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Investigation of Lumbar Vertebrae and Disc Morphometry with Computed Tomography in Turkish Adults

Investigación de Vértebras Lumbares y Morfometría del Disco con Tomografía Computarizada en Adultos Turcos

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SUMMARY: Conducting morphometric studies including many parameters and establishing certain standards for the anatomy of the lumbar spine will facilitate clinical applications. The Turkish example of lumbar vertebrae and disc morphometry has not yet been presented comprehensively.In our study, abdominal computed tomography images of 700 adults were evaluated retrospectively. It was observed that the anterior height of the vertebral bodies increased from L1 to L4 in males, and from L1 to L5 in females. The posterior height of the vertebral bodies was lowest at L5 in both sexes, while it was highest at L3 in males and L4 in females. In all age groups, the values for males were greater ($p<0.05$). It was observed that the width and depth of the spinal canal increased from L1 to L5 in males and from L2 to L5 in females, with L2 being the smallest in females. The values for males were greater in the same age groups for both parameters ($p=0.05$). The values for the right transverse pedicle angle increased from upper levels to lower levelsin both sexes, while for the left transverse pedicle angle, it was smallest at L2 and increased towards L5. There was no sex-related difference ($p>0.05$). In all age groups and both sexes, an increase in anterior disc heights towards disc 5 was observed. The values for males were greater than those for females ($p<0.05$). The posterior disc height at disc 5 was higher in females, and in other discs, it was higher in males ($p<0.05$). In conclusion, it was found that the measurement values of the parameters examined varied according to lumbar level and sex, but were independent of age. The morphometric data we obtained are important in terms of providing a reference for the people of our region and contributing to the literature.

KEY WORDS: Lumbar vertebrae; Morphometry; Computed tomography; Intervertebral disc.

INTRODUCTION

The column located on the posterior side of the torso, along the midline, is referred to as the spine. The vertebrae that make up the spine are fundamentally similar to each other. However, they have acquired different structural features based on their location, the tasks they undertake, and regional functions (Standring, 2008).

Structural and compositional changes occur in the anatomical structures constituting the spine with aging. This condition can increase the risk of trauma-related damage and have a negative impact on the quality of life. Aging leads to changes such as loss of bone mineral density, trabecular thinning, and loss of connection between trabeculae, all of which contribute to an increased risk of vertebral fractures. Changes in the shape and composition of intervertebral discs due to aging restrict movements and alter the mechanical properties of the spine (Ferguson & Steffen, 2003).

Vertebral fractures and disc pathologies due to trauma are quite common. Sufficient knowledge of the anatomy of the lumbar region is essential for successful surgery. The pedicle, which serves as a junction between the posterior and anterior parts of the spine, is important in vertebral surgery, and the use of pedicle screws has become a key element in lumbar fusion surgery (Tall *et al*., 2018). With the increasing use of screws in vertebral surgery, the risk of injury to both the vertebra and the adjacent vessels and nerves with improperly sized screws has also increased significantly (Singh *et al*., 2014).

Given the potential serious complications of incorrect instrument application, it is important to distinguish the differences in vertebral morphometrics between males and females and understand the changes that occur with aging (Mohanty *et al*., 2018).

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Determining the normal morphometric values of lumbar vertebras and discs and contributing to the selection of implants for vertebral surgery in appropriately sized individuals constitute the aim of our study for the benefit of our community.

MATERIAL AND METHOD

Ethical approval for this study was obtained from the ethics committee (OMU KAEK date: 13.04.2017 decision no: 2017/08). Abdominal computed tomography (CT) images taken with an 8-channel spiral CT of individuals who applied to the Health Research and Application Center of Tokat Gaziosmanpas¸a University between 2014 and 2016 were examined. Individuals with no deformities, no history of fractures, and no prior surgeries were included in the study. Measurements were performed on axial, coronal, and sagittal reformatted images created using the SECTRA PACS system. Vertebral morphometric data were assessed from the CT images of the lumbar region to generate the study's data.

A total of 700 images belonging to individuals between the ages of 20 and 69 were evaluated in our study group, consisting of 429 (61.29%) males and 271 (38.71%) females (Table I).

