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Anatomic evaluation OF SUB-AXIAL cervical spine among Nigerians

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ABSTRACT

Introduction: Cases of tumor, fracture, or rheumatoid arthritis associated with cervical spine instability are now on the increase. An attempt to stabilize the vertebra by the placement of cervical spine screws involves some risk to the spinal cord, vertebral vessels and exiting nerve roots. To better assist injuries that occur to this region without an impingement of neurovascular structures, it is imperative to understand cervical spine anatomy and its possible variations across populations.

Method: In this study, gross morphometry of 80 fully ossified human cervical vertebrae (C3–C7) was carried out. Eleven parameters were measured using digital Vernier calipers. The means and standard errors for linear and area dimensions of the vertebra body, endplates, spinal canal, and spinous and transverse processes were obtained for each vertebra.

Result: All parameters increased progressively down the spine with very few changes at some vertebra level. Spinous process length increased significantly down the vertebrae. Most of these parameters were different from the reports from other populations.

Conclusion: We concluded that possible variation in cervical spine morphometry of Nigerians compare to other races exist and should be taken into consideration when designing cervical vertebra related instruments and in any spinal reconstruction surgery as a size of instrument may not be generally fit for all populations.

1. Introduction

The sub-axial cervical spine comprises of five multicomponent vertebrae with related morphology and functions [1]. They border major neurovascular-structures transmitting canals, transmit major neurovascular structures, and are employed in cervical spine instrumentations [1,2].

The vertebral canal is an osseous ring formed by conjoined vertebral foramen, transmitting the upper portion of the spinal cord and its associated vascular structures [3]. Each foramen is bothered by vertebral components such as the pedicle, laminae and dorsum of the vertebral body [4]. Transverse foramina are another opening sited on the transverse process which transmits vertebral vessels and sympathetic chain in the foramina of vertebral C3 to C6. However, it transmits vertebral vein in C7 while the vertebral artery crosses anteriorly to it before proceeding cranially through the transverse foramina of C6 [3,5]. The groove lying between the anterior and posterior tubercles of the transverse processes house the exiting spinal nerves roots [5]. The remaining cervical vertebrae components which include pedicle, laminae, spinous process, lateral mass, and facet joints can be safely employed in intraoperative or postoperative instrumentation to add stability to the spine [6,7]. A severe dislocation or fracture of spine components injure the spinal cord and affects other associated neurovascular structures [2,5].

Ethnic variations in cervical spine dimensions have been reported across various populations [8,9]. Thus, in order to better assist lower cervical spine injuries in Nigeria populations with precision, avoid damage to neurovascular structures like vertebral artery, spinal medulla, or nerve roots during fixation interventions, and to provide more accurate modelling for analysis and design of spinal implants and instrumentations as may be related to our population, it is important to understand the peculiarities of the anatomy of our vertebrae. This study was undertaken because no detailed citable literature relating to Nigeria population is available.

2. Materials and methods (Figs. 1 and 2)

Cervical spines of fresh adult human cadavers of both sexes were

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dissected and harvested at the Gross Anatomy Dissection room of the Department of Anatomy and Cell Biology, Obafemi Awolowo University, Nigeria. They died from a variety of causes, with no gross evidence of abnormality of the spine. Ethical approval was not required for this study. Cadavers were numbered from 1 to 6 at random. C3 to C7 spines were removed under macroscopic view, followed by careful removal of soft tissues. The bones were immersed in sodium hydrochloride solution for 30 min to facilitate the dissolution of other tissue remnants [8]. To remove the sodium hydrochloride, spinal units were rinsed under lukewarm water for 20 min [8]. Bones were air dried following rinsing and stored at a constant temperature and humidity [8]. Gross morphometry of 80 fully ossified human cervical vertebrae (C3–C7) were carried out. Measurements were performed in accordance with a previously published study by Hueston [10] and Prabavathy et al. [11]. All measurements were done using digital Vernier calipers. The following measurements were included:

