Journal of Anatomical Sciences

Email:anatomicaljournal@gmail.com

J Anat Sci 12 (1)

Correlation between the Cervical Spine Angle and Disc Height of the Cervical Vertebrae: A Prospective Radiogrammetric Study

[1]Giami B, [1]Oyakhire MO, [1]Oghenemavwe LE and [2]Aigbogun Jr. EO
[1]Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Science, University of Port Harcourt, Rivers State, Nigeria
[2]Research Department, Derindam Research Institute of Biotechnology, Akwa Ibom State, Nigeria

Corresponding Author: Oyakhire MO
E-mail: michael.oyakhire@uniport.edu.ng; +2347066131880

ABSTRACT
This study evaluated the relationship between the radiogrammetric linear and angular parameters of the cervical vertebrae of healthy adult male and female Nigerian subjects. The research was a cross-sectional study involving radiogrammetric dimensions of the cervical vertebrae obtained from plain film lateral radiographs of the cervical spine of one hundred (100; 62 males, 38 females) apparently normal volunteer subjects. The measurements; cervical spine angle (CSA) and disc height (CDH) were obtained using the PACS software, which managed in MS office excel sheet 2016. The data was stratified by sex and transferred to STATGRAPHICS centurion CVI version 16.1.11 (StatPoint Tech., Inc.) for analysis. SPSS Spearman Rho was used to test the relationship between CSA and CDH. From the analysis, the correlations between CSA and CDH were not significant (P>0.05); however, CSA was positively correlated with CDH of C2-C3 (r=0.090), but negatively correlated with lower vertebrae disc; C3-C4 (r=-0.150), C4-C5 (r=-0.166), C5-C6 (r=-0.147), and C6-C7 (r=-0.101). The extent of variation in model fitting explained by sex ranged from 3.10 to 4.20% for CDH, which were not significant (P>0.05). Notably was the high sex-associated variance in the relationship between CSA and CDH: C2-C3. In conclusion, though the correlations between CSA and CDH of C2 to C7 were not significant, nevertheless, it is important to note when the relationship is inverted, it suggests an abnormality of clinical importance. The existing relationship could be observed to be slightly influenced by sex, especially for C2-C3. It would be useful if the relationship between these parameters is studied for a spectrum of clinical conditions.

Keywords: Cervical spine angle (CSA), cervical disc height (CDH), correlations, sex influence, Nigerian population

INTRODUCTION
The lordosis angle (cervical spine angle; CSA) is determined by measuring the angle between the straight lines that connect the posterior edges of the C2 and C7 vertebrae [(1)(2)]. The four most common methods for measuring cervical lordosis include the modified Cobb method (mCM), Jackson physiological stress lines (JPS), Harrison's posterior tangent method (HPT), and the Ishihara Index [(3)(4)(5)]. Spinal curvature is one of the most significant spine parameters for the evaluation of spinal deformities [(4)(6)(7)], providing support to various spine-related clinical measurements, and image processing techniques [(8).] Although the sagittal alignment of the cervical vertebrae can vary with age and sex [(9)(10)(11),] the natural sagittal curve of the cervical spine is known to have a lordosis [(12)(1) (13)(11)]. Harrison *et al*. reported a mean C2–C7 lordotic angle of 26.89±9.72° in 72 healthy participants [(1).]

The discs (intervertebral disc) are the specialized cushions that reside between each of the spinal vertebrae [(14)]. It is the distance (at the midpoint) between the corresponding superior and inferior vertebrae [(15).] After age 40, almost 60% of the population has radiographic evidence of cervical spine degeneration and by age 65, 95% of men and 70% of women will have some sort of degenerative change on X-ray [(16)(17)(18)]. A range of 4.6-6.8mm for cervical disc height has been reported to be normal by different researchers [(18)(19)(20).]

The majority of research on sagittal cervical balance focused on analysing radiographs of the cervical spine and comparing them with clinical symptoms [(21)(22)(4),] whereas few studies focused on the clinical relationship between cervical sagittal alignment and disc degeneration as seen on magnetic resonance imaging (MRI) [(23).] However, there is a paucity of information regarding a potential relationship between the cervical lordosis and disc height. Therefore, the aim of this study was to evaluate the correlation between cervical lordosis and cervical disc height in apparently normal population. This relationship would be useful in explaining the changes in disc height that could affect the lordosis.