Table I. Distribution of the study group according to age and sex.

Age Group (years)	Male (n)	Female (n)	Total (n)
20-29	109	40	149
30-39	68	52	120
40-49	68	61	129
0-59	72	57	129
60-69	112	61	173
Total	429	271	700

The parameters measured in the lumbar region were as follows: vertebral body width (VBW), vertebral body depth (VBD), spinal canal width (SCW), spinal canal depth (SCD), pedicle length (PL), pedicle width (PW), transverse pedicle angle (TPA), anterior height of vertebral body (CAH), posterior height of vertebral body (CPH), anterior height of intervertebral disc (DAH), mid-height of intervertebral disc (DMH), and posterior height of intervertebral disc (DPH) (Fig. 1).

Statıstical Analysis. The SPSS 20.0 software package was used to analyze the data. As the data met the assumptions of parametric tests, groups were compared using the independent sample T-test. The Levene test was utilized to assess homogeneity. A significance level of $p < 0.05$ was considered statistically significant.

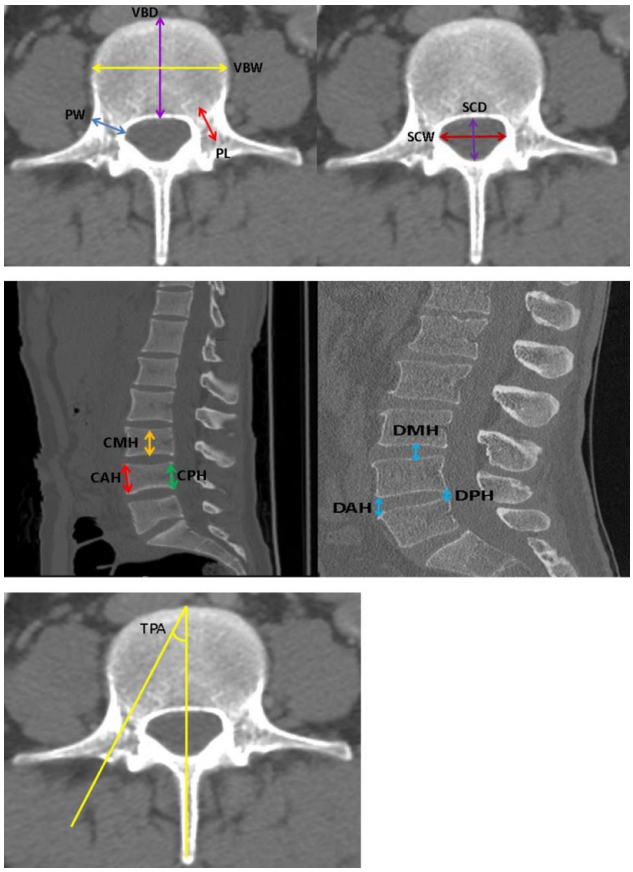

Fig. 1. Parameters measured in the lumbar region with computed tomography (CT) 8-channel spiral CT. VBW, vertebral body width; VBD, vertebral body depth; SCW, spinal canal width; SCD, spinal canal depth; PL, pedicle length; PW, pedicle width; TPA, transverse pedicle angle; CAH, anterior height of vertebral body; CPH, posterior height of vertebral body; DAH, anterior height of intervertebral disc; DMH, mid-height of intervertebral disc; DPH, posterior height of intervertebral disc.

RESULTS

The measurement values of lumbar VCW, VCD, SCW, SCD, PL (left), PL (right), PW (left), PW (right), TPA (left), and TPA (right) were found to increase from L1 to L5 in both males and females, with the smallest values observed at L2 for SCW, SCD, TPA (left) in females, and PL (left) in males (Tables II and III).

Additionally, when comparing the measurement values of VCW, VCD, SCW, SCD, PL (left), PL (right), PW (left), PW (right), CAH, and CPH between males and females for all age groups, it was determined that these values were larger in males ($p=0.000$) (Fig. 2).

In females, TPA (left) measurement values were larger than those of males at all lumbar vertebral levels, while

TPA (right) values were larger in males at L2 and L4 levels (Tables II and III), (Fig. 3). Only in the 60-69 age group, the differences in TPA (left) values at L2 and L4 levels were statistically significant ($p<0.05$) (Fig. 3).

