

## Morphometric Study of Cervical Vertebrae C3-C7 in a Population from Northeastern Mexico

Estudio Morfométrico de las Vértebras Cervicales C3-C7 en una Población del Noreste de México

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**SUMMARY:** Knowing the dimensions of the vertebral elements is very important for the development of instrumentation related to the cervical spine. Ethnic variations have been reported in these dimensions and, to date, there have been no morphometric studies of this area performed on the Mexican population. We conducted a morphometric study of 150 cervical vertebrae (C3-C7) obtained from a northeastern Mexican population to determine the dimensions of the bodies, pedicles, laminae, spinous processes, and superior and inferior articular processes. We did not find significant differences ( $p < 0.05$ ) in measurements taken of the left and right sides. The dimensions of the vertebral bodies were larger at lower levels. The pedicles of the C3 vertebra were larger in all dimensions compared to the other vertebrae. The largest height of the laminae was observed at C7 and the largest transverse length was observed at C5. The dimensions of the bodies, spinous processes, and laminae increased from C3-C7, whereas the dimensions of the pedicles and superior and inferior articular process height decreased toward the lower cervical levels.

**KEY WORDS:** Cervical vertebrae; Pedicle; Morphology.

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### INTRODUCTION

Instrumentation of the vertebral column is used for the treatment of cervical instability, as well as for the decompression of neural structures. One of the most frequent and complex procedures for this is the placement of transpedicular screws (Kayalioglu *et al.*, 2007; Yusof *et al.*, 2007; Sieradzki *et al.*, 2008; Abuzayed *et al.*, 2010).

Morphometric studies of the cervical, thoracic, and lumbar vertebrae have been conducted (Abuzayed *et al.*; Kayalioglu *et al.*; Pal & Routal, 1986; Olsewski *et al.*, 1990; Hou *et al.*, 1993; Ebraheim *et al.*, 1996; Pal & Routal, 1996; Christodolou *et al.*, 2005; Liau *et al.*, 2006; Ebraheim *et al.*, 2008; Urrutia-Vega *et al.*, 2009), and the majority of these studies highlight the importance of such studies in the development of vertebral column instrumentation (Urrutia-Vega *et al.*; Ebraheim *et al.*, 1996; Olsewski *et al.*). These studies have used diverse techniques to obtain the vertebral column measurements, among which the following are notable: CT scan (Abuzayed *et al.*; Sieradzki *et al.*; Yusof *et al.*), cadaveric studies (Kayalioglu *et al.*, 2007), radiography

(Sieradzki *et al.*) and fluoroscopy (Urrutia-Vega *et al.*). The majority of the studies focus on the pedicle, because this is the site where vertebral column fixation procedures are most frequently implemented. Only a few of the studies describe the characteristics of the remaining elements that comprise the vertebra (Pal & Routal, 1986; Pal & Routal, 1996; Winkelstein *et al.*, 2001; Ebraheim *et al.*, 2008).

The majority of spinal column surgeons agree regarding the need for adequate cervical column morphology knowledge to avoid damage to the vertebral artery, spinal medulla, or nerve roots during fixation interventions involving the posterior cervical spine (Karaikovic *et al.*, 2000; Tomasino *et al.*, 2010).

Differences in cervical spine morphometrics have been reported across different study populations (Yusof *et al.*; Abuzayed *et al.*), where these may have implications for the actions of spinal column surgeons. To date, no studies exist that determine the measurement of the vertebral

elements of the cervical spine in the Mexican population. The objective of this study was to determine the morphometric characteristics of the vertebral elements of cervical spine vertebrae C3-C7 in a population located in northeastern Mexico.

