosis.[19] However, the measurements based on these references were statistically different from the other thoracic kyphosis measurements, whichshould be used with caution considering the current concepts about the measurement and interpretation of spinal sagittal parameters.[16-18]

Currently there is consensus around the anatomical references for measuring lumbar lordosis and L1-S1 has been used, replacing L1-L5, which was previously used.[1,6] Different geometric measurementmethods (circular arc, elliptical quadrant, etc.) have been used.[1,6,16,19] In the spine, there was no statistical difference between the anatomical and functional segmentationlordosis angle values. However, the limits of the lordosis, which have clinical importance in therapeutic planning and have been indicated in the etiology of junctional kyphosis,[11,20,21] were different in about 30% of the study participants. The level of the inflection point determines the alternation of the curves and the number of lordotic or kyphotic vertebrae of the curves. The absolute value of the lordosis should not be considered alone, and the shape, number of vertebrae, and measurement proportions must also be involved in the evaluation and therapeutic decision.[6,14,21]

The present study had limitations related to the sample size,which did not permit consideration of sex, age range, and pelvic parameters. The study was a pilot project in preparation for a more detailed and in-depth study of anatomical and functional spinal segmentation. Even though the study sample was small, the results observed are corroborated by studies conducted with larger samples, demonstrating the importance of the T1-T12 segment in the evaluation of kyphosis, and that lower values are obtained when the T4-T12 or T5-T12 segment is used.[11] The preliminary results indicated the great research potential of these topics in clinical applications, considering the variability observed even in a small sample.

The study and evaluation of spinal curves has received more attention with the recognition of the importance of sagittal balance to the outcomes of spinal interventions.[2-5] The reports by Duval-Beauperier represent amilestone in the incorporation of spinal sagittal parameters into the assessment and treatment of spinal diseases, and many theories have emerged based on these concepts. Lumbar lordosis has been the focus of more attention and more research than the other curves. However, the definition of functional segmentation described by Berthonnaud et al.[6] presented the same concept for the other curves, and has received increasing attention in recognition of its clinical importance.[1]

The results observed in the study showed the differences between lumbar lordosis and thoracic kyphosis values by measurement method. These differences should be considered in the evaluation and design of the treatment, as well as in the interpretation of the relationships already described between these and the pelvic parameters. The values and overall relationships described should be used as general guidance and the individual analysis of each patient should be considered in the assessment and therapeutic design.

CONCLUSIONS

There was no correlation between the anatomical and dynamic references for the points of inflection of the cervicothoracic and thoracolumbar transitions in 30% of the individuals studied. No statistical difference was observed between the lumbar lordosis measured using anatomical references and that measured using dynamic references. There was a statistical difference between the thoracic kyphosis values measured using the different anatomical references. There was a statistical difference between thoracic kyphosis evaluated using the different dynamic references and that measured using T5-T12 as a reference.

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. MPD and RM were the main contributors to the writing of the manuscript. GAM and GPP collected the clinical data. MPD, GAM, and GPP evaluated the statistical analysis data. MPD and RM conducted the bibliographical research andthe revision of the manuscript and contributed with the intellectual concept of the study.

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