Eur J Anat, 28 (4): 517-524 (2024)

Computed-tomography assessment of the lumbar spine body/canal index and review of the literature

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SUMMARY

Lumbar spinal stenosis (LSS) involves narrowing of the lumbar spinal space due to various factors. Torg-Pavlov Index measures predict LSS. The objective was to define the mean characteristics of the lumbar spine body/canal index in a Hispanic population stratified by age and sex. A retrospective, observational, transverse, and descriptive study was performed. Imaging studies included consecutive bone window full abdominal CT scans, in adult patients (≥18 years), without evidence of bone disease, musculoskeletal pathology, or traumatic event and a fully visible lumbar spine (L1-L5). The anteroposterior diameter (APD) and midsagittal diameter (MSD) of each vertebral level were measured using the Carestream image reformatting program at each lumbar vertebral level from L1 to L5 of the CT scan.

A total of 400 CTs of subjects with a mean age of 47.7±14.8 (range 18-80 years) were evaluated, of which 59.3% (n 237/400) were women. The presence of a ≤0.5 body/canal index was 31.6% (n 126). The MSD/APD lumbar index did not differ significantly between age groups in any of the vertebrae. However, there was a tendency to decrease with age. An mean index higher than 0.5 was the mean found in the patients evaluated where there was no previous data of spinal cord involvement. This study provides an accurate description of the normal morphometric parameters of the lumbar body/canal ratio in a Mexican population to assess clinical scenarios of lumbar spinal stenosis. Few studies evaluate the use of cut-off points to define an LSS.

Key words: Torg-Pavlov – Lumbar spinal stenosis – Computed tomography – Hispanic population

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Submitted: January 18, 2024 **Accepted:** February 9, 2024

https://doi.org/10.52083/KNGA7524

INTRODUCTION

Lumbar spinal stenosis (LSS) is defined as a narrowing of the spinal space at the lumbar level due to anatomical changes as a cascade of events including degeneration of the intervertebral disc, facet joint osteoarthritis, and hypertrophy of the ligamentum flavum (Verbiest, 1950; Jensen et al., 2020). LSS is classified into two types: Congenital and Acquired. Congenital or primary LSS can be mainly attributed to either a congenital abnormality or a postnatal development disorder, contrary to acquired or secondary LSS, which results from degenerative changes, trauma, infections, or surgical origin. (Genevay et al., 2010) Symptoms associated with this stenosis mainly include lower back pain, lower extremities weakness, paresthesia, and numbness (Jensen et al., 2020). Spinal stenosis increases the risk of neurological injuries in traumatic, degenerative, and inflammatory conditions (Zhang et al., 2012).

The measurement of the sagittal diameter of the lumbar canal has traditionally been considered the best predictor of lumbar stenosis (Eisenstein, 1977; Gepstein et al., 1991; Visuri et al., 2005). In the setting of the cervical spine the Torg-Pavlov method was developed to classify stenosis. This method calculates an index between the sagittal diameter of the body and the canal of the spine of the cervical vertebrae to determine stenosis (Pavlov et al., 1987). Some studies have correlated having cervical stenosis with having lumbar spinal stenosis (Iizuka et al., 2012). The measurement of the Torg-Pavlov Index in lumbar vertebrae in a cadaveric study proposed that it could be a useful technique for predicting lumbar stenosis (Bajwa et al., 2013). Based on their findings, the authors concluded a Torg ratio <0.5 predicted LSS. The primary objective of this study was to define the mean characteristics of the lumbar spine body/canal index in a Hispanic population stratified by age and sex, with comparison to other populations found in the literature.

MATERIAL AND METHODS

A retrospective, observational, transverse, and descriptive study was performed. Imaging studies included consecutive bone window full abdominal CT scans obtained from the Radiology and Imaging Department of the University Hospital in Monterrey, Mexico. All studies were performed using a General Electric CT99 LightSpeed VCT 64-slice Scanner ® (rotation 0.4s helicoidal acquisition, 20 mm detector covering, 120 Kv, 400+, 0.625 mm width slices).