## MATERIAL AND METHOD

One hundred and fifty C3-C7 cervical vertebrae from a Mexican population were obtained from the Department of Human Anatomy, School of Medicine, Universidad Autónoma de Nuevo León. All of the vertebrae included, were in good condition, without signs of trauma or infectious or neoplastic diseases, and without apparent deformities. All of the measurements were conducted by two independent observers in a bilateral manner using a digital Vernier caliper (Fowler Sylvac) with 0.01 mm precision. The parameters we evaluated were the following (Fig. 1):

**Body.** Anteroposterior diameter (AP): distance at the medial line of the vertebral body from the anterior face to the posterior face. Transverse diameter: distance between the two lateral faces of the vertebral body at the medial portion of the body. Height: distance between the superior and inferior borders of the vertebral body at the medial line running through the anterior face.

**Pedicles.** Length: distance between the anterior limit of the superior articular facet and the posterior limit of the vertebral body. Width: distance between the medial and lateral borders. Height: distance between the superior and inferior borders.

**Laminae.** Height: distance between the superior and inferior borders. Transverse length: distance between the spinous process

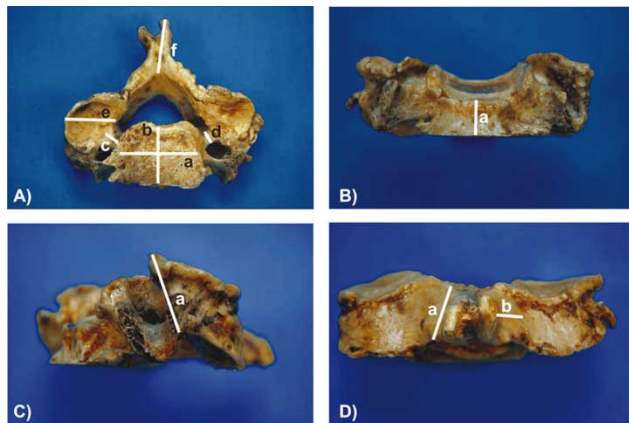


Fig. 1. Typical cervical vertebrae. A) Superior view. a) transverse diameter and b) anteroposterior diameter (AP) of the vertebral body, c) pedicle length, d) pedicle width, e) superior articular process width, f) spinal process length. B) Anterior view. a) vertebral body height. C) Lateral view. a) superior articular process height, b) inferior articular process height. D) Posterior view. a) height and b) transverse length of lamina.

and the lateral border of the superior articular process.

**Spinous process.** Length: distance from the superior border to the tip of the spinous process (in the sagittal plane).

**Superior articular process.** Height: measured from the inferior border to the superior vertex of the process. Width: length of the transverse diameter of the process.

**Inferior articular process.** Height: from the superior border to the inferior vertex of the process.

Width: length of the transverse diameter of the process.

All of the measurements were recorded using Microsoft Excel and are reported in tables and graphs as the mean and standard deviation. The Student t-test was used to compare the means of the parameters.

## RESULTS

A total of 150 cervical vertebrae were analyzed, of which there were 30 for each level (C3, C4, C5, C6, C7). No significant differences were found ( $p < 0.05$ ) between the right and left side for any of the evaluated parameters.

**Bodies.** The dimensions (AP and transverse diameters and height) of the C3-C7 vertebral bodies are reported in Table I. The greatest AP diameter was seen at C6 and the smallest diameter at C3 (Fig. 2). The transverse diameter was greatest at C7 and smallest at C3, while the maximum height was found at C7 and the minimum at C5 (Fig. 2). The dimensions of the vertebral bodies increased at the lowest levels (C6-C7).