MATERIALS AND METHODS

This research was a prospective cross-sectional study, which involved taking linear and angular dimensions of one hundred (100; 62 males, 38 females) apparently normal volunteer subjects using lateral radiographs (radiogrammetry). The study was conducted between the month of February to September 2019. Before carrying out the study, ethical clearance (with reference number UPH/CEREMAD/REC/MM56/012) was received from the University of Port Harcourt Research Ethics Committee, while written informed was obtained from the participating individuals.
The suitable sample size for radiologic studies was estimated using the formula provided by Pagano and Gauvreau [24], and modified by Eng [25], the minimum sample size for comparative radiological study could be determined using the formula;

$$SS = \frac{4\sigma^2 \times (Z_{crit}+Z_{pwr})^2}{D^2}$$

Where;
n = minimum sample size
Z_{crit} = (1.96) critical value at the level of significance.
Z_{pwr} = (1.282) probability equivalence of statistical power of 90%, at 0.05 level of significance [25].
S.D = (6.35°) standard deviation from a previous study [26].
D = expected difference of clinical significance = 2.5 [27][28].

$$n = \frac{4 \times 6.35^2 \times (1.282 + 1.96)^2}{5^2} = \frac{1695.24}{25} = 68$$

Adding 10% attrition = 68 + 7 = 75 suitable sample size. Purposive sampling technique was adopted for this study considering that normal values of the dimensions of the cervical vertebrae of adult Nigerians are to be determined. The growing concern of exposure to radiation affected the number of volunteers for this study. Eligible adult Nigerians across Rivers State were enlightened about the essence of the study and only those that gave their informed consent were recruited for the study.

The following were the inclusion criteria; adult Nigerians (20 – 45 years) with no history of traumatic injury to the neck; no acute/chronic severe neck pain; no associated cervical vertebra and region abnormalities. The exclusion criteria were those that did not meet the inclusion criteria; radiographs that indicates abnormal degeneration of the cervical vertebrae; trauma or injuries. The protocol was carried out in accordance with the safety guideline of
The age range for the study population was 21 to 45 years (mean age; female=28.68±5.14 and male=28.55±6.85) as shown in Fig. A1.1

The lordosis angle (cervical spine angle; CSA) is the angle formed by the intersection of two parallel lines to the posterior wall of the C2 to C7 vertebral bodies [29]. The study obtained the angle using the posterior tangent method [16] as shown in Fig A1.2.

The cervical disc height (CDH) of a given disc was determined using the following steps [17];

1. The study determined the four corners of the two adjacent vertebral bodies, which are in the farthest outer surface of the cortical bone from the centre of each vertebral body (A, A', B, and B').
2. A straight bisecting line (C) is drawn passing through the centers of lines A–B and A'–B'.
3. The sum of the shortest distances from the midpoint of the upper and lower endplates to the bisecting line (a + b) is calculated, and documented as disc height as shown in Fig A1.3 (Appendix B).

The data was stratified by sex in Microsoft Office excel sheet and transferred to STATGRAPHICS centurion CVI version 16.1.11 (StatPoint Tech., Inc.) for analysis. SPSS Spearman Rho was used to test the relationship between cervical lordosis and disc height, and comparison of regression lines accessed the influence of sex on the relationship.

RESULTS

The radiogrammetric dimensions of the cervical vertebrae are presented and the descriptive characteristics of CSA) and CDH were presented in Table 4.1. The mean (±standard deviation) for CSA were 25.47±4.31° for females and 23.42±5.51°. The mean (±standard deviation) for CDH at C2-C3 were 7.67±0.69mm for the females and 7.55±0.73mm for the males, for C3-C4 were 7.40±0.91 for the females and 7.68±0.98 for the males, C4-C5 (F=7.98±1.99mm, M=7.85±1.01mm), C5-C6 (F=7.40±0.91mm, M=7.96±1.08mm), and C6-C7 (F=7.94±1.05mm, M=8.08±1.14mm).