There was no specific ranking of disc height measurement values at each lumbar level, and it was observed that in some levels, females had higher measurement values, while in others, males had higher values (Tables IV and V), (Fig. 3).

In the 20-29 and 30-39 age groups, males had larger DAH measurement values at disc levels 4 and 5, and in the 40-49 age group, males had larger values at disc levels 3, 4, and 5 compared to females, and this difference was statistically significant ($p<0.05$). Again, in the 50-59 and 60-69 age groups, males had larger values at disc levels 4 and 5, which was significant ($p=0.000$).

For DMH measurement values, males had larger values at each lumbar level (Table IV and V), (Fig. 3). This difference was significant at disc levels 3, 4, and 5 in the 20-29, 50-59, and 60-69 age groups, at disc levels 2, 4, and 5 in the 30-39 age group, and at disc levels 2, 3, 4, and 5 in the 40-49 age group ($p<0.05$).

When comparing DPH measurement values between males and females, males had larger values at disc levels 1, 2, 3, and 4, while females had larger values at disc level 5 (Tables IV and V), (Fig. 3). These differences were significant at disc levels 1, 2, and 4 in the 20-29 and 50-59 age groups, at disc levels 1, 2, 3, and 4 in the 40-49 and 60-69 age groups, at disc levels 2 and 4 in the 30-39 age group, and at disc level 5 in all age groups ($p<0.05$).

It was observed that there were differences in lumbar levels and sex for the evaluated parameters, and no age-related changes were detected.

Table II. Mean results of linear and angular measurement of lumbar vertebrae (male overall average).

VCW (mm)	VCD (mm)	SCW (mm)	SCD (mm)	PL left (mm)	PL right (mm)	PW left (mm)	PW right (mm)	TPA left (°)	TPA right (°)	CAH (mm)	CPH (mm)
42,48	31,54	22,04	14,47	22,53	22,51	7,99	7,96	14,43	14,46	29,58	28,03
47,56	33,55	24,32	16,03	22,45	22,54	9,51	9,54	14,44	14,51	29,99	28,05
51,48	35,41	25,52	17,53	24,46	24,50	12,02	11,86	15,57	15,50	30,64	28,94
55,45	37,53	26,39	19,03	25,91	26,06	16,93	17,04	15,97	16,05	30,66	29,01
59,53	38,90	27,48	20,09	26,96	26,98	20,03	20,07	17,97	18,19	30,58	27,54

Table III. Mean results of linear and angular measurement of lumbar vertebrae (female overall average).

VCW (mm)	VCD (mm)	SCW (mm)	SCD (mm)	PL left (mm)	PL right (mm)	PW left (mm)	PW right (mm)	TPA left (°)	TPA right (°)	CAH (mm)	CPH (mm)
37,40	28,07	20,59	13,10	20,52	20,49	6,97	6,97	14,66	14,45	26,84	26,75
40,48	28,51	20,30	13,09	20,55	20,54	8,47	8,51	14,60	14,65	27,46	26,09
43,47	28,98	22,95	15,10	22,50	22,49	10,43	10,48	15,61	15,43	27,92	27,17
47,06	31,52	24,63	16,94	23,49	23,38	15,02	14,88	16,04	16,11	27,92	27,11
52,21	33,65	25,38	17,61	23,94	23,98	16,81	16,60	18,00	18,18	27,95	25,48

Table IV. Mean results of linear measurement of lumbar discs (male overall average)

	DAH (mm)	DMH (mm)	DPH (mm)
Disc 1	6,03	7,00	4,03
Disc 2	6,03	8,42	4,58
Disc 3	8,37	8,52	4,94
Disc 4	10,39	9,42	5,50
Disc 5	11,93	10,52	3,96

Table V. Mean results of linear measurement of lumbar discs (female overall average)

	DAH (mm)	DMH (mm)	DPH (mm)
Disc 1	6,08	6,85	3,58
Disc 2	6,09	8,07	3,97
Disc 3	8,07	8,04	4,48
Disc 4	9,02	8,39	5,03
Disc 5	10,42	9,41	6,94

