



Original Article

Morphometric analysis of cervical disc space height and interpedicular distance using computed tomography

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ABSTRACT

Background: This study utilized computed tomography (CT) to establish normative radiographic morphometric measurements of cervical disc space height (DSH) and interpedicular distance (IPD) and document the influence of patient sex, race, ethnicity, and anthropometric characteristics.

Methods: Cervical CTs of 1000 patients between 18 and 35 years of age without known spinal pathology were reviewed. Statistical analyses included the assessment of associations between patient height, weight, sex, race, and ethnicity regarding DSH and IPD.

Results: Irrespective of disc level, average DSH measurements were as follows: anterior height of 2.6 ± 1.0 mm, middle height of 4.1 ± 1.2 mm, and posterior height of 1.8 ± 1.0 mm. IPD was only measured between C3 and C7 vertebrae, and irrespective of disc level, the mean IPD measurement was 21.1 ± 1.5 mm. Significant differences for anterior, middle, posterior DSH, and IPD were observed in all disc levels. Significant differences in DSH and IPD were observed for all anthropometric factors of sex, race, and ethnicity relative to vertebral level. Males had significantly larger DSH and IPD measurements across all vertebral levels compared to females. Caucasians had larger DSH and IPD at select vertebral levels compared to African Americans and Hispanics.

Conclusion: This study describes measurements of DSH and IPD between C2 and T1 levels in 1000 healthy 18–35-year-old subjects without known pathology. DSH and IPD measurements varied based on patient sex, race, ethnicity, and disc level.

Keywords: Cervical, Computed tomography, Disc space height, Ethnicity, Interpedicular distance

INTRODUCTION

Few studies have investigated measurements of disc space height (DSH) or interpedicular distance (IPD), with previous exploration of DSH focusing significantly on lumbar, rather than cervical, intervertebral disc space.^[3] Both DSH and IPD have demonstrated significant usage in

the indication of spinal pathology.^[6] However, the literature has neither adequately explored the normative values of DSH and IPD nor investigated deviations from the norm as indicators of spinal pathology.

To address these needs, this study aims to build on the foundations laid by Razzouk *et al.* in determining normative measurements of spinal anatomy. This prior study sought to establish normative measurements of cervical neuroforaminal dimensions (CNFD).^[10] Similarly, the purpose of this study was to use computed tomography (CT) of young patients free of spinal pathology to establish normative measurements of DSH and IPD and to investigate the influence of patient sex, race, ethnicity, and anthropometric characteristics.

MATERIALS AND METHODS

Patient selection

Following IRB approval (#5240124), we reviewed CT (GE Discovery 750 HD 64-slice CT scanner) of the cervical spine without contrast or soft neck tissue of 1000 patients between 18 and 35 years of age free of spinal pathology. All CT scans were performed between January 2014 and January 2023. Patient consent was not required due to the nature of this retrospective and radiographic study. Relevant spinal pathology was identified based on previous diagnoses in either the patient’s radiographic or electronic medical records. A total of 4762 subjects were screened, of which 3762 were excluded from the study. Table 1 reports all exclusion criteria and a description of the excluded cohort. Patient weight, height, body mass index (BMI), sex, race, and ethnicity were recorded at the time of imaging. Racial and ethnic data were obtained through the patient’s self-reported answers regarding their racial and ethnic heritage in the

electronic medical record. Table 2 reports a description of the included cohort.

Data collection

Images were reviewed and measured by eight medical students trained by a board-certified neuroradiologist (NW) using the IMPAX6 (Agfa-Gavaert, Mortsel, Belgium) picture archiving and communication system with window and level designations of 2000 Hounsfield Unit (HU) and 500 HU, respectively. DSH and IPD were calculated according to the borders of the vertebral outline using the IMPAX6 tracing freeform tool and were measured in the sagittal and axial views, respectively. Anterior, middle, and posterior DSH were defined as the distances between the respective anterior, middle, and posterior edges of neighboring endplates in millimeters (mm). IPD was defined as the maximum



Figure 1: Measurement technique of cervical disc space height. H: Height.

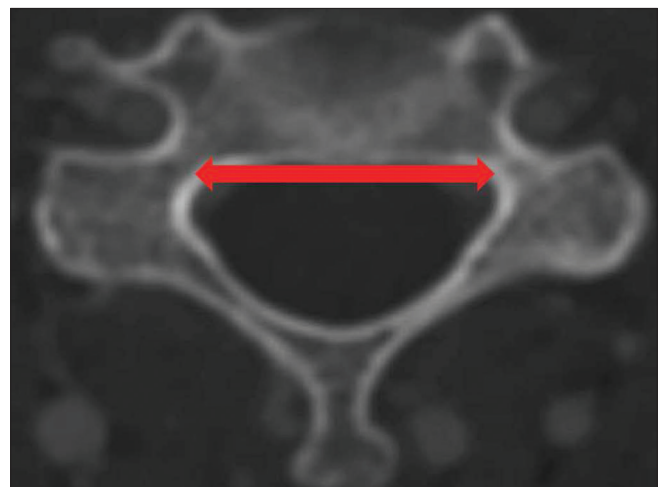


Figure 2: Measurement technique of cervical interpedicular distance. Arrow showcases measurement technique/taken of IPD.

Table 1: Exclusion criteria and excluded cohort.