Inclusion criteria were studies from adult patients (≥18 years), without gender distinction, who had a full abdominal CT performed without evidence of bone disease, musculoskeletal pathology, or traumatic event as an indication, and a fully visible lumbar spine (L1-L5). Exclusion criteria included studies that were part of a pre-surgical evaluation, or follow-up of an underlying disease with a diagnosis involving bone structures or the lumbar spine.

The anteroposterior diameter (APD) and midsagittal diameter (MSD) of each vertebral level were measured using the Carestream image reformatting program at each lumbar vertebral level from L1 to L5 of the CT scan. (Fig. 1) Using

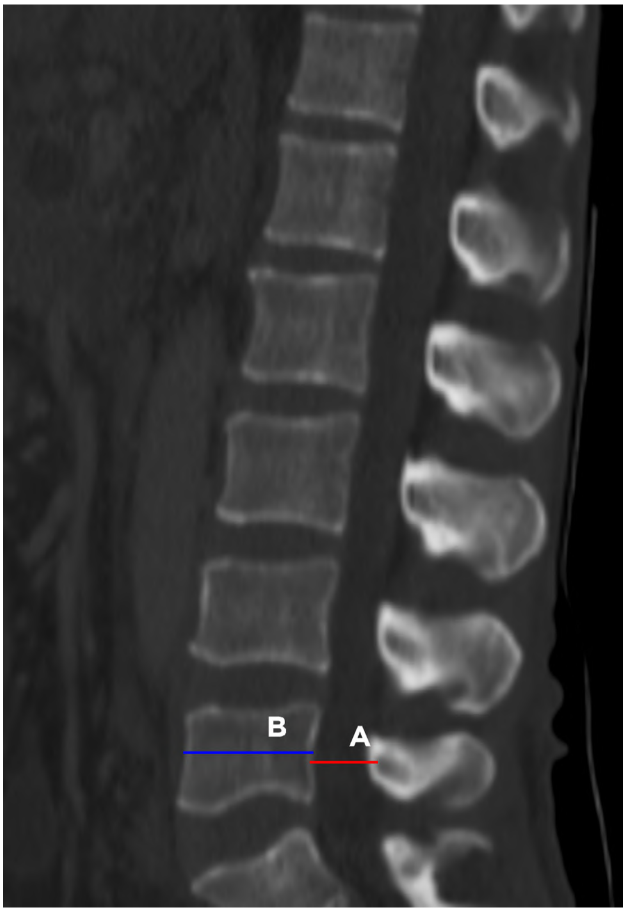

Fig. 1.- Midsagittal CT slice of vertebral column. The midsagittal diameter (A) and the antero-posterior diameter (B) of the vertebral body.

a mid-sagittal plane, the sagittal diameters of the body and canal of the lumbar spine at its 5 levels were taken to determine the lumbar ratio. Studies were evaluated by two non-blinded independent observers with experience in radiology and anatomy to establish measurements.

A sample size calculation was performed estimating the mean in a finite population, with a confidence of 95% and a margin of error of 5%, resulting in a total of 400. Normality tests were carried out using the Kolmogorov-Smirnov test. Central tendency and dispersion data were obtained, expressed as mean with standard deviation, frequencies, and percentages. Comparisons between the different groups obtained from the sample (sex, age) of the study were performed using a bilateral t-student test and One-Way ANOVA or with Mann-Whitney *U* test and Wilcoxon test, depending on the result of the normality tests. A value of $p < 0.05$ was considered statistically significant. SPSS Statistics version 22 (IBM, Armonk, NY, USA) was used for Windows 10.

The study was previously reviewed and approved by the University's Ethics and Research Committees with the registration code AH19-00001, certifying that it adheres to the guidelines of the General Health Law on Health Research in Human Beings of our country and the Helsinki Declaration. None of the CT scans were performed for the purposes of this study.