DISCUSSION

In today's active lifestyle, spinal traumas that affect the spine are quite common. Trauma-related lumbar spine lesions can occur in the elderly due to decreased bone density, and in young individuals due to daily life activities. Postoperative complications can arise with varying severity and perspective depending on the difference in the procedure

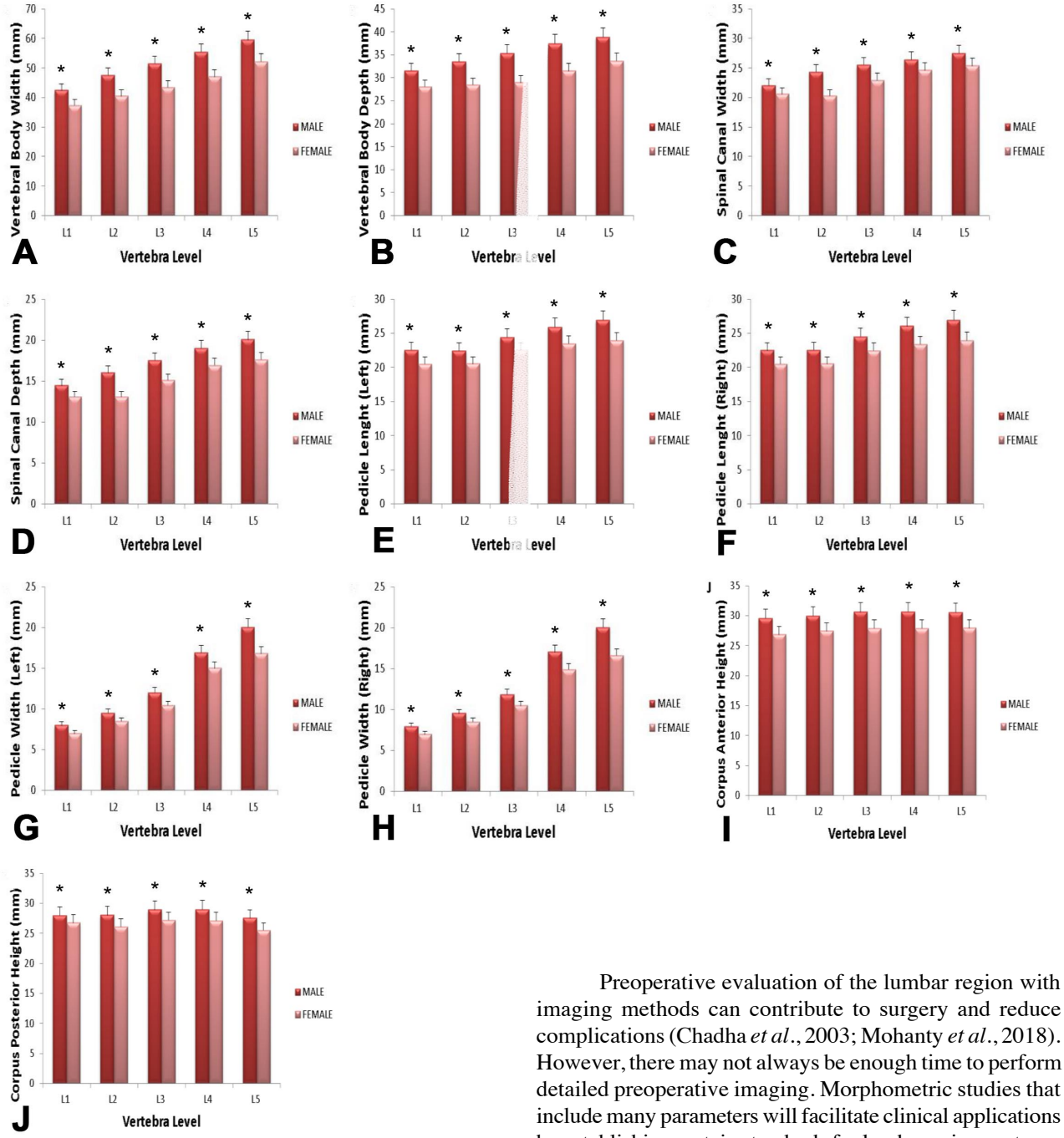

Fig. 2. Comparison of lumbar vertebral dimensions according to sex. *, P=0.000.

to be performed in case of surgery and its duration. In spinal surgery, complications can increase both in terms of the duration of surgery and the need for a more comprehensive approach when instrumentation is required, compared to cases where only decompression is applied. This leads to more complications (Chadha *et al*., 2003; Ferguson & Steffen, 2003; Saleh *et al*., 2017).