Exclusion criteria	Number of excluded patients (Total=3762)
Not between 18 and 35 years of age	1309
Incomplete or poor imaging	967
Congenital cervical stenosis	327
Achondroplasia	2
Cerebral palsy	4
Klippel-Feil anomaly	0
Neck or upper extremity pain or numbness	354
Traumatic spinal injury with/without bone injury	264
Spinal malignancy	22
Spinal infection	27
Existing spinal hardware	0
Previous cervical spinal surgery	486

distance between the medial aspects of the pedicles at a given vertebral level. Figure 1 illustrates the measurement technique for disc space height. Figure 2 illustrates the measurement technique for IPD. Interobserver reliability was assessed through the intraclass correlation coefficient (ICC) two-way mixed model on absolute agreement, and the ICC was found to be excellent at 0.792 with a 95% confidence interval of 0.736 to 0.842.^[2,5,11]

Statistical and power analysis

Data collection and visualization were performed using Microsoft Excel version 16.58 (Microsoft Corporation, 2022, Redmond, WA, USA). SPSS version 28 (IBM Corporation, 2021, Armonk, NY, USA) was utilized for all subsequent statistical analyses with alpha defined as $P < 0.05$. Kolmogorov–Smirnov tests and Q-Q plots were used to assess data normality, and Levene’s homogeneity of variance test and regression residual plots were used to evaluate homoscedasticity.^[8,12,13] Pearson correlation tests were performed to assess associations among radiographic, demographic, and anthropometric variables, with correlation coefficients categorized as weak, moderate, and strong, corresponding to value ranges of 0–0.4, 0.4–0.7, and 0.7–1, respectively.^[9] Differences in DSH and IPD based on sex, race, and ethnicity were assessed using a two-way analysis of covariance with anthropometric covariates, estimated marginal means, and type III sum-of-square specification.

Measurement differences among disc levels were analyzed using one-way analysis of variance (ANOVA) with *post hoc* Bonferroni and Tukey corrections.

Non-directional partial correlation power analysis was conducted with a sample size of 1000, specified parameters of 0.05 for an alpha, a null value of zero, a partial correlation parameter of 0.300, and an assumed number of four variables to be partially out. An achieved power of 100% was determined by power analysis. A one-way ANOVA power analysis was conducted with specified parameters of 0.05 for alpha, a standard deviation of 1.0, and sample groups of 357, 245, 144, and 83 (corresponding to the racial and ethnic subgroups of our study) with similar achieved power of 100%.

RESULTS

Disc space height and IPDs

Irrespective of disc level, average DSH measurements were as follows: anterior height of 2.6 ± 1.0 mm, middle height of 4.1 ± 1.2 mm, and posterior height of 1.8 ± 1.0 mm. IPD was only measured between C3 and C7 vertebrae, and irrespective of disc level, the mean IPD measurement was 21.1 ± 1.5 mm. Table 3 displays both mean DSH and IPD measurements per disc level. Significant differences for anterior, middle, and posterior DSH, and IPD were observed in all disc levels. Table 4 reports disc-level dependent comparisons in DSH and IPD measurements.

Table 2: Description of included cohort.

1000 patients total					
Patient characteristic	Mean (SD)	Sex		Race	
Age	25.9±5.8 years	Male	514	Caucasian	245
		Female	486	African American	144
Height	1.68±0.11 m	*	*	Asian	83
Weight	81.88±24.11 kg	*	*	Hispanic	357
Body mass index	27.68±7.89 kg/m ²	*	*	Other	18
*	*	*	*	N/A	153

SD: Standard deviation, Asterix shows no value.

Table 3: Mean (SD) cervical DSH and IPD.

Disc Level	DSH			C3-C7 IPD		
	Anterior	Middle	Posterior	Mean (SD)	Min	Max
C2-C3	2.4 (0.8)	4.0 (1.1)	2.0 (0.8)	24.2 (1.5)	22.0	31.0
C3-C4	2.5 (0.9)	4.3 (1.0)	2.0 (1.5)	25.2 (1.7)	22.5	30.1
C4-C5	2.6 (1.0)	4.1 (1.0)	2.0 (0.8)	25.8 (1.9)	22.5	31.9
C5-C6	2.8 (1.1)	4.1 (1.0)	1.9 (0.9)	26.2 (1.9)	23.0	31.8
C6-C7	2.9 (1.1)	4.4 (2.2)	1.8 (1.0)	25.4 (1.9)	22.5	32.0
C7-T1	2.3 (1.0)	3.7 (1.0)	1.4 (0.8)	*	*	*

DSH: Disc space height, IPD: Interpedicular distance, SD: Standard deviation, Asterix shows no value.

Table 4: Differences in cervical DSH and IPD measurements based on disc level.