RESULTS

A total of 400 CTs were evaluated with a mean age of 47.7 ± 14.8 (range 18-80 years), of which 59.3% (n 237/400) were women (Table 1). Men tended to have a statistically significantly larger APD than women, while MSD had no differences, except in L5. This in turn resulted in a larger vertebral body, while the vertebral canal remained similar when compared by sex, causing a statistically significant difference in the MSD/APD lumbar index, with women having the higher value (Table 1, Fig. 2).

Subcategorization was carried out stratified by age decades for comparison between the variables. A statistically significant difference was found for all groups of the lumbar vertebral body using the APD, with a clear increase with age (Table 2, Fig. 3). A post hoc statistical adjustment with Bonferroni a statistical change was noted

Table 1. Measurements of vertebrae from L1 to L5 with comparison between sex.

		General (n 400)		Men (n 163)	Women (n 237)	p
		Mean±SD	Range	Mean±SD	Mean±SD	
L1	MSD	16.3±1.5	11.9-20.5	16.3±1.5	16.3±1.4	0.784
	APD	28.2±2.9	22.0-36.6	30.3±2.5	26.8±2.2	<0.001*
	Index	0.58±0.08	0.38-0.86	0.54±0.07	0.61±0.08	<0.001*
L2	MSD	15.7±1.5	11.0-22.3	15.7±1.6	15.7±1.5	0.995
	APD	29.2±3.0	22.1-37.6	31.2±2.6	27.9±2.4	<0.001*
	Index	0.54±0.08	0.35-0.79	0.51±0.07	0.57±0.08	<0.001*
L3	MSD	15.2±1.8	10.0-29.3	15.3±2.0	15.2±1.6	0.972
	APD	30.3±3.1	14.1-40.0	32.2±3.1	28.9±2.4	<0.001*
	Index	0.51±0.11	0.32-2.08	0.48±0.15	0.53±0.08	<0.001*
L4	MSD	15.5±1.9	10.4-22.3	15.7±2.0	15.4±1.8	0.118
	APD	30.9±3.0	22.2-40.0	32.8±2.7	29.6±2.4	<0.001*
	Index	0.51±0.08	0.32-0.79	0.48±0.08	0.52±0.08	<0.001*
L5	MSD	16.4±2.6	10.4-31.0	16.8±2.9	16.1±2.4	0.014*
	APD	30.8±3.0	17.3-39.0	32.5±3.1	29.6±2.3	<0.001*
	Index	0.54±0.11	0.32-1.79	0.53±0.14	0.55±0.09	0.001*

Values expressed as millimeters. P value calculated for Statistical significance with Mann-Whitney U test for independent samples; significance set a p <0.05. n: sample size; MSD: Midsagittal diameter, APD: Anteroposterior diameter, SD: Standard deviation.