Preoperative evaluation of the lumbar region with imaging methods can contribute to surgery and reduce complications (Chadha *et al*., 2003; Mohanty *et al*., 2018). However, there may not always be enough time to perform detailed preoperative imaging. Morphometric studies that include many parameters will facilitate clinical applications by establishing certain standards for lumbar spine anatomy (Choubey *et al*., 2018). Looking at the literature, it can be observed that there are not many studies evaluating lumbar vertebrae and discs, and the number of individuals evaluated in these studies is also limited (Gilsanz *et al*., 1994; Abuzayed *et al*., 2010; Göçmen-Mas *et al*., 2010). When looking at the examined parameters, our study is more comprehensive than other studies in the literature; however, it was also observed that some parameters evaluated in other studies were not included in our evaluation (Chadha *et al*., 2003; Alam *et al*., 2014).

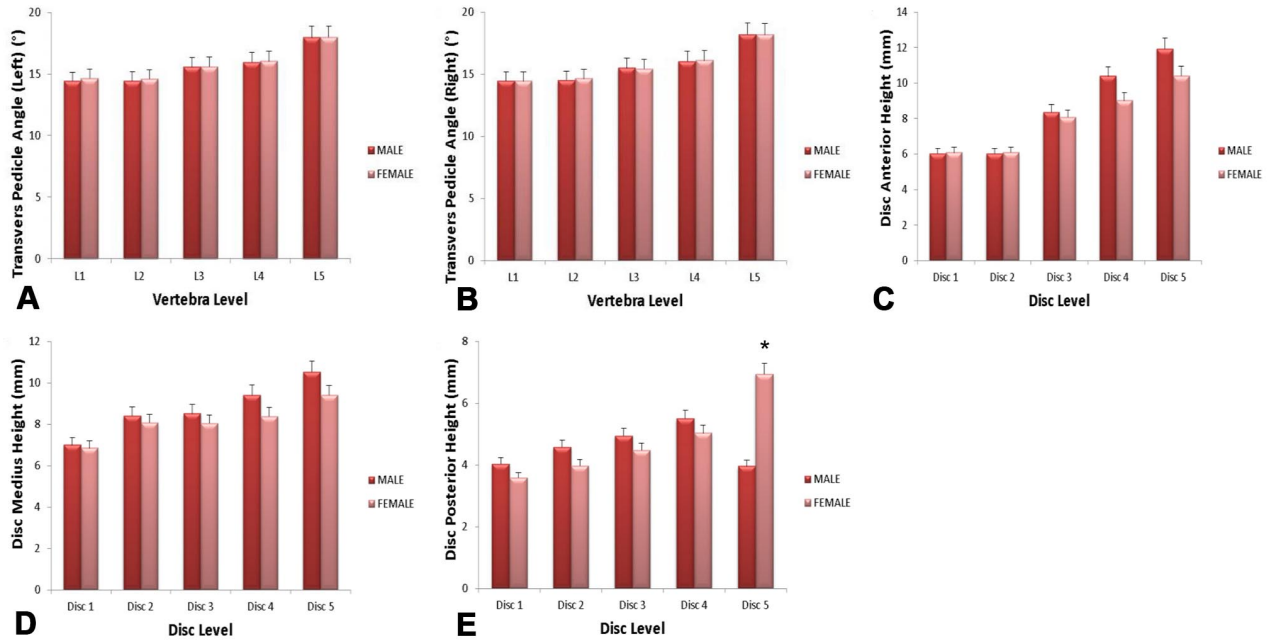

Fig. 3. Comparison of lumbar vertebra and disc dimensions according to sex. *, P=<0.05.