- EPW_u (Upper Endplate Width) was measured on the superior surface of the vertebra on the location of the upper endplate from one uncinate process to the other.
- EPW_l (Lower Endplate Width) was measured on the inferior surface of the vertebra from one area of uncovertebral articulation to the other
- VBH_a (Anterior Vertebral Body Height) was measured on the anterior surface of the vertebral body as the distance between the anterosuperior and the anteroinferior borders at the midline
- VBH_p (Posterior Vertebral Body Height) was measured on the posterior surface of the vertebral body as the distance between the anterosuperior and the anteroinferior borders at the midline
- *SCW* (Spinal Canal Width) was measured from the farthest point of one side of the spinal canal to the other.
- *SCD* (Spinal Canal Depth) was measured from the farthest anterior point of the spinal canal to the farthest posterior point of the spinal canal at the midline
- *TPW* (Transverse Process Width) was measured from the farthest part of one transverse process to the other of the same vertebra
- *SPL* (Spinous Process Length) was measured as the distance from the superior border to tip of the spinous process.
- *EPAu and EPAl* (Upper and Lower Endplate Area) were calculated by initiating the formula for analyzing the total surface area of upper and lower vertebral end plates respectively. This formula is analogous to that of an area of a circle, where EPW was approximated to serve as the diameter. Hence, the mathematic deduction for the end plate area is formulated below;

$$EPA = \pi\frac{EPW^2}{4}$$

- *SCA* (Spinal Canal Area): An exact analysis for rendering the area for the spinal canal was obtained by propotionating its value to the product of the spinal canal width and the spinal canal depth, where $\frac{1}{2}$served as the constant of proportionality.

$$SCA = \frac{1}{2} \times SCW \times SCD$$

2.1. Statistical analysis

Data obtained were analyzed using Graph Pad Prism 5.0 statistical software. One-way analysis of variance followed by Students Newman-Keuls (SNK) post hoc tests were used for multiple comparisons. Descriptive statistics are presented as means $\pm$ standard deviations (SD). P value $<$ 0.05 was considered significant.

3. Results

EPWu and *EPWl* maintained a relatively constant progression from C3 to C5 with highest difference of 2.33 mm between C3 and C4 *EPWl*. The progression changed at the level of C6- *EPWu* with a striking difference of 4.23 mm between C5 and C6. *EPWu and EPWl* were maximum at C7 and C6 respectively. Similar progression was noticed for *EPAu* and *EPAl* with the highest values observed at C6 for both parameters (Table 1).

VBHa and *VBHp* increased from C3 to C7, however, a decrease was observed at the level of C6 relative to C5 which then increased again at C7. The highest mean difference was not up to 2 mm on both sides. The maximum height was recorded at C5 and C7 levels respectively and was minimum at C3 on both sides. The smallest mean value of vertebral body height was found in the *VBHa* (Table 2). Generally, in this study, *VBHa* was greater than *VBHp*. *TPW* increased down the spine, except at the level of C7 where a decrease was observed relative to C6. *SPL* increased significantly down the spine. At C6 and C7, it increased significantly when compared with C3 and C4. SPL at C7 was significantly larger than C5. *TPW* was highest at C6 vertebra while *SPL* was highest at C7. Minimum values recorded were at the level of C3 for both parameters. Maximum values were at the level of C6 and C7 for both *TPW* and *SPL* respectively. The former was generally larger than later (Table 2).