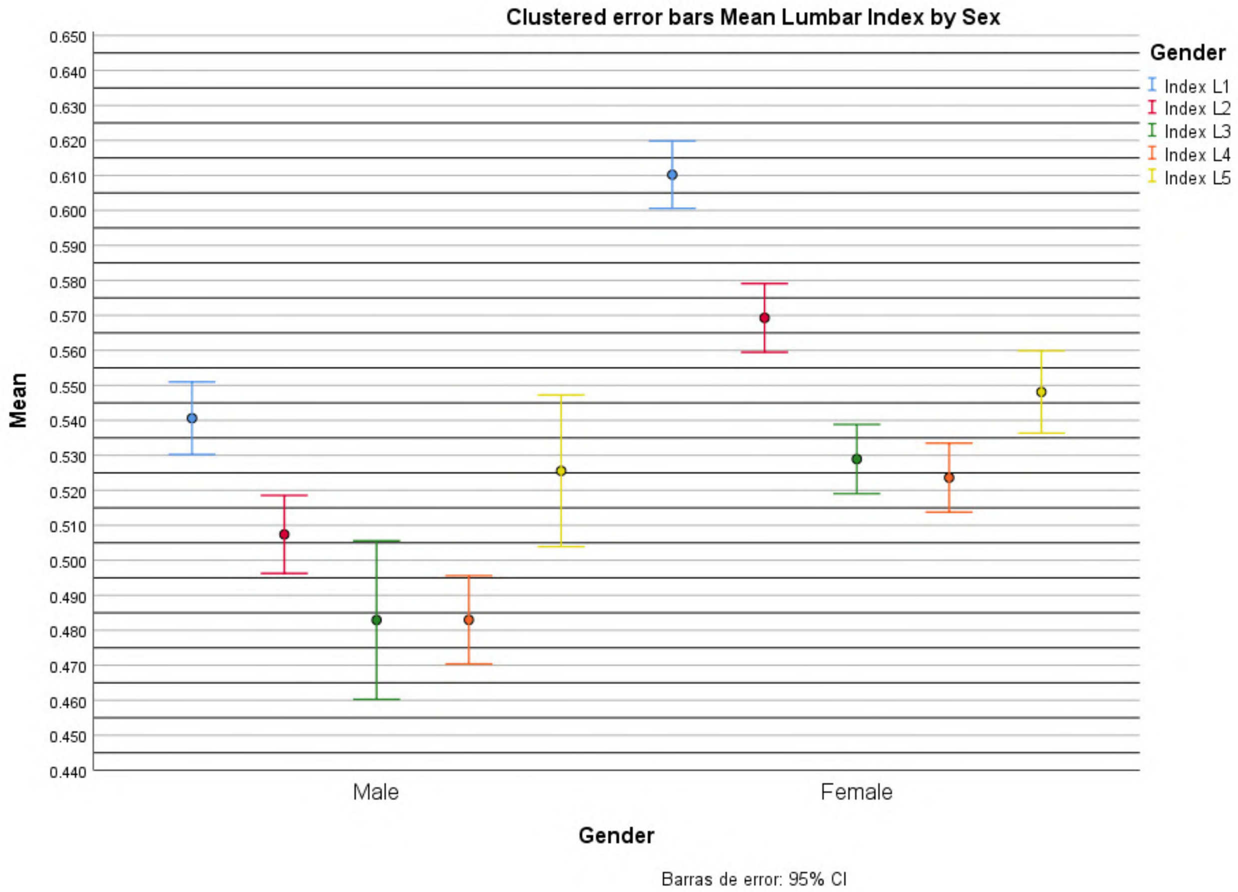

Fig. 2.- Pooled 95% error bar graph with mean MSD/APD ratio (y-axis) between men and women (x-axis).

Table 2. Measurements of vertebrae from L1 to L5 with comparison between categorical age groups.

		Mean±SD by Age groups						p
		≤29 (n)	30-39 (n)	40-49 (n)	50-59 (n)	60-69 (n)	≥70 (n)	
L1	MSD	16.3±1.6	16.2±1.3	16.1±1.4	16.3±1.5	16.3±1.3	16.3±1.7	0.879
	APD	27.3±2.9	28.3±2.9	28.0±3.1	28.2±2.5	29.0±2.7	29.5±2.7	0.004*
	Index	0.60±0.08	0.58±0.08	0.58±0.08	0.59±0.08	0.57±0.07	0.56±0.08	0.145
L2	MSD	15.6±1.3	15.4±1.3	15.6±1.5	15.9±1.7	16.0±1.6	16.1±1.6	0.171
	APD	28.4±2.8	29.3±2.9	29.1±3.2	29.2±2.8	29.8±3.2	30.3±2.6	0.035*
	Index	0.55±0.07	0.53±0.08	0.54±0.08	0.55±0.08	0.55±0.09	0.54±0.08	0.638
L3	MSD	15.2±1.5	14.9±1.4	15.2±2.2	15.2±1.7	15.5±1.9	15.6±1.9	0.375
	APD	29.1±2.9	30.3±3.0	30.0±3.5	30.4±2.8	31.2±3.2	31.7±3.0	0.001*
	Index	0.53±0.07	0.50±0.08	0.52±0.18	0.51±0.08	0.50±0.09	0.50±0.09	0.201
L4	MSD	15.7±1.9	15.4±1.7	15.4±1.8	15.4±1.9	15.7±2.1	15.8±1.9	0.697
	APD	29.7±2.9	30.7±2.7	30.6±3.1	31.0±2.6	32.0±3.1	32.5±2.9	0.000*
	Index	0.54±0.09	0.51±0.08	0.51±0.08	0.50±0.08	0.50±0.09	0.49±0.08	0.084
L5	MSD	16.5±2.9	16.6±2.6	16.1±2.4	16.3±2.9	17.0±2.6	16.3±1.7	0.414
	APD	29.7±3.0	30.8±2.8	30.4±3.0	30.9±2.9	31.7±2.9	32.2±2.6	0.002*
	Index	0.56±0.12	0.55±0.10	0.53±0.08	0.54±0.16	0.54±0.08	0.51±0.07	0.315