In various studies where measurements were made using CT and MR images, as well as cadaver and dry bones, VCW and VCD were measured as the smallest at L1 and gradually increased to the largest at L5 (Abuzayed *et al*., 2010; Kang *et al*., 2011; Karabekir *et al*., 2011; Singh *et al*., 2014; Alam *et al*., 2014; Yadav *et al*., 2020). VCW values have been reported to be higher in males than in females in various CT and MR studies (Gilsanz *et al*., 1994; Göçmen-Mas *et al*., 2010; Tall *et al*., 2018). However, there is also a study in the literature reporting no sex difference in VCD values (Göçmen-Mas *et al*., 2010). Abuzayed *et al*. (2010) reported that knowing VCD would help determine the safe maximum length of screws to be placed in vertebral surgery. In our study, in line with the literature (Abuzayed *et al*., 2010; Kang *et al*., 2011; Karabekir *et al*., 2011; Singh *et al*., 2014; Alam *et al*., 2014; Tall *et al*., 2018; Yadav *et al*., 2020), lumbar VCW and VCD were found to be the lowest at L1 and gradually increased to the highest at L5. However, it was observed that VCW and VCD of males in all age groups were larger than those of females in the same age range. Additionally, it was determined that these parameters did not vary with age.

Tall *et al*. (2018), found SCW to be larger in males than females, while conversely, Acar *et al*. (2013) found it to be larger in females than males. However, in both studies, SCW was measured as the smallest at L1 and gradually increased to the largest at L5. Alam *et al*. (2014) stated that SCW was the smallest at L3. In addition, values for males were found to be larger than those for females. Our results were consistent with the literature (Karabekir *et al*., 2011). In our study, SCW was found to be larger in males than females. Also, although females had the smallest SCW value at L2, it was determined that SCW increased from L1 to L5 in both males and females. In various studies evaluating SCD (Acar *et al*., 2013; Kumar *et al*., 2016; Tall *et al*., 2018; Yadav *et al*., 2020), the largest value was found at L1 in both males and females. Tall *et al*. (2018), determined that L3 had the smallest SCD in both sexes, while Acar *et al*. (2013) only found this in males. According to Alam *et al*. (2014), SCD decreased from L1 to L4 in males and from L1 to L5 in females. Yadav *et al*. (2020) and Kumar *et al*. (2016) found that SCD decreased below L1. Studies reporting that SCD values in females are larger than those in males (Karabekir *et al*., 2011; Acar *et al*., 2013; Kumar *et al*. 2016; Yadav *et al*., 2020), were contrary to our study where SCD values were larger in males. However, it was determined that SCD increased towards L5, unlike the literature, where it did not vary with age.

Looking at studies in the literature, PL and PW are reported to be the smallest at L1 and gradually increase to the largest at L5. It is emphasized that knowing pedicle morphometrics is necessary to avoid damage to adjacent structures due to the selection of incorrect pedicle screws (Chadha *et al*., 2003; Abuzayed *et al*., 2010; Karabekir *et al*., 2011; Güleç *et al*., 2017; Tall *et al*., 2018). Karabekir *et al*. (2011), found that pedicle values in males were higher than those in females. In our study, while PL and PW were evaluated separately on the left and right sides, the results

were similar to the literature (Chadha *et al*., 2003; Abuzayed *et al*., 2010; Karabekir *et al*., 2011; Güleç *et al*., 2017; Tall *et al*., 2018), increasing towards L5, being higher in males. However, Choubey *et al*. (2018), in contrast to other results, reported that there was no difference between sexes when measuring PL as the smallest at L5 and the largest at L1. Singh *et al*. (2014), found PL to be the smallest at L5 and the largest at L3. In our study, it was found that there was no change in PL and PW values with increasing age. When comparing the lumbar vertebrae at the same level between males and females, males had larger values.

In various studies on lumbar vertebrae, the measurements of TPA have been observed to be the lowest at L1 and gradually increase, reaching the highest at L5 (Chadha *et al*., 2003; Abuzayed *et al*., 2010; Singh *et al*., 2014; Güleç *et al*., 2017; Tall *et al*., 2018). Additionally, TPA values have been examined in relation to sex in various studies, but no differences in TPA between females and males have been reported (Alam *et al*., 2014; Güleç *et al*., 2017). In contrast to these studies, Karabekir *et al*. (2011), found that when comparing the left TPA of males and females at the same level, females had higher values, and when comparing the right TPA, females had higher values at L1, L2, and L4, while males had higher values at L3 and L5. In our study, while left and right TPAs were measured separately, the results were similar on both sides, and no age-related changes were observed.