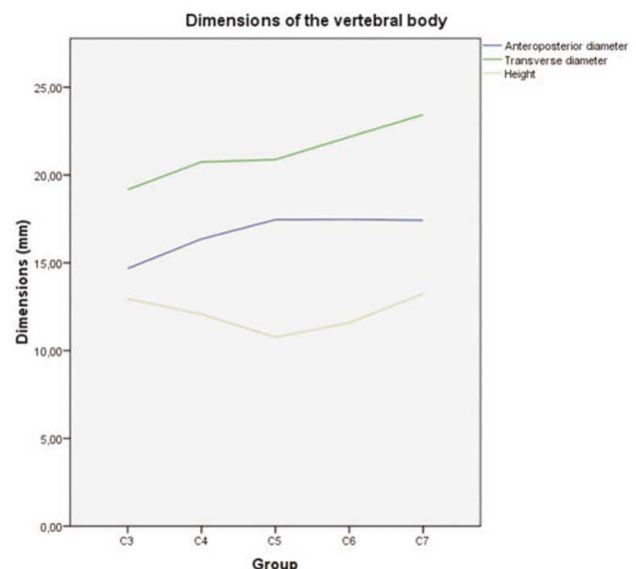


Fig. 2. Vertebral body (C3-C7). Anteroposterior (AP) and transverse diameters, and height.

**Pedicles.** The dimensions (length, width, and height) of the left and right pedicle for each vertebral level are reported in Table II. The greatest length was found at the C3 pedicles and the smallest at the C5-C6 pedicles (Fig. 3). The width was largest at C3 and smallest at C4-C5, while the height was largest at C3 and smallest at C6-C7 (Fig. 3). As evidenced by these results, the C3 pedicles are larger in all dimensions and a gradual decrease in dimensions occurs, up to C6.

**Laminae.** The dimensions (height and transverse length) of the laminae are shown in Table III. We observed the greatest height at C7 and the smallest at C5, while the transverse length was largest at C5 and smallest at C3 (Fig. 4).

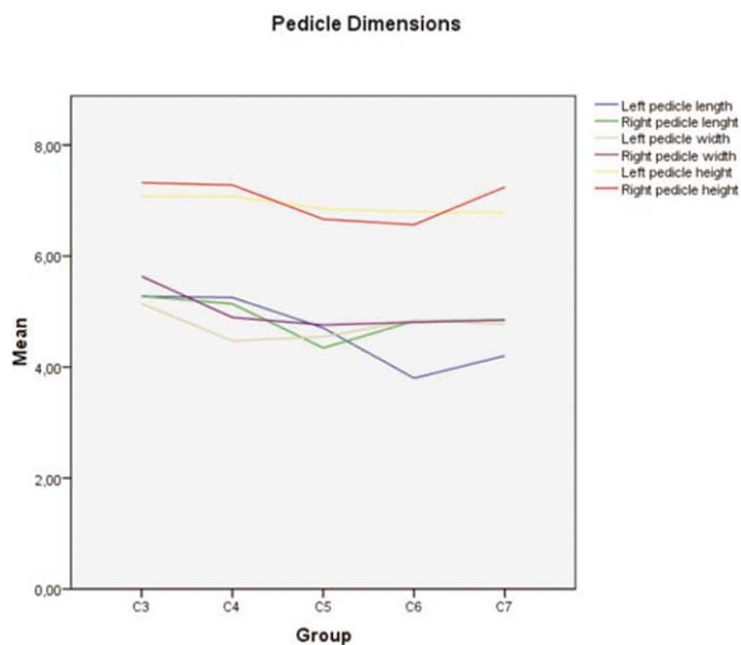


Fig. 3. Pedicles (C3-C7). Right- and left-side length, width, and height.

Table I. Morphometric characteristics of vertebral bodies C3-C7.

VERTEBRA	Anteroposterior diameter (mm)			Transverse diameter (mm)				
	Mean	Range	SD	Mean	Range	SD		
C3	14.68	17.54	8.19	±2.63	19.17	24.37	12.55	±3.04
C4	16.36	17.92	15.03	±0.99	20.75	23.82	18.16	±1.86
C5	17.45	19.24	15.24	±1.29	20.88	24.58	12.65	±3.73
C6	17.47	20.10	15.34	±1.48	22.17	25.57	18.36	±2.17
C7	17.42	18.93	15.40	±1.33	23.44	30.31	18.91	±3.48

Table II. Pedicle dimensions of vertebrae C3-C7.