Values expressed as millimeters. P value calculated for Statistical significance with Kruskal-Wallis test for independent samples; significance set a p <0.05. n: sample size; MSD: Midsagittal diameter, APD: Anteroposterior diameter, SD: Standard deviation.

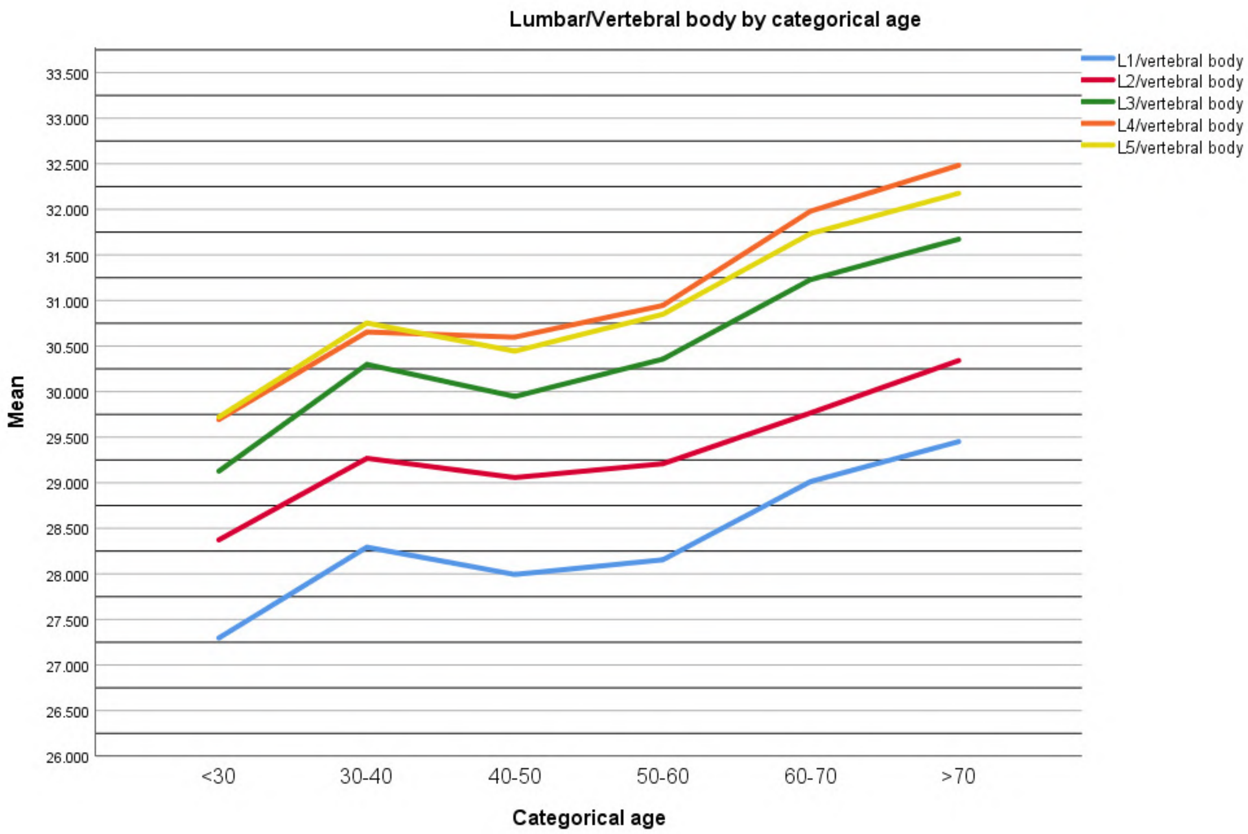

Fig. 3.- Comparison between categorical age groups of the APD ratio stratified by age decades.

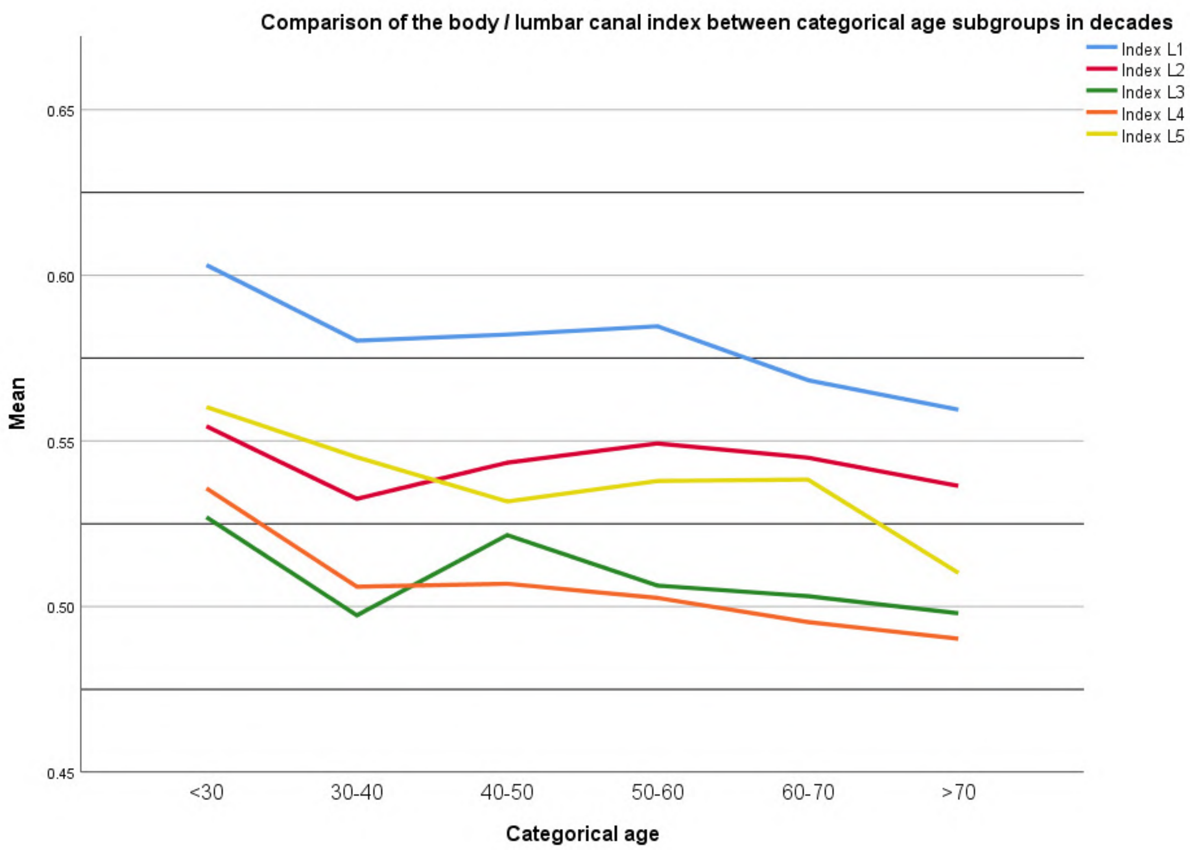

Fig. 4.- Comparison of the MSD/APD ratio between categorical age subgroups stratified by age decades.