Level of reference	Level of comparison	Mean difference (Reference-Comparison)							
		Anterior DSH		Middle DSH		Posterior DSH		C3-C7 IPD	
		MD	P	MD	P	MD	P	MD	P
C2-C3	C3-C4	-0.2	0.040	-0.3	0.010	-0.1	1.000	-1.0	<0.001
	C4-C5	-0.3	<0.001	-0.1	1.000	-0.1	1.000	-1.6	<0.001
	C5-C6	-0.5	<0.001	-0.1	1.000	0.0	1.000	-2.0	<0.001
	C6-C7	-0.6	<0.001	-0.4	<0.001	0.2	0.010	-1.2	<0.001
	C7-T1	0.0	1.000	0.3	<0.001	0.5	<0.001	*	*
C3-C4	C2-C3	0.2	0.040	0.3	0.010	0.1	1.000	1.0	<0.001
	C4-C5	-0.2	0.210	0.2	0.530	0.0	1.000	-0.6	<0.001
	C5-C6	-0.3	<0.001	0.2	0.630	0.1	1.000	-1.0	<0.001
	C6-C7	-0.4	<0.001	-0.2	0.470	0.2	<0.001	-0.3	0.196
	C7-T1	0.2	0.010	0.6	<0.001	0.5	<0.001	*	*
C4-C5	C2-C3	0.3	<0.001	0.1	1.000	0.1	1.000	1.6	<0.001
	C3-C4	0.2	0.210	-0.2	0.530	0.0	1.000	0.6	<0.001
	C5-C6	-0.1	0.490	0.0	1.000	0.1	1.000	-0.4	0.006
	C6-C7	-0.2	<0.001	-0.3	<0.001	0.2	<0.001	0.4	0.020
	C7-T1	0.3	<0.001	0.4	<0.001	0.5	<0.001	*	*
C5-C6	C2-C3	0.5	<0.001	0.1	1.000	0.0	1.000	2.0	<0.001
	C3-C4	0.3	<0.001	-0.2	0.630	-0.1	1.000	1.0	<0.001
	C4-C5	0.1	0.490	0.0	1.000	-0.1	1.000	0.4	0.006
	C6-C7	-0.1	0.710	-0.3	<0.001	0.2	0.020	0.7	<0.001
	C7-T1	0.5	<0.001	0.4	<0.001	0.5	<0.001	*	*
C6-C7	C2-C3	0.6	<0.001	0.4	<0.001	-0.2	0.010	1.2	<0.001
	C3-C4	0.4	<0.001	0.2	0.470	-0.2	<0.001	0.3	0.196
	C4-C5	0.2	<0.001	0.3	<0.001	-0.2	<0.001	-0.4	0.020
	C5-C6	0.1	0.710	0.3	<0.001	-0.2	0.020	-0.7	<0.001
	C7-T1	0.6	<0.001	0.7	<0.001	0.3	<0.001	*	*
C7-T1	C2-C3	0.0	1.000	-0.3	<0.001	-0.5	<0.001	*	*
	C3-C4	-0.2	0.010	-0.6	<0.001	-0.5	<0.001	*	*
	C4-C5	-0.3	<0.001	-0.4	<0.001	-0.5	<0.001	*	*
	C5-C6	-0.5	<0.001	-0.4	<0.001	-0.5	<0.001	*	*
	C6-C7	-0.6	<0.001	-0.7	<0.001	-0.3	<0.001	*	*

DSH: Disc space height, IPD: Interpedicular distance, Bold denotes values with $P < 0.05$ which is significant. Asterix shows no value.

Table 5: Differences in DSH and IPD measurements based on patient sex.

Measurement	Male		Female		Mean difference (Male-Female)	95% confidence interval		P-value
	Mean	SD	Mean	SD		Lower Bound	Upper Bound	
C2-C3								
DSH								
Anterior	2.6	0.9	2.2	0.9	0.4	0.3	0.5	<0.001
Middle	4.3	1.0	3.9	1.1	0.4	0.2	0.6	<0.001
Posterior	2.1	0.9	1.9	0.9	0.2	0.1	0.4	<0.001
IPD								
C3	24.4	1.7	23.8	1.2	0.6	0.3	0.9	<0.001
C3-C4								
DSH								
Anterior	2.8	1.0	2.3	0.9	0.5	0.3	0.6	<0.001
Middle	4.5	1.0	4.1	1.0	0.5	0.3	0.6	<0.001
Posterior	2.3	1.8	1.9	0.8	0.4	0.2	0.6	<0.001
IPD								
C4	25.4	1.7	24.7	1.5	0.6	0.3	1.0	<0.001

(Contd...)

Table 5: (Continued).

Measurement	Male		Female		Mean difference (Male-Female)	95% confidence interval		P-value
	Mean	SD	Mean	SD		Lower Bound	Upper Bound	
C4-C5								
DSH								
Anterior	3.0	1.1	2.4	0.9	0.6	0.5	0.8	<0.001
Middle	4.4	1.0	4.1	2.7	0.4	0.1	0.7	0.013
Posterior	2.2	0.9	1.9	0.8	0.2	0.1	0.4	<0.001
IPD								
C5	26.1	1.9	25.2	1.6	0.9	0.6	1.2	<0.001
C5-C6								
DSH								
Anterior	3.2	1.1	2.4	1.0	0.8	0.6	1.0	<0.001
Middle	4.4	1.0	4.0	1.0	0.5	0.3	0.6	<0.001
Posterior	2.1	0.9	1.9	0.8	0.1	0.0	0.3	0.043
IPD								
C6	26.5	1.9	25.7	1.6	0.8	0.5	1.1	<0.001
C6-C7								
DSH								
Anterior	3.4	1.2	2.4	1.0	1.0	0.8	1.1	<0.001
Middle	4.8	2.6	4.2	1.0	0.6	0.3	0.9	<0.001
Posterior	1.9	1.1	1.8	0.9	0.0	-0.1	0.2	0.655
IPD								
C7	25.7	1.9	25.0	1.6	0.7	0.4	1.1	<0.001
C7-T1								
DSH								
Anterior	2.6	1.0	2.1	0.9	0.5	0.4	0.7	<0.001
Middle	3.9	1.0	3.7	1.0	0.2	0.1	0.4	0.005
Posterior	1.6	0.8	1.5	0.8	0.1	0.0	0.2	0.092

DSH: Disc space height, IPD: Interpedicular distance, SD: Standard deviation, Bold denotes values with $P < 0.05$ which is significant.

Table 6: Mean DSH and IPD measurements based on patient race and ethnicity.