Data obtained from *SCW* and *SCD* revealed a relatively constant

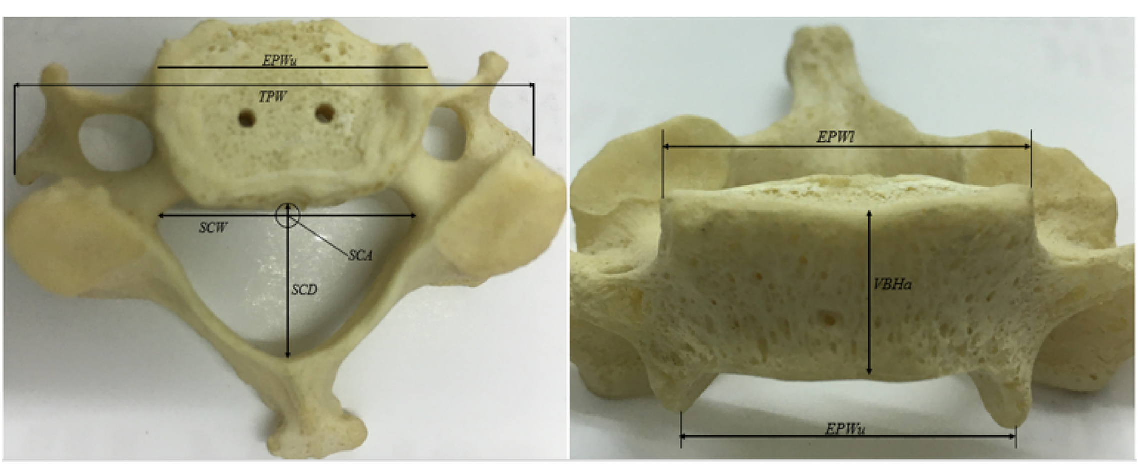

Fig. 1. Representative pictures of top (superior) and front (anterior) views of 4th and 7th cervical spine showing the measurements of - Upper Endplate Width (EPWu), Transverse Process Width (TPW), Spinal Canal Width (SCW), Spinal Cana Depth (SCD), Spinal Canal Area (SCA), Anterior Vertebral Body Height (VBHa), Lower Endplate Width (EPWl).

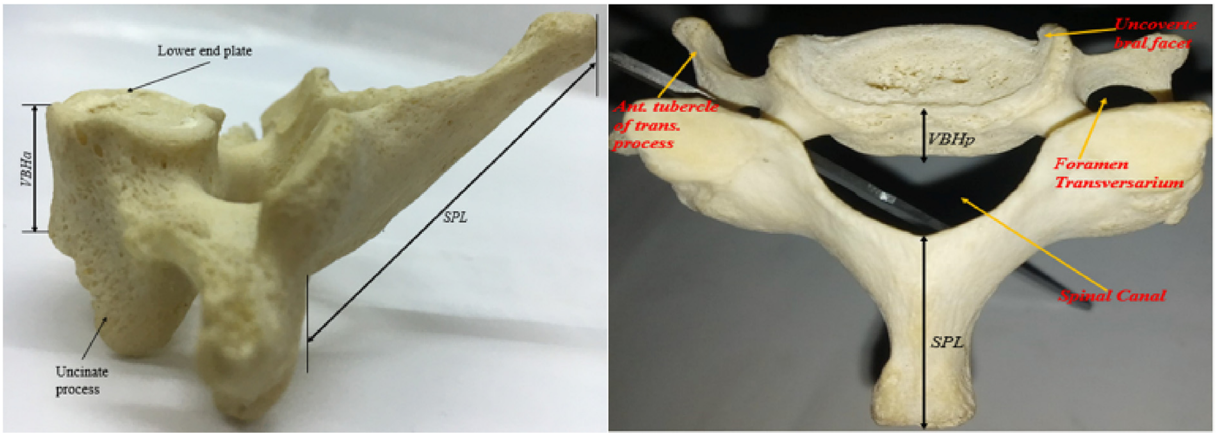

Fig. 2. Representative pictures of side (lateral) and top (superior) views of 7th cervical spine showing the measurements of - Anterior Vertebral Body Height (VBHa), Spinous process length (SPL) and Posterior Vertebral Body Height (VBHa). Components of the vertebra (uncinate process, lower end plate, transverse process, uncovertebral facet, foramen transversarium and spinal canal) were also labelled.

Table 1
Dimensions of Upper and Lower End Plate Widths and Areas of C3 to C7 vertebrae.