between the groups of 50 to 60 years and older than 70 years with all the other age subgroups ($p < 0.05$). The MSD/APD lumbar index did not differ significantly between age groups in any of the vertebrae, however, there was a tendency to decrease with age (Fig. 4).

The presence of index lower than 0.5 was determined. In 126 (31.6%) of the patients the index was lower than 0.5, these patients being considered asymptomatic. In the case of women, 45 (35.7%) had an index lower than 0.5 while in men 81 patients (64.3%) had an index lower than 0.5.

DISCUSSION

Multiple morphometric studies focus on studying different measurements of the vertebral bones (Eisenstein et al., 1977; Gepstein et al., 1991; Bajwa et al., 2013; Amonoo-Kuofi et al., 1985; Azu et al., 2016). However, it's worth pointing out that vertebral anatomy goes beyond the bony structures, and involves a complex set of soft tissue structures that are vulnerable to many factors, both congenital and acquired, such as age, trauma, occupation, posture, etc (Genevay et al., 2010). Although LSS is defined as a narrowing of the spinal space at the lumbar level due to anatomical changes, there is no consensus on a strict measure to be able to identify it through imaging studies such as magnetic resonance imaging or computed tomography.

In a sample obtained from the Framingham Study of patients with LBP (Lower Back Pain), stenosis in the study population was defined as ≤12 mm ("relative" stenosis) and ≤10 mm ("absolute" stenosis). These cut-off points were arbitrarily obtained based on the cut-off points used in multiple studies (Kalichman et al., 2009).

Normal cut-off points for the MSD/APD lumbar index have not been described. Qudsieh et. al mentions in his study conducted in the Jordanian population, in patients without spinal pathology or LBP an average index of 0.45 (0.43-0.46) (Qudsieh et al., 2022)

In our population, we found a statistically significant difference in the vertebral body with age. The older populations had a greater APD. The spinal column functions as a shock-absorbent structure mainly by intervertebral discs, but involves skeletal structures as well, and gradually decreases its shock-absorbing capability with senescence (Brzuszkiewicz-Kuźmicka et al., 2018). The increase of APD with age may be hypothesized to be related to the decrease in shock absorption capability.

In turn, there is a decrease in the Torg-Pavlov index, associated with age, where for each decade of life this index decreases, especially when going from the fourth decade of life to the fifth, although this relationship was not statistically significant. The mean in the index in these patients without spinal pathology was not lower than 0.5 in any of the vertebral levels.

The importance of anatomy research with a clinical orientation is well established (Quiroga-Garza et al., 2020; Yammine, 2014; Tapia-Nañez et al., 2022). Anatomical understanding of the different clinical problems arising can guide clinical decisions and the learning of physicians (Garcia-Leal et al., 2021; Muñoz-Leija et al., 2018; Esparza-Hernández et al., 2017). Examples of how knowledge of morphometric characteristics in skeletal structures with the purpose of better understanding and predicting clinical outcomes can be found widely in medical literature, both in basic and clinical sciences (Muñoz-Leija et al., 2018; Vázquez-Barragán et al., 2016; Guzman-Lopez et al., 2019; Vazquez-Zorrilla et al., 2020). Bajwa et al. (2013) described 420 skeletal specimens and concluded that a ratio of lower than 0.5 could be associated with a probability of spinal stenosis. In our study, in the general measurements of the patients, evaluated by each one of the vertebral levels, an index higher than 0.5 was observed, taking into account that these patients did not present previous alterations at the lumbar spinal cord level before performing the imaging study.