The correlations between CSA presented in Table 2 indicated that although the correlations between CSA with CDH were not significant (P>0.05), however, CSA was positively correlated with CDH of C2-C3 (r=0.090), but negatively correlated with lower vertebrae disc; C3-C4 (r=-0.150), C4-C5 (r=-0.166), C5-C6 (r=-0.147), and C6-C7 (r=-0.101).

From the ANOVA result in Table 3, there are slight differences in the regression equation for CSA estimation from CDH with regards to sex; however, the differences were not statistically significantly. The extent of variation in model fitting explained by sex ranged from 3.10 to 4.20% for CDH (Table 3a). The analysis of the regression lines and coefficients are presented in Table 3b.

The linear regression model that describes the relationship between CSA and CDH (C2-C3, C3-C4, C4-C5, C5-C6, and C6-C7 vs Sex (Table 3b; Fig. 2) is as follows:

- For C2-C3, when sex=female, CSA = 9.316 + 2.126×CDH: C2-C3, and when Sex=male,

CSA = 23.624 - 0.040×CDH: C2-C3.

- For C3-C4, when sex=female, CSA = 29.114 - 0.454×CDH: C3-C4, and when Sex=male, CSA = 30.562 - 0.941×CDH: C3-C4.
- For C4-C5, when sex=female, CSA = 32.121 - 0.829×CDH: C4-C5, and when Sex=male, CSA = 28.922 - 0.705×CDH: C4-C5.
- For C5-C6, when sex=female, CSA = 29.071 - 0.456×CDH: C5-C6, and when Sex=male, CSA = 28.136 - 0.611×CDH: C5-C6.
- For C2-C3, when sex=female, CSA = 32.690 - 0.884×CDH: C6-C7, and when Sex=male, CSA = 24.991 - 0.207×CDH: C6-C7.

Table 1: Descriptive statistics of cervical spine angle (CSA) and cervical disc height (CDH)

	CSA (º)	CDH (mm): C2-C3	CDH (mm): C3-C4	CDH (mm): C4-C5	CDH (mm): C5-C6	CDH (mm): C6-C7
Total						
Mean±S.D	24.20±5.16	7.59±0.71	7.69±0.99	7.90±1.07	7.75±1.05	8.03±1.10
Minimum	16.0	6.0	6.0	6.0	6.0	6.0
Maximum	35.0	9.0	10.2	10.2	10.2	10.4
Female						
Mean±S.D	25.47±4.31	7.67±0.69	7.71±1.03	7.98±1.19	7.40±0.91	7.94±1.05
Minimum	17.0	6.0	6.0	6.0	6.0	6.0
Maximum	35.0	8.9	9.4	10.2	9.2	10.0
Male						
Mean±S.D	23.42±5.51	7.55±0.73	7.68±0.98	7.85±1.01	7.96±1.08	8.08±1.14
Minimum	16.0	6.0	6.0	6.0	6.0	6.0
Maximum	35.0	9.0	10.2	10.2	10.2	10.4

Table 2: Correlation between cervical spine angle (CSA) and cervical disc height (CDH)

Variables		CDH: C2-C3	CDH: C3-C4	CDH: C4-C5	CDH: C5-C6	CDH: C6-C7
CSA	R	0.090	-0.150	-0.166	-0.147	-0.101
	P-value	0.374	0.137	0.099	0.146	0.315

Table 3a: Summary of the Analysis of Variance for the comparison of regression lines for evaluating the influence of sex on the relationship between and CDH of C2-C3, C3-C4, C4-C5, C5-C6, and C6-C7