Measurement	African American		Caucasian		Hispanic		Asian		Other	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C2-C3										
DSH										
Anterior	2.4	0.9	2.7	0.9	2.3	0.9	2.3	0.9	2.5	0.8
Middle	3.9	1.1	4.3	1.3	4.0	1.0	3.9	1.1	4.2	1.0
Posterior	2.1	1.0	2.1	1.0	1.9	0.9	1.9	0.8	1.9	0.9
IPD										
C3	24.0	1.6	24.6	1.7	24.0	1.5	24.2	1.6	24.5	1.2
C3-C4										
DSH										
Anterior	2.5	1.0	2.7	1.0	2.5	1.0	2.3	0.9	2.5	0.9
Middle	4.1	1.0	4.5	1.0	4.3	1.0	4.3	1.1	4.5	1.0
Posterior	2.1	0.8	2.2	0.9	2.1	1.8	1.9	0.8	2.0	1.0
IPD										
C4	25.0	1.4	25.5	1.8	25.0	1.6	24.8	1.8	25.5	1.1
C4-C5										
DSH										
Anterior	2.7	1.1	2.9	1.1	2.7	1.0	2.3	0.8	2.7	1.0
Middle	4.2	1.0	4.3	1.0	4.3	2.5	4.1	1.0	4.1	1.0
Posterior	2.2	0.9	2.1	0.8	2.0	0.9	1.8	0.7	2.1	0.8

(Contd...)

Table 6: (Continued).

Measurement	African American		Caucasian		Hispanic		Asian		Other	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
IPD										
C5	25.7	1.7	26.2	2.0	25.6	1.8	25.7	1.7	26.1	1.3
C5-C6										
DSH										
Anterior	2.8	1.1	3.1	1.2	2.8	1.1	2.6	1.1	2.8	1.0
Middle	4.2	0.9	4.3	1.0	4.2	1.0	4.1	1.1	4.3	0.9
Posterior	2.3	0.9	2.0	0.9	25.9	1.8	1.6	0.5	2.0	0.7
IPD										
C6	26.1	1.8	26.6	1.8	1.9	0.9	26.3	2.6	25.9	1.3
C6-C7										
DSH										
Anterior	2.9	1.2	3.2	1.2	2.9	1.2	2.6	1.3	3.1	1.0
Middle	4.3	1.1	4.5	1.1	4.6	2.6	4.3	1.2	4.7	0.8
Posterior	2.0	0.8	1.8	0.9	1.8	1.1	1.5	0.9	1.7	0.7
IPD										
C7	25.3	1.8	25.8	1.9	25.2	1.8	25.4	1.9	25.6	1.5
C7-T1										
DSH										
Anterior	2.3	0.9	2.6	1.1	2.3	1.0	2.3	1.1	2.5	0.8
Middle	3.9	1.0	3.7	1.1	3.8	1.0	4.0	1.0	3.9	0.9
Posterior	1.8	0.8	1.5	0.8	1.5	0.8	1.4	0.7	1.4	0.8

DSH: Disc space height, IPD: Interpedicular distance, SD: Standard deviation

Table 7: Mean differences in cervical DSH and IPD measurements among African American, Caucasian, Hispanic, and Asian cohorts.

Disc level	Reference	Comparison	Mean difference (Reference-Comparison)							
			Anterior DSH		Middle DSH		Posterior DSH		IPD	
			MD	P	MD	P	MD	P	MD	P
C2-C3	African American	Caucasian	-0.3	0.007	-0.4	0.009	0	1	-0.6	0.034
	African American	Hispanic	0.1	1	-0.2	0.633	0.2	0.071	-0.1	1
	African American	Asian	0.0	1	0.0	1	0.2	1	-0.2	1
	Caucasian	African American	0.3	0.007	0.4	0.009	0	1	0.6	0.034
	Caucasian	Hispanic	0.4	<0.001	0.2	0.033	0.3	0.006	0.5	0.008
	Caucasian	Asian	0.4	0.918	0.4	1	0.2	1	0.4	1
	Hispanic	African American	-0.1	1	0.2	0.633	-0.2	0.071	0.1	1
	Hispanic	Caucasian	-0.4	<0.001	-0.2	0.033	-0.3	0.006	-0.5	0.008
	Hispanic	Asian	-0.1	1	0.1	1	0.0	1	-0.1	1
	Asian	African American	0.0	1	0.0	1	-0.2	1	0.2	1
	Asian	Caucasian	-0.4	0.918	-0.4	1	-0.2	1	-0.4	1
C3 - C4	Asian	Hispanic	0.1	1	-0.1	1	0.0	1	0.1	1
	African American	Caucasian	-0.2	0.556	-0.4	0.012	0	1	-0.5	0.158
	African American	Hispanic	0	1	-0.2	0.264	0	1	0.1	1
	African American	Asian	0.3	1	-0.2	1	0.3	1	0.2	1
	Caucasian	African American	0.2	0.556	0.4	0.012	0	1	0.5	0.158
	Caucasian	Hispanic	0.2	0.201	0.2	0.191	0.1	1	0.6	0.005
	Caucasian	Asian	0.4	0.746	0.2	1	0.3	1	0.7	1
	Hispanic	African American	0	1	0.2	0.264	0	1	-0.1	1
	Hispanic	Caucasian	-0.2	0.201	-0.2	0.191	-0.1	1	-0.6	0.005
	Hispanic	Asian	0.3	1	0.0	1	0.2	1	0.1	1
	Asian	African American	-0.3	1	0.2	1	-0.3	1	-0.2	1

(Contd...)

Table 7: (Continued).