VERTEBRA	Length (mm)			Width (mm)			Height (mm)					
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD			
C3	5.27	7.54	3.26	±1.39	5.14	10.78	3.17	±2.22	7.08	10.27	4.48	±1.69
C4	5.25	6.56	4.21	±0.81	4.47	6.07	2.87	±1.08	7.07	8.97	5.47	±1.19
C5	4.71	6.18	2.18	±1.24	4.55	5.77	3.28	±0.98	6.85	9.25	4.55	±1.41
C6	3.80	5.08	1.96	±1.00	4.84	6.53	3.35	±1.17	6.80	8.13	5.33	±0.89
C7	4.20	4.85	3.15	±0.54	4.78	6.61	3.72	±1.01	6.78	8.26	5.60	±1.04

Table III. Lamina dimensions of vertebrae C3-C7.

VERTEBRA	Height (mm)			Width (mm)				
	Mean	Range	SD	Mean	Range	SD		
C3	12.27	20.20	8.86	±3.30	13.92	15.67	9.98	±1.82
C4	11.37	13.11	9.85	±1.03	15.27	18.37	12.53	±1.77
C5	11.27	13.35	9.94	±1.12	15.59	19.32	12.61	±2.01
C6	12.24	15.48	10.05	±1.78	14.81	18.69	11.29	±2.03
C7	14.31	16.75	11.73	±1.50	15.39	18.19	13.26	±1.57

Table IV. Morphometric characteristics of the superior and inferior articular processes of vertebrae C3-C7.

VERTEBRA	SUPERIOR-ARTICULAR PROCESS			INFERIOR-ARTICULAR PROCESS			SPINOUS PROCESS		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
C3	10.68	6.96-16.86	±3.39	11.51	8.10-15.75	±2.14	15.53	19.17-30.71	±3.10
C4	11.05	8.21-15.35	±1.90	11.21	7.92-14.32	±1.30	15.38	17.60-21.50	±2.61
C5	10.27	8.84-11.79	±1.15	9.75	6.39-13.08	±1.68	16.63	21.50-30.71	±3.04
C6	10.22	7.89-12.82	±1.66	9.85	8.47-12.64	±2.32	21.81	30.71-35.12	±5.00
C7	10.55	7.52-13.32	±2.08	10.79	8.02-14.08	±2.61	29.12	35.12-45.86	±5.86

**Spinous process and superior and inferior articular processes.** The dimensions of the spinous processes and superior and inferior articular processes are shown in Table IV. The spinous process length was greatest at C7 and smallest at C4 (Fig. 5). The height of the superior articular process was greatest at C4 and smallest at C6, while the width was greatest at C6 and smallest at C3 (Fig. 6). The height of the inferior articular process was greatest at C3 and smallest at C5, while the width was greatest at C7 and smallest at C5 (Fig. 6).