Models	Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
1	CDH: C2-C3					
	Model	183.142	3	61.0474	2.39	0.0736
	Residual	2452.86	96	25.5506		
	Total (Corr.)	2636	99			
	R-Sq = 6.95%, R -Sq (adjusted for d.f.) = 4.04%					
2	CDH: C3-C4					
	Model	188.692	3	62.8974	2.47	0.0668
	Residual	2447.31	96	25.4928		
	Total (Corr.)	2636	99			
	R-Sq = 7.16%, R -Sq (adjusted for d.f.) = 4.26%					
3	CDH: C4-C5					
	Model	189.075	3	63.0249	2.47	0.0663
	Residual	2446.93	96	25.4888		
	Total (Corr.)	2636	99			
	R-Sq = 7.12%, R -Sq (adjusted for d.f.) = 4.27%					
4	CDH: C5-C6	159.885	3	53.2951	2.07	0.1098
	Model	2476.11	96	25.7929		
	Residual	2636	99			
	Total (Corr.)					
	R-Sq = 6.07%, R -Sq (adjusted for d.f.) = 3.13%					
5	CDH: C6-C7	161.335	3	53.7785	2.09	0.1071
	Model	2474.66	96	25.7778		
	Residual	2636	99			
	Total (Corr.)					
	R-Sq = 6.12%, R -Sq (adjusted for d.f.) = 3.19%					

Table 3b: ANOVA for variables in the order fitted for the linear dimensions for CDH of C2-C3, C3-C4, C4-C5, C5-C6, and C6-C7

Model	Source	Sum of Squares	Df	F-Ratio	P-Value	Coefficients (Female)		Coefficients (Male)	
						Intercept	Slope	Intercept	Slope
1	CDH: C2 - C3	21.3137	1	0.830	0.363	9.316	2.126	23.623	-0.040
	Intercepts	117.472	1	4.600	0.035				
	Slopes	44.3567	1	1.740	0.191				
	Model	183.142	3						
2	CDH: C3 - C4	59.0822	1	2.320	0.131	29.114	-0.454	30.562	-0.941
	Intercepts	124.38	1	4.880	0.030				
	Slopes	5.22976	1	0.210	0.652				
	Model	188.692	3						
3	CDH: C4 - C5	72.4569	1	2.840	0.095	32.121	-0.829	28.922	-0.705
	Intercepts	116.243	1	4.560	0.035				
	Slopes	0.375153	1	0.010	0.904				
	Model	189.075	3						
4	CDH: C5 - C6	56.6769	1	2.200	0.142	29.071	-0.456	28.136	-0.611
	Intercepts	102.666	1	3.980	0.049				
	Slopes	0.542058	1	0.020	0.885				
	Model	159.885	3						
5	CDH: C6 - C7	27.1184	1	1.050	0.308	32.690	-0.884	24.992	-0.207
	Intercepts	121.758	1	4.720	0.032				
	Slopes	12.4586	1	0.480	0.489				
	Model	161.335	3						