Reviewing the literature, CAH is reported to be the smallest at L1 and the largest at L5 (Karabekir *et al*., 2011; Atta-Alla *et al*., 2014; Singh *et al*., 2014; Tall *et al*., 2018). However, there are studies reporting different results in CAH values (Abuzayed *et al*., 2010; Alam *et al*., 2014). Furthermore, CAH values in males have been reported to be higher than in females (Karabekir *et al*., 2011; Alam *et al*., 2014; Tall *et al*., 2018). In our study, CAH values in males increased from L1 to L3, while in females, they increased from L1 to L5. Male values were higher in all age groups, and no change occurred with age.

Various studies on CPH have found the smallest CPH value at L5 and the largest at L2 (Abuzayed *et al*., 2010; Singh *et al*., 2014; Alam *et al*., 2014; Tall etal., 2018). However, there are also studies with different results in CPH values (Karabekir *et al*., 2011; Alam *et al*., 2014; Atta-Alla *et al*., 2014). CPH values have been reported to be higher in males than females (Karabekir *et al*., 2011; Alam *et al*., 2014; Tall *et al*., 2018). In our study, similar to the literature, there were no age-related changes in CPH, and values were larger in males than females at every level.

Looking into studies on intervertebral discs, Göçmen-Mas *et al*. (2010), reported that DAH decreases with age. Atta-Alla *et al*. (2014), focusing only on females, and Fyllos *et al*. (2018), evaluating both sexes, observed an increase in DAH from disc 1 to disc 5, and no significant relationship between disc morphometric measurements and individual weights was found. In our study, consistent with the literature, DAH increased from disc 1 to disc 5, and no age-related changes were observed.

Bach *et al*. (2018) found that DMH increases in advanced age groups, with no changes in DAH and DPH values. They also noted no correlation between disc heights and age, and females had significantly lower disc heights than males.

In our study, the results of DMH were increasing from disc 1 to disc 5 in both sexes, and were lower in females compared to males. Additionally, no age-related changes were detected. In accordance with Atta-Alla *et al*. (2014), our study yielded different results in DPH measurements based on level and sex, with no age-related changes identified.

Looking into various studies, different results have been reported, which we believe may stem from genetic and environmental variations in the measured structures or individual differences in the approach of the investigators.

In spinal surgery, it is crucial to evaluate vertebral morphology with precision before the operation to select implants of suitable size for the individual and prevent unwanted complications (Chadha *et al*., 2003). It has been emphasized that a sufficient understanding of lumbar vertebral morphometrics is essential for successful surgery and proper instrumental techniques, and this knowledge is crucial for the posterior fixation technique in spinal anatomy (Karabekir *et al*., 2011; Alam *et al*., 2014).

Various interventional procedures and surgical techniques, such as vertebral biopsy, pedicle screw implantation, discectomy, transforaminal endoscopic surgery, and intervertebral foramen decompression, are applied in clinical practice (Liu *et al*., 2019). The success of spinal fusion surgeries is said to depend on factors such as pedicle size, bone structure, and accuracy in screw selection (Singh *et al*., 2014). The pedicle, intersecting between the posterior and anterior parts of the spine, is highly significant in vertebral surgery, and the use of pedicle screws has become a central element in lumbar fusion surgery (Tall *et al*., 2018). The increasing use of various screw instrumentation has led to an increase in

pedicle, facet joint, and nerve root injuries. Concerns about abnormally sized pedicle screws near vital organs are growing. It has been observed that larger diameter screws are stronger and yield better results, but concerns arise from the relatively large size of screws leading to pedicle fractures (Singh *et al*., 2014). Compared to transpedicular screw applications, there is a higher risk of damaging lumbar arteries and branches in extrapedicular screw applications (Heo & Cho, 2011; Liu *et al*., 2016). For the safe and accurate placement of pedicle screws, it is crucial to have knowledge about vertebral morphometrics, ensuring the correct entry point and selecting screws of appropriate length and diameter. Adequate knowledge about vertebral morphometrics plays a significant role in preventing accidental injuries to vital structures such as vessels and nerves adjacent to the pedicle (Mohanty *et al*., 2018).