Disc level	Reference	Comparison	Mean difference (Reference-Comparison)							
			Anterior DSH		Middle DSH		Posterior DSH		IPD	
			MD	P	MD	P	MD	P	MD	P
C4 - C5	Asian	Caucasian	-0.4	0.746	-0.2	1	-0.3	1	-0.7	1
	Asian	Hispanic	-0.3	1	0.0	1	-0.2	1	-0.1	1
	African American	Caucasian	-0.2	0.296	-0.1	1	0.1	0.908	-0.5	0.246
	African American	Hispanic	0	1	-0.1	1	0.2	0.059	0.1	1
	African American	Asian	0.4	1	0.1	1	0.4	0.633	-0.1	1
	Caucasian	African American	0.2	0.296	0.1	1	-0.1	0.908	0.5	0.246
	Caucasian	Hispanic	0.2	0.075	0	1	0.1	0.425	0.6	0.01
	Caucasian	Asian	0.6	0.263	0.2	1	0.3	1	0.4	1
	Hispanic	African American	0	1	0.1	1	-0.2	0.059	-0.1	1
	Hispanic	Caucasian	-0.2	0.075	0	1	-0.1	0.425	-0.6	0.01
	Hispanic	Asian	0.4	1	0.2	1	0.2	1	-0.2	1
C5 - C6	Asian	African American	-0.4	1	-0.1	1	-0.4	0.633	0.1	1
	Asian	Caucasian	-0.6	0.263	-0.2	1	-0.3	1	-0.4	1
	Asian	Hispanic	-0.4	1	-0.2	1	-0.2	1	0.2	1
	African American	Caucasian	-0.3	0.071	-0.1	1	0.2	0.12	-0.5	0.221
	African American	Hispanic	0	1	0	1	0.4	<0.001	0.1	1
	African American	Asian	0.2	1	0.1	1	0.7	0.024	-0.2	1
	Caucasian	African American	0.3	0.071	0.1	1	-0.2	0.12	0.5	0.221
	Caucasian	Hispanic	0.3	0.008	0.1	0.811	0.1	0.222	0.6	0.004
	Caucasian	Asian	0.5	0.919	0.2	1	0.5	0.348	0.3	1
	Hispanic	African American	0	1	0	1	-0.4	<0.001	-0.1	1
	Hispanic	Caucasian	-0.3	0.008	-0.1	0.811	-0.1	0.222	-0.6	0.004
C6 - C7	Hispanic	Asian	0.2	1	0.1	1	0.3	1	-0.4	1
	Asian	African American	-0.2	1	-0.1	1	-0.7	0.024	0.2	1
	Asian	Caucasian	-0.5	0.919	-0.2	1	-0.5	0.348	-0.3	1
	Asian	Hispanic	-0.2	1	-0.1	1	-0.3	1	0.4	1
	African American	Caucasian	-0.3	0.154	-0.2	1	0.2	0.231	-0.5	0.208
	African American	Hispanic	0	1	-0.3	0.638	0.2	0.116	0.1	1
	African American	Asian	0.3	1	0.0	1	0.5	0.477	-0.1	1
	Caucasian	African American	0.3	0.154	0.2	1	-0.2	0.231	0.5	0.208
	Caucasian	Hispanic	0.3	0.035	-0.1	1	0	1	0.5	0.017
	Caucasian	Asian	0.5	0.585	0.1	1	0.3	1	0.4	1
	Hispanic	African American	0	1	0.3	0.638	-0.2	0.116	-0.1	1
C7 - T1	Hispanic	Caucasian	-0.3	0.035	0.1	1	0	1	-0.5	0.017
	Hispanic	Asian	0.3	1	0.3	1	0.3	1	-0.1	1
	Asian	African American	-0.3	1	0.0	1	-0.5	0.477	0.1	1
	Asian	Caucasian	-0.5	0.585	-0.1	1	-0.3	1	-0.4	1
	Asian	Hispanic	-0.3	1	-0.3	1	-0.3	1	0.1	1
	African American	Caucasian	-0.3	0.051	0.1	0.74	0.3	0.038	*	*
	African American	Hispanic	0	1	0.1	0.976	0.3	0.016	*	*
	African American	Asian	-0.1	1	-0.1	1	0.4	0.85	*	*
	Caucasian	African American	0.3	0.051	-0.1	0.74	-0.3	0.038	*	*
	Caucasian	Hispanic	0.3	0.019	0	1	0	1	*	*
	Caucasian	Asian	0.2	1	-0.3	1	0.1	1	*	*
Hispanic	African American	0	1	-0.1	0.976	-0.3	0.016	*	*	
Hispanic	Caucasian	-0.3	0.019	0	1	0	1	*	*	
Hispanic	Asian	0.0	1	-0.2	1	0.1	1	*	*	
Asian	African American	0.1	1	0.1	1	-0.4	0.85	*	*	
Asian	Caucasian	-0.2	1	0.3	1	-0.1	1	*	*	
Asian	Hispanic	0.0	1	0.2	1	-0.1	1	*	*	

DSH: Disc space height, IPD: Interpedicular distance, Bold denotes values with P < 0.05 which is significant., MD: Mean Difference

Table 8: Correlation matrix among patient anthropometric factors and cervical NFD, DSH, and IPD[†].