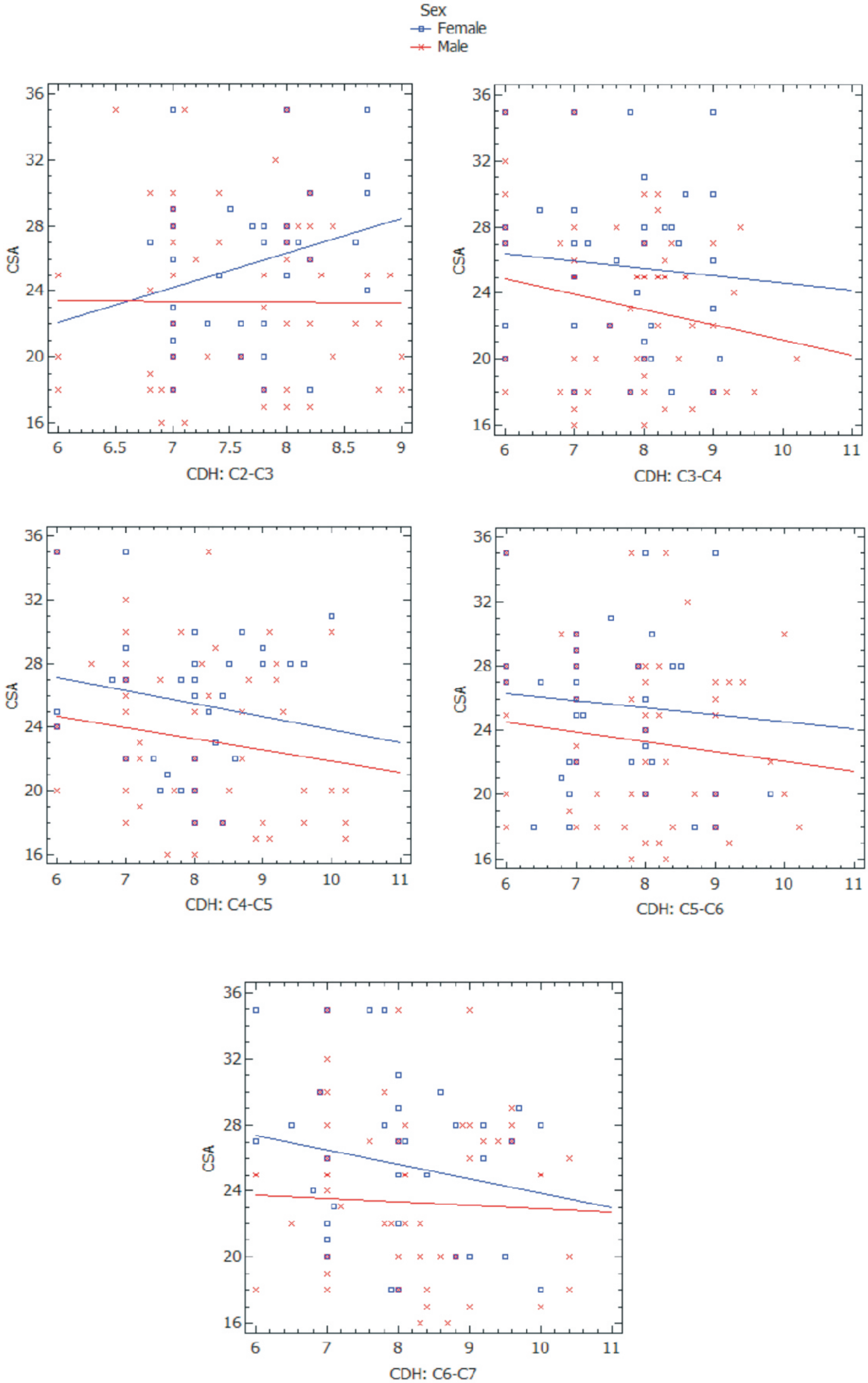

Figure 2: Comparison of regression lines of male and female on the relationship between CSA and CDH

DISCUSSION

The relationship between the clinical symptoms and the changes in CSA and CDH are well researched [(21)(22)(4)(30)], with a few studies evaluating clinical relationship between cervical sagittal alignment and disc degeneration [(23)(13).] Although the sagittal alignment of the cervical vertebrae can vary with age and sex [(31)(4)(6)], the natural sagittal curve of the cervical spine is known to have a lordosis [(12)(1)(13)]). Several studies have demonstrated that there are several cervical disorders associated with a loss of cervical lordosis, such as kyphosis and disc degeneration [(4)(32)(8)(33).]

The lordotic nature of the cervical region compensate for the kyphotic curvature of the thoracic region [(12)(1)(13)(11)].); thus, maintaining the centre of gravity and balance. The progressive loss of cervical lordosis rapidly increases the abnormality as there is introduction of abnormal forces to the head and neck region [(31)(4)]. The vertebral disc is designed to maintain an isotropic form by transmitting axial load uniformly across the disc and vertebral endplate [(34)(35)(36)]. The extent of CSA deviation with degenerative changes in cervical disc has been reported to associated with distortion of axis of load transmission across the spine, therefore causing an uneven pressure [(23)]. In this study, positive correlation was found between CSA and CDH for C2-C3, while the CDH for C3-C4 to C6-C7 were negatively correlated with CSA. The structural alignment of C2-C3 is significant in the observed negative correlations for C3-C4 to C6-C7. A recent cohort study found that an increased occipito-cervical angle may result in large biomechanical stress on the adjacent structures or deformation of cervical alignment [(37)], and in another study, the loss of the natural C2–C7 angle facilitates cervical disc degeneration [(38).]