Vertebrae	EPWu (mm)	EPWl (mm)	EPAu (mm^2)	EPAl (mm^2)
C3	15.34 ± 2.47	18.27 ± 4.66	188.7 ± 60.06	276.4 ± 120.9
C4	17.03 ± 0.92	20.6 ± 4.37	228.5 ± 24.00	345.8 ± 137.9
C5	16.23 ± 2.27	20.81 ± 5.56	212.4 ± 57.73	360.5 ± 165.6
C6	20.46 ± 3.75	22.49 ± 5.92	298.5 ± 65.87	420.1 ± 204.9
C7	22.18 ± 8.28	21.48 ± 4.04	274.1 ± 108.8	373.0 ± 129.5

Table 2
Dimensions of anterior and posterior vertebral body heights, transverse process width and spinous process length.

Vertebrae	VBHa (mm)	VBHp (mm)	TPW (mm)	SPL (mm)
C3	9.64 ± 2.26	10.76 ± 2.16	44.72 ± 3.59	7.66 ± 1.71
C4	11.61 ± 1.87	12.68 ± 1.81	46.36 ± 2.42	12.32 ± 2.62
C5	12.42 ± 2.30	13.27 ± 2.38	47.78 ± 5.81	13.06 ± 3.97
C6	11.32 ± 1.45	12.99 ± 0.76	52.43 ± 5.90	22.21 ± $7.85^{\alpha\beta}$
C7	12.12 ± 1.92	13.71 ± 3.09	51.94 ± 6.98	25.92 ± $8.19^{\alpha\beta\gamma}$

α – Significantly different from C3; β - Significantly different from C4; γ - Significantly different from C5 at $p < 0.05$.

Table 3
Dimensions of width, depth and area of spinal canal.

Vertebrae	SCW (mm)	SCD (mm)	SCA (mm^2)
C3	19.25 ± 6.12	14.06 ± 4.47	140.30 ± 7.73
C4	19.71 ± 4.14	15.48 ± 5.09	151.90 ± 16.29
C5	19.68 ± 5.45	15.75 ± 3.70	156.50 ± 23.87
C6	20.00 ± 5.10	14.54 ± 4.43	147.50 ± 25.85
C7	20.03 ± 4.64	15.33 ± 5.55	159.00 ± 33.15

value from C3 to C7, though, a decrease was found in C5 *SCW* and in C6 *SCD* which then increase again at C6 and C7 respectively. The mean difference at each level was not more than 0.46 for *SCW* and 1.42 for *SCD*. Values were maximum at C7 and C5 respectively. *SCA* was also fairly constant down the vertebrae, though, a decrease was observed at C6 level. The area was minimum at C3 and maximum at C7. The *SCW* was on the minimum 3.93 mm larger than *SCD* at the level of C5 and on the maximum 5.45 mm larger at C6 vertebra level. The mean difference is thus approximately 5 mm at all vertebrae levels. *SCW* was generally larger than *SCD* (Table 3).

No interdependency of values was observed in the morphometry of the spine as all values to a large extent increased down the spine except at a few vertebrae levels. So, morphometric data of the spine are all independent of each other.

4. Discussion

General and racial knowledge of the dimensions of cervical spine components is very important in developing instruments related to this region and to approach spine-related surgical interventions with caution. Endplate dimensions revealed a constant progression from C3 to C7 except at C4 *EPWu*, C7 *EPWl*, *EPAu and EPAl* where slight decreases were observed relative to the vertebra above. In most population, endplate dimensions increased progressively down the spine. Panjabi et al. [12], Liguoro [13], Tan et al. [8] and Zhu et al. [14] all recorded such progressive increase in Caucasian population, French population, Caucasian and African American, Chinese Singaporeans and Chinese population respectively. This peculiarity observed in this study should be put in mind in surgical interventions and instrumentation that may involve this region or uncovertebral joints, a secondary joint that add to lateral stability of the body. It is important to note that the description of *EPWu* considered in this study included the bilateral uncus. This is against the description given by Zhu et al., they described *EPWu* as the center mediolateral diameter of the upper or lower endplate excluding bilateral uncinate processes.