Measurement	Left NFD			Right NFD			Disc Space Height			IPD	Height	Weight	BMI
	Width	Height	Area	Width	Height	Area	Anterior	Middle	Posterior				
C2-C3	1.000	0.065	-0.041	0.592	0.000	-0.049	0.007	-0.034	-0.018	0.179	0.010	-0.082	-0.089
Left NFD	0.065	1.000	0.393	0.009	0.219	0.324	0.200	0.195	0.222	0.025	0.406	0.168	0.026
Width	-0.041	0.393	1.000	-0.127	0.252	0.717	0.263	0.333	0.287	0.146	0.414	0.145	-0.002
Area	0.592	-0.127	-0.069	1.000	-0.032	-0.069	-0.075	-0.063	-0.053	0.112	-0.038	-0.107	-0.104
Right NFD	0.009	0.219	0.252	-0.032	1.000	0.261	0.163	0.114	0.149	-0.007	0.153	0.089	0.013
Width	0.219	0.252	0.717	-0.069	0.261	1.000	0.284	0.341	0.295	0.134	0.404	0.113	-0.015
Height	-0.049	0.263	0.263	-0.075	0.163	0.284	1.000	0.483	0.468	0.146	0.304	0.075	-0.073
Area	0.007	0.263	0.333	-0.075	0.114	0.341	0.483	1.000	0.512	0.133	0.283	0.043	-0.090
DSH	-0.034	0.195	0.287	-0.063	0.114	0.341	0.483	0.512	1.000	0.063	0.137	0.038	-0.001
Anterior	-0.018	0.222	0.287	-0.053	0.149	0.295	0.468	0.512	1.000	0.100	0.227	0.063	-0.072
Middle	0.179	0.025	0.146	0.112	-0.007	0.134	0.146	0.133	0.063	1.000	0.227	0.063	-0.072
Posterior	0.014	0.014	-0.027	0.659	-0.013	-0.093	0.024	-0.051	-0.044	0.251	-0.099	-0.143	-0.026
IPD	0.014	1.000	0.494	-0.075	0.383	0.273	0.139	0.183	0.136	0.068	0.279	0.160	0.026
C3-C4	-0.027	0.494	1.000	-0.106	0.410	0.711	0.300	0.382	0.223	0.161	0.342	0.104	-0.024
Left NFD	0.659	-0.075	-0.106	1.000	-0.009	-0.051	-0.011	-0.071	-0.064	0.165	-0.096	-0.129	-0.018
Width	-0.013	0.383	0.410	-0.009	1.000	0.616	0.235	0.281	0.216	0.111	0.352	0.136	-0.008
Height	-0.093	0.273	0.711	-0.051	0.616	1.000	0.324	0.419	0.224	0.166	0.325	0.082	-0.019
Area	0.024	0.139	0.300	-0.011	0.235	0.324	1.000	0.499	0.330	0.144	0.250	0.026	-0.077
DSH	-0.051	0.183	0.382	-0.071	0.281	0.419	0.499	1.000	0.336	0.134	0.223	0.005	-0.102
Anterior	-0.044	0.136	0.223	-0.064	0.216	0.224	0.330	0.336	1.000	0.100	0.184	0.154	0.078
Middle	0.251	0.068	0.161	0.165	0.111	0.166	0.144	0.134	0.100	1.000	0.195	0.064	-0.110
Posterior	0.063	0.063	0.166	0.165	0.111	0.166	0.144	0.134	0.100	1.000	0.195	0.064	-0.110
IPD	0.063	0.063	0.166	0.165	0.111	0.166	0.144	0.134	0.100	1.000	0.195	0.064	-0.110
C4-C5	1.000	0.063	0.005	0.605	0.071	-0.027	-0.089	-0.020	-0.033	0.196	-0.065	-0.088	-0.051
Left NFD	0.063	1.000	0.618	0.039	0.265	0.422	0.174	0.122	0.260	0.087	0.314	0.203	0.070
Width	0.005	0.618	1.000	-0.044	0.204	0.710	0.322	0.152	0.267	0.149	0.318	0.116	-0.022
Height	0.605	0.039	-0.044	1.000	0.026	-0.055	-0.120	-0.028	-0.085	0.164	-0.093	-0.130	-0.147
Area	0.071	0.265	0.204	0.026	1.000	0.310	0.127	0.078	0.162	0.125	0.312	0.120	0.056
Right NFD	-0.027	0.422	0.710	-0.055	0.310	1.000	0.356	0.170	0.296	0.107	0.278	0.071	-0.053
Width	0.422	0.310	1.000	-0.055	0.310	1.000	0.356	0.170	0.296	0.107	0.278	0.071	-0.053
Height	0.310	0.310	1.000	-0.055	0.310	1.000	0.356	0.170	0.296	0.107	0.278	0.071	-0.053
Area	-0.055	0.310	1.000	-0.055	0.310	1.000	0.356	0.170	0.296	0.107	0.278	0.071	-0.053

(Contid...)

Table 8: (Continued).