The analysis of the influence of sex on the relationship between CSA and CDH of C2 to C7, showed that CSA vs CDH: C2-C3, was most influenced by sex. The comparison of regression lines showed a stronger positive correlation in males, but a nearly negative correlation in females. Studies have shown that cervical alignment and dimensions are influenced by sex and age in both asymptomatic patients and normal populations [(34)(31)(13)(11)]. Sampson [(39)] found that sex had significant influence on cervical spine segmental range of motion (ROM) only at C2-C3. The observed significant gender variation in cervical lordosis prompted Been [(31)] to suggest that before neck stabilization procedures or correction and restoration are carried out on a patient, the gender and age differences in cervical lordosis should be taken into account.

CONCLUSION

Although the correlations between CSA and CDH of C2 to C7 were not significant, nevertheless, it is important to note when the relationship is inverted, it suggests an abnormality of clinical importance. The existing relationship could be observed to be slightly influenced by sex, especially for C2-C3. Understanding the relationship between these parameters for a spectrum of clinical conditions would be very useful to clinical practice.

Study Limitation

The study noted with concern the difficulty in obtaining volunteer subjects willing to undergo a none-clinical associated or prescribed x-ray procedure. This ruled out randomisation and reduced the possibility of recruiting above the used sample size.

REFERENCES

1. Harrison, Donald D., Harrison, D. E., Janik, T. J., Cailliet, R., Ferrantelli, J. R., Haas, J. W., & Holland, B. Modeling of the Sagittal Cervical Spine as a Method to Discriminate Hypolordosis. Spine. 2004b; 29(22): 2485–2492. https://doi.org/10.1097/01.brs.0000144449.90741.7c
2. Nojiri, K., Matsumoto, M., Chiba, K., Maruiwa, H., Nakamura, M., Nishizawa, T., & Toyama, Y. Relationship between alignment of upper and lower cervical spine in asymptomatic individuals. Journal of Neurosurgery. 2003; 99(1 SUPPL.): 80–83. https://doi.org/10.3171/spi.2003.99.1.0080
3. Ames, C. P., Blondel, B., Scheer, J. K., Schwab, F. J., Le Huec, J. C., Massicotte, E. M., Patel, A. A., Traynelis, V. C., Kim, H. J., Shaffrey, C. I., Smith, J. S., & Lafage, V. Cervical radiographical alignment: Comprehensive assessment techniques and potential importance in cervical myelopathy. Spine. 2013; 38(22): S149–S160. https://doi.org/10.1097/BRS.0b013e3182a7f449
4. Scheer, J. K., Tang, J. A., Smith, J. S., Acosta, F. L., Protopsaltis, T. S., Blondel, B., Bess, S., Shaffrey, C. I., Deviren, V., Lafage, V., Schwab, F., Ames, C. P. Cervical spine alignment, sagittal deformity, and clinical implications. Journal of Neurosurgery: Spine. 2013; 19(2): 141–159. https://doi.org/10.3171/2013.4.SPINE12838
5. Tan, L. A., Straus, D. C., & Traynelis, V. C. Cervical interfacet spacers and maintenance of cervical lordosis. 2015; 22: 466–469. https://doi.org/10.3171/2014.10.SPINE14192.Disclosure
6. Steinmetz, M. P., Stewart, T. J., Kager, C. D., Benzel, E. C., & Vaccaro, A. R. CERVICAL DEFORMITY CORRECTION. Neurosurgery. 2007; 60(suppl_1), S1-90-S1-97. https://doi.org/10.1227/01.NEU.0000215553.49728.B0
7. Tundo, F., Avila, M. J., Willard, L., Fanous, S., Curri, C., Hussain, I., & Baaj, A. A. Spinal alignment, surgery, and outcomes in cervical deformity: A practical guide to aid the spine surgeon. In Clinical Neurology and Neurosurgery.