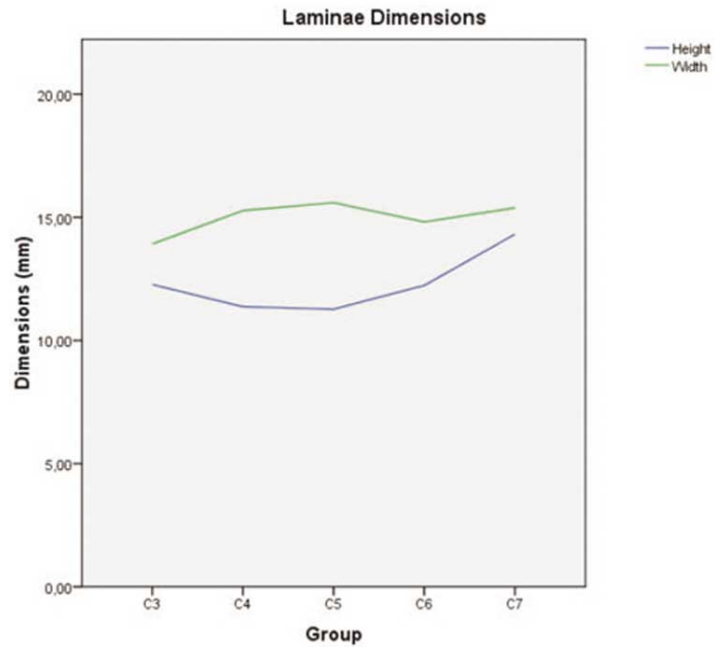


Fig. 4. Laminae (C3-C7). Height and transverse length.

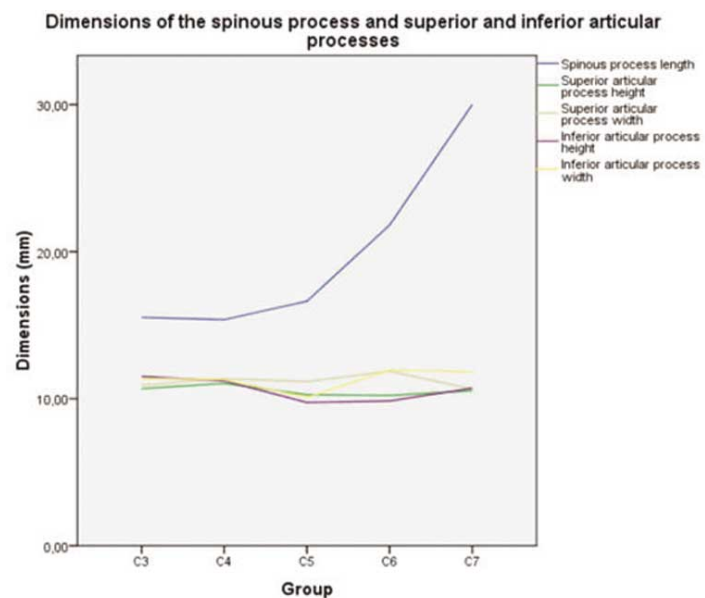


Fig. 5. Spinous process and superior and inferior articular processes. Height and width.

## DISCUSSION

Implantation of cervical spine instrumentation requires detailed anatomical information to avoid harming the patient (Abuzayed *et al.*). Many authors have described the morphologic characteristics of the vertebral column and have studied its dimensions via CT scan, direct measurements of specimens, and 3D reconstructions (Abuzayed *et al.*; Sieradzki *et al.*; Yusof *et al.*; Kayalioglu *et al.*; Sieradzki *et al.*; Urrutia-Vega *et al.*). It has also been shown that vertebral dimension differences exist amongst different races (Yusof *et al.*; Abuzayed *et al.*), which is why, in this study, we analyzed cervical vertebral dimensions (C3-C7) in the Mexican population.

**Bodies.** The morphometry of vertebral bodies is useful for surgeons who perform anterior cervical reconstructions using plate fixation (Abuzayed *et al.*). The anteroposterior diameter of the vertebral bodies is an important parameter for the anterior fixation of bicortical screws. A study by Abuzayed *et al.* conducted in a Turkish population using CT scan reported a mean anteroposterior diameter of 15.6-17.6 mm, which is slightly larger than the values reported in the cadaveric studies conducted by Ebraheim *et al.* (1998; 1996) or the present study (14.68 - 17.47 mm). The transverse diameter of the vertebral body reported by Abuzayed (2010) is also slightly greater than what we found in the Mexican population (19.17 – 23.44 mm). These slight variations may be explained by the differences in race, but they must be taken into consideration during surgical procedures.