In this study, *VBHa* and *VBHp* increased insignificantly from C3 to C7; although, the case was different at C6 vertebral level where a decrease was noticed. This knowledge of dimensional interchange at C6 level is important in anterior and posterior cervical reconstructions using plate fixation and in the diagnosis of stenosis [15]. Also, this study recorded minimum and maximum vertebral body height at the level of C3 and C5 respectively anteriorly and C3 and C7 respectively posteriorly. This result agrees with a previously reported study by Bazaldua et al. [16] who also reported a minimum and maximum heights at these levels of C3 and C7 respectively in Northeastern Mexicans. However, it is against the earlier reports of Mahto and Omar [17] and Prabavathy et al. [11] where minimum and maximum VBH was observed at the levels of C4 and C6 in Indian population. These differences could be a pointer to racial variation in vertebral body morphometry. The posterior VBH is larger than the anterior VBH due to the wedge shape of the vertebra [8].

TPW increased progressively down the spine in this study. This agrees with the report of Tan et al. [8] who also recorded similar increase in Chinese Singaporeans. However, it is against the reports of Panjabi et al. [12] who reported inconsistent values (alternating increase and decrease) in Caucasian and African American populations. It is important to note that the transverse process has a transverse foramen in which vertebral artery and vein traverse. This is not so at C7, where the foramen encloses only the accessory vertebral vein. Laterally, the transverse processes also have an anterior and a posterior tubercle, with a groove in between them where spinal nerves lie. This knowledge of transverse process dimension across populations is therefore important to prevent damage to these important neurovascular structures during surgical procedures.

Result from this study showed significant increase in spinous process length down the spine. This is in line with previous reports of Panjabi et al. [12] who reported for Caucasian population, Tan et al. [5] who reported for Chinese Singaporeans, Prabavathy et al. [11] for South Indian population. However, the length of spinous process recorded for these populations were far higher than what we observed in this study. Mean and standard deviation value of C3 in each of this population are 29.6 ± 0.78, 25.6 ± 0.5, 10.46 ± 1.54 respectively while the length recorded in this study is 7.66 ± 1.71. C7 average length reaches as much as 45.7 ± 0.84 in Caucasian population, 46.9 ± 1.1 in Chinese Singaporeans while the value recorded in this study is 25.92 ± 8.19. It has been earlier reported that the spinous processes of C6 and C7 are longer and taper off towards the ends. C7 has the longest spinous process and is otherwise referred to as vertebra prominens [2].

Spinal canal parameters *(SCW, SCD, SCA)* measured in this study showed relatively constant values down the spine. These observations correlate with the fairly constant values reported by Tan et al. [8] for Chinese Singaporeans. Nevertheless, the point of record of maximum spinal canal parameters was not the same for both studies. While they observed a maximum value at C6 for *SCW*, C7 for *SCD* and C7 for *SCA,* the present study observed these at the levels of C7, C5 and C7 respectively. It is also important to note that values reported in this study were larger than what was reported at all vertebrae levels for *SCD,* while they recorded a larger value for *SCA* also at all vertebrae levels. These differences also point to possible racial difference in spinal canal parameters denoting the fact that a size of instrument cannot be adapted across populations.

The difference between the values obtained in this study with other races could be attributed to the fact that most of the citizens engage in peasant farming and carry farm produce on the head to their homes. This axial loading of the sub-axial spine could lead to hypertrophy of the bone under repetitive stress. The need for surgeons to be aware of this measurement is to guide them in sourcing for screws and plate sizes of lengths and diameter of average values of their citizens since there is not enough money to stock implants of various sizes.

The limitations of this research relate to the following points; the sample size and regional coverage of this study was not large enough compare to the available geopolitical zones in the country. Attempt should be made in future researches to cover quite a number of teaching hospitals across different geopolitical zones in order to have a more robust coverage and sample size. Also, due to limited access to the biodata of the cadavers, the primary of them being age, it prevented us from doing the age distribution and finding a relationship between age and spine parameters.

5. Conclusion

Data gotten from this study revealed a possible variation in cervical spine morphometry of Nigerians compare to other races. The differences recorded should be taken into consideration when designing cervical vertebra related instruments and in any spinal reconstruction surgery as a size of instrument may not be generally fit for all populations.

Ethical statement

"Not applicable".