Measurement	Left NFD			Right NFD			Disc Space Height			IPD	Height	Weight	BMI
	Width	Height	Area	Width	Height	Area	Anterior	Middle	Posterior				
DSH	-0.089	0.174	0.322	-0.120	0.127	0.356	1.000	0.301	0.465	0.123	0.272	-0.011	-0.139
Anterior	-0.020	0.122	0.152	-0.028	0.078	0.170	1.000	1.000	0.270	0.018	-0.007	-0.031	-0.046
Middle	-0.033	0.260	0.267	-0.085	0.162	0.296	1.000	0.270	1.000	0.135	0.153	0.121	0.092
Posterior	0.196	0.087	0.149	0.164	0.125	0.107	1.000	0.018	0.135	1.000	0.281	0.071	-0.049
C5	1.000	0.053	0.014	0.633	0.029	-0.019	1.000	-0.075	0.030	0.152	-0.052	0.009	0.029
C5-C6	0.053	1.000	0.219	0.022	0.112	0.238	1.000	0.105	0.070	-0.064	0.311	0.116	0.086
Left NFD	0.014	0.219	1.000	-0.033	0.154	0.690	1.000	0.303	0.271	0.089	0.360	0.150	0.007
Width	0.633	0.022	-0.033	1.000	-0.025	0.002	1.000	-0.081	-0.060	0.130	-0.071	-0.041	-0.013
Height	0.029	0.112	0.154	-0.025	1.000	0.222	1.000	0.056	0.073	-0.038	0.010	0.012	-0.016
Area	-0.019	0.238	0.690	0.002	0.222	1.000	1.000	0.370	0.266	0.044	0.280	0.073	-0.014
DSH	-0.137	0.089	0.365	-0.157	0.079	0.365	1.000	0.629	0.347	0.121	0.333	-0.012	-0.151
Anterior	-0.075	0.105	0.303	-0.081	0.056	0.370	1.000	1.000	0.489	0.032	0.270	0.049	-0.065
Middle	0.030	0.070	0.271	-0.060	0.073	0.266	1.000	0.489	1.000	0.040	0.114	0.288	0.284
Posterior	0.152	-0.064	0.089	0.130	-0.038	0.044	1.000	0.032	0.040	1.000	0.291	0.067	-0.020
IPD	1.000	0.107	0.065	0.606	0.308	0.307	1.000	-0.068	0.045	0.145	-0.042	0.055	0.100
C6	0.107	1.000	0.635	0.013	0.330	0.585	1.000	0.044	0.091	0.021	0.269	0.181	0.066
C6-C7	0.065	0.635	1.000	-0.037	0.330	1.000	1.000	0.132	0.233	0.125	0.340	0.188	0.076
Right NFD	0.606	0.013	-0.037	1.000	0.005	-0.016	1.000	-0.045	0.010	0.081	-0.095	-0.005	0.078
Width	-0.017	0.308	0.330	0.005	1.000	0.382	1.000	0.076	0.126	-0.066	0.215	0.187	0.105
Height	-0.054	0.307	0.585	-0.016	0.382	1.000	1.000	0.139	0.176	0.072	0.289	0.131	0.025
Area	-0.140	0.109	0.315	-0.126	0.148	0.335	1.000	0.349	0.261	0.121	0.424	0.047	-0.088
DSH	-0.068	0.044	0.132	-0.045	0.076	0.139	1.000	1.000	0.167	-0.003	0.246	0.032	-0.067
Anterior	0.045	0.091	0.233	0.010	0.126	0.176	1.000	0.167	1.000	0.025	0.092	0.258	0.294
Middle	0.145	0.021	0.125	0.081	-0.066	0.072	1.000	-0.003	0.025	1.000	0.250	0.025	-0.035
Posterior	1.000	0.144	0.219	0.634	0.055	0.154	1.000	0.028	-0.046	*	0.137	-0.033	-0.037
IPD	0.144	1.000	0.717	0.081	0.452	0.414	1.000	0.184	0.067	*	0.285	0.112	-0.007
C7	0.144	1.000	0.717	0.081	0.452	0.414	1.000	0.184	0.067	*	0.285	0.112	-0.007
C7-T1	1.000	0.144	0.219	0.634	0.055	0.154	1.000	0.028	-0.046	*	0.137	-0.033	-0.037
Left NFD	0.144	1.000	0.717	0.081	0.452	0.414	1.000	0.184	0.067	*	0.285	0.112	-0.007
Width	0.144	1.000	0.717	0.081	0.452	0.414	1.000	0.184	0.067	*	0.285	0.112	-0.007
Height	0.144	1.000	0.717	0.081	0.452	0.414	1.000	0.184	0.067	*	0.285	0.112	-0.007

(Contd...)

Table 8: (Continued).

Measurement	Left NFD			Right NFD			Disc Space Height			IPD	Height	Weight	BMI
	Width	Height	Area	Width	Height	Area	Anterior	Middle	Posterior				
Area	0.219	0.717	1.000	0.103	0.398	0.619	0.296	0.171	0.160	*	0.330	0.121	0.004
Right NFD													
Width	0.634	0.081	0.103	1.000	0.088	0.161	-0.053	-0.021	-0.090	*	0.120	-0.061	-0.029
Height	0.055	0.452	0.398	0.088	1.000	0.687	0.120	0.202	0.043	*	0.335	0.179	0.036
Area	0.154	0.414	0.619	0.161	0.687	1.000	0.258	0.196	0.127	*	0.325	0.135	0.030
DSH													
Anterior	-0.006	0.151	0.296	-0.053	0.120	0.258	1.000	0.433	0.341	*	0.209	-0.063	-0.153
Middle	0.028	0.184	0.171	-0.021	0.202	0.196	0.433	1.000	0.397	*	0.150	0.003	-0.067
Posterior	-0.046	0.067	0.160	-0.090	0.043	0.127	0.341	0.397	1.000	*	0.142	0.256	0.196
C2-T1													
Left NFD													
Width	1.000	0.078	0.051	0.629	0.029	-0.002	-0.070	-0.044	-0.023		-0.021	-0.050	-0.015
Height	0.078	1.000	0.466	0.029	0.238	0.318	0.131	0.101	0.107	0.125	0.295	0.146	0.040
Area	0.051	0.466	1.000	-0.023	0.251	0.681	0.291	0.197	0.225	0.071	0.348	0.135	0.005
Right NFD													
Width	0.629	0.029	-0.023	1.000	0.014	0.011	-0.101	-0.055	-0.067	0.076	-0.048	-0.079	-0.040
Height	0.029	0.238	0.251	0.014	1.000	0.339	0.125	0.085	0.096	0.002	0.141	0.095	0.021
Area	-0.002	0.318	0.681	0.011	0.339	1.000	0.308	0.222	0.217	0.048	0.315	0.100	-0.008
DSH													
Anterior	-0.070	0.131	0.291	-0.101	0.125	0.308	1.000	0.410	0.347	0.181	0.296	0.010	-0.111
Middle	-0.044	0.101	0.197	-0.055	0.085	0.222	0.410	1.000	0.301	0.042	0.137	0.010	-0.060
Posterior	-0.023	0.107	0.225	-0.067	0.096	0.217	0.347	0.301	1.000	0.055	0.131	0.174	0.153
IPD													
C3-C7	0.125	0.005	0.071	0.076	0.002	0.048	0.181	0.042	0.055	1.000	0.234	0.053	-0.059