2019; 185 Elsevier B.V. https://doi.org/10.1016/j.clineuro.2019.105496
8. Kim, Y. H., Dorj, A., Han, A., Kim, K., & Nha, K. W. Improvements in spinal alignment after high tibial osteotomy in patients with medial compartment knee osteoarthritis. Gait and Posture. 2016; 48: 131–136. https://doi.org/10.1016/j.gaitpost.2016.05.001
9. Gay, R. E. The curve of the cervical spine: Variations and significance. In Journal of Manipulative and Physiological Therapeutics. 1993; 16(9): 591–594). http://europepmc.org/article/MED/8133194
10. Harrison, D. D., Troyanovich, S. J., Harrison, D. E., Janik, T. J., & Murphy, D. J. A normal sagittal spinal configuration: A desirable clinical outcome. In Journal of Manipulative and Physiological Therapeutics. 1996; 19(6): 398–405).
11. Simpson, A. K., Biswas, D., Emerson, J. W., Lawrence, B. D., & Grauer, J. N. Quantifying the effects of age, gender, degeneration, and adjacent level degeneration on cervical spine range of motion using multivariate analyses. Spine. 2008; 33(2): 183–186. https://doi.org/10.1097/BRS.0b013e31816044e8
12. Gangnet, N., Pomero, V., Dumas, R., Skalli, W., & Vital, J. M. Variability of the spine and pelvis location with respect to the gravity line: A three-dimensional stereoradiographic study using a force platform. Surgical and Radiologic Anatomy. 2003; 25(5–6): 424–433. https://doi.org/10.1007/s00276-003-0154-6
13. Liu, B., Wu, B., Van Hoof, T., Okito, J. P. K., Liu, Z., & Zeng, Z. Are the standard parameters of cervical spine alignment and range of motion related to age, sex, and cervical disc degeneration? Journal of Neurosurgery: Spine. 2015; 23(3): 274–279. https://doi.org/10.3171/2015.1.SPINE14489
14. Fryer, J. Disc height loss cervical.pdf. https://www.drfryer.ca/disc-height/
15. Mehta, H. P., Santos, E. R., & Sembrano, J N; Hunt, MA; Parr, A; Polly Jr., DW; Nuckley, D. (2012). Radiographic Measurement of Cervical Disc Height and the Inter-Surgeon Variability in its Application. 2016; 2192: 2192.
16. Takeshita, K., Murakami, M., Kobayashi, A., Nakamura, C. Relationship between cervical curvature index (Ishthara) and cervical spine angle (C2-C7). Journal of Orthopaedic Science. 2001; 6: 223-226.
17. Gore, D.R., Sepic, S.B., & Gardner GM. Neck pain: a long-term follow-up of 205 patients. Spine. 1987; 12: 1—5.
18. Rampersaud, R., Fehlings, M., Harrop, J., Kuklo, T., Massicotte, E., Salonen, D., Shaffrey, C., & Vaccaro, A. Validation of digital radiology measurement tools for quantitative spinal imaging. Topics in Spinal Cord Injury Rehabilitation. 2006; 12(1): 11–21.
19. Chung, C-T., Thai, Sen-Wei., Chen, Chun-Jung., Wu, Ting-Chung., Wang, D., Lan, Haw-Chang H., & Wu, Shyi-Kuen. Comparison of the intervertebral disc spaces between axial and anterior lean cervical traction. European Spine Journal. 2009; 18 (11): 1669-1676.
20. Yukawa, Y., Kato, F., Suda, K., Yamagata, M., & Ueta, T. Age-related changes in osseous anatomy, alignment, and range of motion of the cervical spine: part I. radiographic data from over 1,200 asymptomatic subjects. European Spine Journal. 2012; 21(8): 1492–1498.
21. Choi, S.H., Lee, H., Cho, J.H., Jung, J.I., & Lee, D.H. Radiological Parameters of Undegenerated Cervical Vertebral Segments in a Korean Population. Clinical Orthopaedic Surgery. 2017; 9(1): 63-70.
22. Bao, H., Varghese, J., Lafage, R., Liabaud, B., Diebo, B., Ramchandran, S., Day, L., Jalai, C., Cruz, D., Errico, T., Protopsaltis, T., Passias, P., Buckland, A., Qiu, Y., Schwab, F., & Lafage, V. (2017). Principal Radiographic Characteristics for Cervical Spinal Deformity. Spine, 42(18), 1375–1382. https://doi.org/10.1097/BRS.0000000000002144
23. Le Huec, J. C., Demezon, H., & Aunoble, S. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. European Spine Journal. 2015; 24(1): 63–71. https://doi.org/10.1007/s00586-014-3632-0
24. Lee, H. J., Jeon, D. G., & Park, J. H. Correlation between kinematic sagittal parameters of the cervical lordosis or head posture and disc degeneration in patients with posterior neck pain. Open Medicine. 2021; 16(1): 161–168. https://doi.org/10.1515/med-2021-0219
25. Pagano, M., & Gauvreau K. Principles of biostatistics.2nd ed. Pacific Grove, Calif: Duxbury. 2000; 246–249: 330–331.
26. Eng, J. Sample Size Estimation: How Many Individuals Should Be Studied? Statistical Concepts Series. Radiology. 2003; 227(2): 309-313.
27. Asal, N and Şahan, M.H. Is there a relationship between migraine disease and the skull base angles? Ortadoğu Tıp Dergisi. 2018; 10(4): 456–470.
28. Meschan, R., & Farrer, M.F. Synopsis of Radiologic Anatomy. 1975; 2: 332-354.
29. Oyakhire, O.M., and Didia, B.C. Metric analysis of the lumbosacral angle in a population of asymptomatic Nigerians. *Afr. J. Med. Med. Sci*., 2011; 4: 1SSN:2141- 0151.
30. Been, E., Shefi, S., & Soudack, M. Cervical lordosis: the effect of age and gender. Spine Journal. 2017; 17(6): 880–888. https://doi.org/10.1016/j.spinee.2017.02.007
31. Gum, J. L., Glassman, S. D., Douglas, L. R., & Carreon, L. Y. Correlation between cervical spine sagittal alignment and clinical outcome after anterior cervical discectomy and fusion. American