Understanding vertebral morphometrics is of vital importance for comprehending the biomechanical models of the spine and spine implants. Additionally, it plays a crucial role in planning various procedures used in vertebral surgery. The size, shape, harmony between vertebrae, and accurate anatomical descriptions of vertebrae and intervertebral discs are highly valuable for various surgical approaches (Choubey *et al*., 2018).

Knowledge of normal lumbar disc morphometrics is crucial for interpreting pathological changes related to intervertebral disc degeneration and determining the surgical method (Fyllos *et al*., 2018). It is reported that no component of the musculoskeletal system undergoes more dramatic changes with age than intervertebral discs (Buckwalter, 1995). Disc herniations, a commonly encountered health problem, not only adversely affect human health but also lead to significant loss of workforce and economic impact. In surgery, achieving adequate decompression is aimed by considering the size, position of the disc, the patient's current complaints, and neurological condition (Albayrak *et al*., 2015). Knowledge of normal disc morphometrics before surgery for correcting degenerated intervertebral discs and reduced disc spaces will facilitate the restoration of displaced parts to their original positions and the calculation of the correct amount of distraction (Fyllos *et al*., 2018).

In conclusion, the morphometric data we obtained are important for establishing references for individuals in our region and contributing to the literature. Personal variations, as well as changes related to sex and age, should be taken into account in surgery involving lumbar vertebrae and discs. However, we believe that further studies on a much larger population are needed.

SAMUT, C.; SAPMAZ, H. I. & ALTUNKAS, A. Investigación de vértebras lumbares y morfometría del disco con tomografía computarizada en adultos turcos. *Int. J. Morphol., 42(3)*:577-584, 2024.

RESUMEN: La realización de estudios morfométricos que incluyan diversos parámetros anatómicos y el establecimiento de ciertos estándares para la anatomía de la columna lumbar facilitarán los procedimientos clínicos. Como ejemplo, aún no se ha presentado de manera detallada la morfometría de las vértebras lumbares y del disco intervertebral en individuos turcos. En nuestro estudio evaluamos retrospectivamente imágenes de tomografía computarizada abdominal en 700 individuos adultos de ambos sexos. Observamos que la altura anterior de los cuerpos vertebrales aumentaba de L1 a L4 en los hombres y de L1 a L5 en las mujeres. La altura posterior de los cuerpos vertebrales fue más baja en L5 en ambos sexos, mientras que fue más alta en L3 en hombres y L4 en mujeres. En todos los grupos etarios los valores para los hombres fueron mayores (p<0,05). Se observó que el ancho y profundidad del canal vertebral aumentaba de L1 a L5 en los hombres y de L2 a L5 en las mujeres, siendo L2 el más pequeño en las mujeres. Los valores para los hombres fueron mayores en los mismos grupos de edad para ambos parámetros (p= <0,05). Los valores para el ángulo pedicular transversal derecho aumentaron desde los niveles superiores a los inferiores en ambos sexos, mientras que para el ángulo pedicular transversal izquierdo, fue más pequeño en L2 y aumentó hacia L5. No hubo diferencias relacionadas con el sexo (p>0,05). En todos los grupos de edad y en ambos sexos se observó un aumento en la altura anterior del disco intervertebral hacia el disco 5. Los valores de los hombres fueron mayores que los de las mujeres (p<0,05). La altura posterior del disco intervertebral en el disco 5 fue mayor en las mujeres y en otros discos fue mayor en los hombres (p<0,05). En conclusión, se encontró que los valores de medición de los parámetros examinados variaron según el nivel lumbar y el sexo, pero fueron independientes de la edad. Los datos morfométricos que obtuvimos son importantes en términos de proporcionar una referencia para la población de nuestra región y contribuir a la literatura.

PALABRAS CLAVE: Vértebras lumbares; Morfometría; Tomografía computarizada; Disco intervertebral.

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