In 126 patients (31.6%), when performing a mean of the vertebral level indices, these were classified with an index of lower than 0.5, although these patients did not have spinal cord compromise when they were chosen for the study.

However, they state the limitation of not considering the soft tissue component in the pathogenesis of disease. (Bajwa et al., 2013) The use of CT not only improves the quality of the evidence, it allows the inclusion of ligaments and other musculoskeletal structures. (Bajwa et al., 2013; Javid et al., 2013).

It is important to emphasize that there is no standard measure in the index that can predict the presence of LSS. Studies in Jordanian patients without lumbar pathology showed an index lower than the means obtained in our population (Table 3) and where the presence of symptoms associated with LSS was not reported (Qudsieh et al., 2022).

Geographic and ethnic characteristic of different populations influences the anatomy (Teran-Garza et al., 2021). Morphometric studies have reported different mean indexes for the lumbar spine, with the highest index among Nepalese (Table 3). However, methodological techniques may influence, such as the use of dry bones (some may have deteriorated), incomplete samples, and lack of inter- and intra-observer confidence coefficients (Bajwa et al., 2013; Azu et al., 2016; Mansur et al., 2020). All studies were also limited by the lack of height and weight of the individuals.

LSS pathophysiology has not been completely understood.N, it has been shown that posture, disc pathology, vascular flow obstruction, and cerebrospinal fluid are influencing factors (Genevay et al., 2010). However, the evaluation of these is limited through imaging techniques, and therefore the relevance of the MSD/APD ratio will continue to be an objective tool, limited for considering only the skeletal structures.

Limitations

Our study has the limitation of being an observational morphometric imaging study that does not consider the clinical characteristics of the patient such as the presence of LBP. Therefore, the clinical correlation of the imaging studies remains the most important assessment of the patient.

CONCLUSIONS

This study provides an accurate description of the normal morphometric parameters of the lumbar body/canal ratio in a Mexican population to assess clinical scenarios of LSS. Few studies evaluate the use of cut-off points to define an LSS.

An index greater than 0.5 was the average found in the patients evaluated where there was no previous data on spinal cord involvement. Further studies are necessary to address both clinical characteristics and radiological characteristics to define the cut-off points associated with the presence of LSS.

Table 3. Torg-Pavlov MSD/APD Index for Lumbar column, differences in populations.

Author, year, country	Sample	L1	L2	L3	L4	L5
Azu et al., 2013 South Africa	107 Dry bone	0.65±0.09	0.52±0.07	0.53±0.07	0.52±0.05	0.53±0.06
Bajwa et al., 2014 USA	420 Dry bone	0.57±0.07	0.55±0.06	0.53±0.06	0.52±0.07	0.52±0.08
Mansur et al., 2020 Nepal	266 CT	0.60±NR	0.60±NR	0.58±NR	0.58±NR	0.54±NR
Qudsieh et al., 2021 Jordanian	68* MR	0.51±0.08	0.46±0.09	0.40±0.08	0.42±0.08	0.46±0.12
Teran-Garza et al., 2023 Mexico	400 CT	0.58±0.08	0.54±0.08	0.51±0.11	0.51±0.08	0.54±0.11

CT: computed tomography; SD: Standard deviation. NR: Not reported.
* Original study by Qudsieh et al. (2022) included 218 patients, however, the general measurements per vertebra were not reported, so the most extensive age group evaluated (50-59 years) was taken for comparison.

Ethical Approval

The study was previously reviewed and approved by the University's Ethics and Research Committees with the registration code AH19-00001, certifying that it adheres to the guidelines of the General Health Law on Health Research in Human Beings of our country and the Helsinki Declaration. None of the CT scans were performed for the purposes of this study.

Availability of data and materials

The data generated and analyzed during the current study are not publicly available but are available through the corresponding author on reasonable request.

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