Journal of Orthopedics (Belle Mead, N.J.). 2012; 41(6): E81-4.
32. Shamji, M. F., Mohanty, C., Massicotte, E. M., & Fehlings, M. G. The Association of Cervical Spine Alignment with Neurologic Recovery in a Prospective Cohort of Patients with Surgical Myelopathy: Analysis of a Series of 124 Cases. World Neurosurgery. 2016; 86: 112–119. https://doi.org/10.1016/j.wneu.2015.09.044
33. Ao, S., Liu, Y., Wang, Y., Zhang, H., & Leng, H. Cervical kyphosis in asymptomatic populations: Incidence, risk factors, and its relationship with health-related quality of life. Journal of Orthopaedic Surgery and Research. 2019; 14(1). https://doi.org/10.1186/s13018-019-1351-2
34. Adams, M. A., McNally, D. S., & Dolan, P. "Stress" distributions inside intervertebral discs. The effects of age and degeneration. Journal of Bone and Joint Surgery - Series B. 1996; 78(6): 965–972. https://doi.org/10.1302/0301-620X78B6.1287
35. McNally, D. S., & Adams, M. A. Internal intervertebral disc mechanics as revealed by stress profilometry. Spine. 1992; 17(1): 66–73. https://doi.org/10.1097/00007632-199201000-00011
36. Mulholland, R. C. The myth of lumbar instability: The importance of abnormal loading as a cause of low back pain. In European Spine Journal. 2008; 17(5): 619–625). Eur Spine J. https://doi.org/10.1007/s00586-008-0612-2
37. Maulucci, C., Ghobrial, G., Sharan, A., Harrop, J., Jallo, J., Vaccaro, A., & Prasad, S. Correlation of Posterior Occipitocervical Angle and Surgical Outcomes for Occipitocervical Fusion. Evidence-Based Spine-Care Journal. 2014; 05(02): 163–165. https://doi.org/10.1055/s-0034-1386756
38. Okada, E., Matsumoto, M., Ichihara, D., Chiba, K., Toyama, Y., Fujiwara, H., Momoshima, S., Nishiwaki, Y., Hashimoto, T., Ogawa, J., Watanabe, M., & Takahata, T. (). Does the sagittal alignment of the cervical spine have an impact on disk degeneration? Minimum 10-year follow-up of asymptomatic volunteers. European Spine Journal. 2009; 18(11): 1644–1651. https://doi.org/10.1007/s00586-009-1095-5