**Pedicles.** The transverse diameter and length of the pedicles are very important parameters for the selection of screw size for placement during transpedicular fixation surgery. The transverse diameter measured by CT scan of pedicles was of 5.1-6.9 mm in the Turkish population (Abuzayed *et al.*), which is slightly greater than our values (4.47 – 5.14 mm) and those observed by Kayalioglu *et al.* in cadavers. Other researchers (Yusof *et al.*) report that when the internal diameter and thickness of the medial and lateral pedicle wall are added to obtain a total diameter, the resulting values are very close to ours.

According to Abuzayed *et al.*, the mean length of the pedicles is 16.1-16.7 mm, which is larger than the results reported by Ebraheim *et al.* (1996). In our study, we found smaller values (3.80 – 5.27 mm) because we measured pedicle length as the distance between the vertebral body and the superior articular process, which was not the case in the Abuzayed *et al.* and Ebraheim *et al.* (1996; 2008) studies.

**Laminae.** Cervical laminoplasty is a surgical procedure frequently used for the treatment of cervical spondylotic myelopathy (Hosono *et al.*, 2006) for the resection of spinal medulla tumors and ossification of the posterior longitudinal

ligament (Wang *et al.*, 1998). It is also known that C7 laminae play an important role in the maintenance of cervical spine stability (Pal & Routal, 1996). The dimensions of the laminae have not been extensively studied previously. In our study, we found that lamina height decreases progressively from C3-C5 and increases at C7, while the transverse length increases from C3-C7. These increases in width coincide with the presence of the cervical bulge in the spinal medulla.

**Spinous process and superior and inferior articular processes.** The spinous process shows a decrease at C3-C4, with a pronounced increase at C6 and C7. This information is in accord with the classical anatomy literature.

The articular processes make up the posterolateral columns that transmit compressive forces exerted on the cervical column (C3-C7) (Pal & Routal, 1996; Pal & Routal, 1986). Transfacet fixation has infrequently been used for cervical column stabilization (Liu *et al.*, 2008), even though it has been shown to carry a smaller risk of nerve root injury (Liu *et al.*, 2006), which is why it should be considered as an alternative to transpedicular fixation (Liu *et al.*, 2008; Jones *et al.*, 1997). Ebraheim *et al.* (2008) reported a decrease in vertical length from C3-C7 of the superior articular facets, with no significant difference by gender or side. On the other hand, we observed a progressive decrease from C3-C6. This difference may be the result of our study taking into account the total length of the superior articular process rather than just articular facet size.

The inferior articular processes correspond in size and orientation to the superior articular processes. It is thought that orientation and size of articular facets are related to the luxation of the articulation. This luxation is most commonly present at C5-C6 when unilateral and at C6-C7 when bilateral (Ebraheim *et al.*, 2008).

The dimensions of the body, spinous process, and laminae increase from C3-C7. The dimensions of pedicle and superior and inferior articular process height decrease as they descend the cervical column. These morphologic characteristics are associated with the change from the cervical lordosis curvature to the thoracic kyphosis curvature and with the increase in cervical column mobility.

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**RESUMEN:** Las mediciones de los elementos vertebrales son importantes para la instrumentación de columna cervical. Se han reportado variaciones étnicas en estas medidas y en la actualidad no exis-

ten estudios morfométricos en la población mexicana. Se realizó un estudio morfométrico en 150 vértebras cervicales (C3-C7) para determinar las medidas de los cuerpos, pedículos, láminas, procesos espinosos y articulares superiores e inferiores. No se encontraron diferencias significativas ( $p < 0.05$ ) en las medidas tomadas entre ambos lados. Las dimensiones de los cuerpos vertebrales se incrementan en niveles más bajos. Los pedículos de la vértebra C3 son mayores en todas sus dimensiones. La mayor altura de las láminas se observó en C7 y la mayor longitud transversal en C5. Las dimensiones del cuerpo, procesos espinosos y láminas se incrementan de C3-C7, mientras las dimensiones de los pedículos, altura de procesos articulares superiores e inferiores disminuyen en los niveles cervicales más bajos.

**PALABRAS CLAVE: Vértebra cervical; Pedículo; Morfología.**

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