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CRediT authorship contribution statement

Adeleke Adegboyega Abiodun: Conceptualization, Methodology, Supervision, Resources, Writing - original draft, Writing - review & editing. **Paul Olugbemiga Awoniran:** Methodology, Project administration, Resources, Writing - original draft, Writing - review & editing, Visualization. **David Adesanya Ofusori:** Project administration, Writing - review & editing. **Kehinde Akinyemi Jolayemi:** Writing - review & editing.

Declaration of competing interest

Declarations of interest: none'.

References

[1] W.K. Hsu, Advanced techniques in cervical spine surgery, J Bone Joint Surg Am 93 (2010) 780–788.
[2] C. Slipman, R.S. Derby, A.F. Simeone, T.G. Mayer, Interventional Spine E-Book: an Algorithmic Approach, Elsevier Health Sciences, 2007, p. 519.
[3] N. Bogduk, S. Mercer, Biomechanics of the cervical spine, I: normal kinematics, Clin. Biomech. 15 (2000) 633–648.
[4] R.J. Bransford, T.B. Alton, A.R. Patel, C. Bellabarba, Upper cervical spine trauma, J Am Acad Orthop 22 (2014) 718–729.
[5] A.M.R. Agur, A.F. Dalley Grant, Atlas of Anatomy, thirteenth ed., Lippincott Williams & Wilkins, Philadelphia, 2013.
[6] D.H. Kim, A.R. Vaccaro, C.A. Dickman, D. Cho, S. Lee, I. Kim, Surgical Anatomy and Techniques to the Spine E-Book, Elsevier Health Sciences, 2013.
[7] J.S. Ross, K.R. Moore, Diagnostic Imaging: Spine E-Book, Elsevier Health Sciences, 2015.
[8] S.H. Tan, E.C. Teo, H.C. Chua, Quantitative three-dimensional anatomy of cervical, thoracic and lumbar vertebrae of Chinese Singaporeans, Eur. Spine J. 13 (2004) 137–146.
[9] M. Chazono, T. Tanaka, Y. Kumagae, T. Sai, K. Marumo, Ethnic differences in pedicle and bony spinal canal dimensions calculated from computed tomography of the cervical spine: a review of the English-language literature, Eur. Spine J. 21 (2012) 1451–1458.
[10] S. Hueston, Anthropometric analysis of the cervical spine", Browse all Theses and Dissertations (2011) 29–31 Paper 487.
[11] G. Prabavathy, X.C. Philip, G. Arthi, T. Sadeesh, Morphometric study of cervical vertebrae C3-C7 in South Indian population –A clinico-anatomical approach, Ital. J. Anat Embryol. 122 (2017) 49–57.
[12] M.M. Panjabi, J. Duranceau, V. Goel, T. Oxland, K. Takata, Quantitative three-dimensional anatomy of the middle and lower regions, Spine 16 (1991) 861–869.
[13] D. Liguoro, B. Vandermeersch, J. Guerin, Dimensions of cervical vertebral bodies according to age and sex, Surg. Radiol. Anat. 16 (1994) 149–155.
[14] Y.H. Zhu, K.L. Cheng, Z. Zhong, Y.Q. Li, Q.S. Zhu, Morphologic evaluation of Chinese cervical endplate and uncinate process by three-dimensional computed tomography reconstructions for helping design cervical disk prosthesis, J. Chin. Med. Assoc. 79 (2016) 500–506.
[15] B. Abuzayed, B. Tutunculer, B. Kucukyuruk, S. Tuzgen, Anatomic basis of anterior and posterior instrumentation of the spine: morphometric study, Surg. Radiol. Anat. 32 (2010) 75–85.
[16] C.J. Bazaldua, L.A. Gonzalez, S.A. Gomez, Morphometric study of cervical vertebrae C3-C7 in a population from Northeastern Mexico, Int. J. Morphol. 29 (2011) 325–330.
[17] A.K. Mahto, S. Omar, Clinico-anatomical approach for instrumentation of the cervical spine: a morphometric study on typical cervical vertebrae, Int. J. Sci. Stud. 3 (2015) 143–145.