*Values in bold denote $P < 0.05$, DSH: Disc space height, IPD: Interpedicular distance, BMI: Body mass index, NFD: Neuroforaminal dimensions. Dark green represents highest correlation, with correlation decreasing with darkness of color, until white, which represents no significant correlation. Pink represents negative correlation. Bold denotes values with $P < 0.05$ which is significant. Asterisk shows no value.

Influence of sex, race, and ethnicity

Significant differences in DSH and IPD were observed for all anthropometric factors. Male patients had significantly larger measurements in both DSH and IPD across all vertebral levels compared to female patients. Table 5 reports significant differences in DSH and IPD measurements based on patient sex. Race-based analyses demonstrated statistically significant differences relative to vertebral level. Table 6 reports mean measurements for DSH and IPD based on patient race and ethnicity, and Table 7 reports significant differences between different racial and ethnic groups with respect to DSH and IPD. Table 8 showcases a correlation matrix which failed to appreciate any significant relationships between height, weight, BMI, CNFD, DSH, and IPD.

DISCUSSION

This study seeks to provide anatomic standards for understanding cervical DSH and IPD. In contrast to Frobin *et al.*, who indicated an average DSH of 0.35, our study measures DSH in three different locations, yielding an average anterior DSH of 2.6 ± 1.0 mm, middle DSH of 4.1 ± 1.2 mm, posterior DSH of 1.8 ± 1.0 mm, thus increasing the precision of measurement. In addition, our study encapsulates 1000 subjects, greatly expanding on their initial 135-subject sample size.^[3] In addition, Razzouk *et al.* found no sex-based differences in CFND measurements,^[10] but we found that males had larger DSH and IPD across all vertebral levels. We also found that Caucasian subjects had larger DSH and IPD at select vertebral levels compared to their African American, Hispanic, and Asian counterparts.

Determining a healthy DSH and IPD is fundamental to defining what constitutes disease and recognizing how changes in postoperative DSH and IPD can impact clinical and radiological outcomes, as seen in patients experiencing nerve root injury or undergoing anterior cervical discectomy and fusion surgery.^[1,4] Although Liu *et al.* sought to investigate ways in which DSH serves as a predictive index for spinal pathology,^[7] the lack of normative values has barred the determination of how variability in these measurements relates to the development of disease. Thus, our study provides a baseline series of normative measurements against which future research can compare measurements in various disease processes.

CONCLUSION

This study describes measurements of DSH and IPD between C2 and T1 in 1000 healthy 18–35-year-old subjects. DSH and IPD measurements vary based on patient sex, race, ethnicity, and disc level.

Ethical approval

The research/study was approved by the Institutional Review Board at Loma Linda University, number 5240124, dated March 18, 2024.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Abudouaini H, Huang C, Liu H, Hong Y, Wang B, Ding C, *et al.* Change in the postoperative intervertebral space height and its impact on clinical and radiological outcomes after ACDF surgery using a zero-profile device: A single-Centre retrospective study of 138 cases. *BMC Musculoskelet Disord* 2021;22:543.
2. Fleiss JL. *The design and analysis of clinical experiments*. 1st ed. United States: Wiley; 1999.
3. Frobin W, Leivseth G, Biggemann M, Brinckmann P. Vertebral height, disc height, posteroanterior displacement and dens-atlas gap in the cervical spine: Precision measurement protocol and normal data. *Clin Biomech* 2002;17:423-31.
4. Joaquim AF, Lee NJ, Riew KD. Circumferential operations of the cervical spine. *Neurospine* 2021;18:55-66.
5. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 2016;15:155-63.
6. Li Y, Huang M, Xiang J, Lin Y, Wu Y, Wang X. Correlation of interpedicular distance with radiographic parameters, neurologic deficit, and posterior structures injury in thoracolumbar burst fractures. *World Neurosurg* 2018;118:e72-8.
7. Liu J, Ebraheim NA, Haman SP, Sanford CG Jr, Sairyo K, Faizan A, *et al.* How the increase of the cervical disc space height affects the facet joint: An anatomy study. *Spine (Phila Pa 1976)* 2006;31:E350-4.
8. Parra-Frutos I. Testing homogeneity of variances with unequal sample sizes. *Comput Stat* 2013;28:1269-97.

9. Ratner B. The correlation coefficient: Its values range between +1/-1, or do they? *J Target Meas Anal Mark* 2009;17:139-42.
10. Razzouk J, Case T, Vyhmeister E, Bono CM, Cheng W, Danisa O, *et al.* Morphometric analysis of cervical neuroforaminal dimensions from C2-T1 using computed tomography of 1,000 patients. *Spine J* 2024.
11. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. *Psychol Bull* 1979;86:420-8.
12. Vetter TR. Descriptive statistics: Reporting the answers to the 5 basic questions of who, what, why, when, where, and a sixth, so what? *Anesth Analg* 2017;125:1797-802.
13. Vetter TR. Fundamentals of research data and variables: The devil is in the details. *Anesth Analg* 2017;125:1375-80.

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